

Australasian Association for Engineering Education

Creating Flexible Learning Environments

Proceedings of the 15th Australasian Conference for the Australasian Association for Engineering Education and the 10th Australasian Women in Engineering Forum

27th-29th September 2004

Edited by Chris Snook and David Thorpe

University of Southern Queensland
Toowoomba, Queensland

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Welcome from the AaeE 2004 Conference Chair

It is with pleasure that I welcome you to the 15th Annual Conference for the Australasian Association for Engineering Education and the 10th Australasian Women in Engineering Forum. I welcome you on behalf of the Organizing Committee and the Faculty of Engineering and Surveying at the University of Southern Queensland.

As you have seen, Toowoomba is a kaleidoscope of colour in September as the diverse range of flowers, shrubs and trees that grow in the city burst forth in blooms that announce the arrival of spring. Please take advantage of the opportunity to visit the many parks and gardens and, in particular, the Japanese Gardens which are located on northern side of the USQ campus. As my daughter would say, the Japanese Gardens are seriously beautiful at this time of year!

The central theme for this year's conference is the need to create flexible learning environments that empower the learner as they progress through their lifelong educational journey. The increasing emphasis on flexible learning presents new challenges for students, educators, and practitioners and these will be explored during the conference. The conference therefore presents an ideal opportunity for you to maximize your learning through participation in the Keynote and Technical sessions, the Workshops as well as the social functions. Take advantage of the opportunity to collaborate with people from other universities and to enjoy the company of new and old friends.

I would like to express my appreciation, and thanks to the members of the Conference Organizing Committee who have worked tirelessly to ensure that everything is in place for the Conference. They have been able to meet many deadlines throughout the year through their dedicated and persistent efforts. It has been a privilege to work with them on the Committee. I would like to thank AaeE for allowing USQ to host the Conference.

Finally I would like to leave you with one word: Enjoy!

David Dowling, Chair
AAEE 2004 Conference Organizing Committee

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An Investigation of Relationship Between Learning Styles, Methods of Instruction and Performance of Learner

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Abstract*: Several studies have established the existence of mismatch between cognitive learning styles of students and teaching styles of teachers. Teachers face enormous difficulties in the present mode of classroom teaching to cater to all styles of learning. Various teaching methodologies, content authoring, and presentation styles have been suggested to meet needs of students with different learning styles. Our research work is aimed to develop an adaptive and interactive online learning environment to bridge this mismatch in learning and teaching styles. This paper presents result of an experiment conducted to investigate the relationship, if any, between learning styles, methods of instruction and performance of learner. Further, the experiment aimed at discovering relationship, if any, between their browsing behaviors and learning styles. Performance in the context of this experiment has been measured in terms of number of attempts made by the learner to reach right answer. The results indicate that there is no significant difference in performance of students due to different methods of instruction. Further, the online behaviors and performance of students with different learning styles were different. Students with visual learning style were more explorative and made more mistakes, where as reflective learners were doing fewer mistakes in online self-evaluation test. We observed difference in browsing behavior of students with different learning styles, during the self-evaluation test.*

Keywords*: Learning styles, Cognitive state, Adaptive learning system.*

Introduction

Effective teaching is to incorporate meaningful information into student's cognitive structure. Students have their own learning styles and preferences. Studies have shown that performance of student enhances when the information is delivered in a manner that suits his/her learning preferences (Felder et al. 1988). In a traditional classroom-teaching environment, an instructor faces enormous difficulty to adopt a teaching style that will match the learning styles of different group of students attending the class.

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Present research and development work is motivated by our desire to bridge this mismatch of learning and teaching styles by supplementing the learning process through an adaptive and interactive online learning environment. The adaption will be based on the learning style and cognitive state of the learner. Cognitive state indicates how much student has mastered the specified domain of knowledge. The course structure, knowledge unit sequencing, presentation and evaluation are planned to be adaptive. Adaptive personalization of the learning process for a particular student involves various activities like creation of student model, assessment of cognitive state, course authoring and structuring, and adaptive presentation.

As a first step we are trying to build a student model, which will exhibit the learning preferences and cognitive state of the student. This paper presents results of an experiment conducted to evaluate the effect of different methods of instruction on student's performance having different styles of learning and to discover the relationship, if any, between their performance, browsing behavior and learning styles.

Background

There have been many significant developments in last decade to use adaption on the basis of user models to improve the user's efficiency. The system using adaption is classified into adaptive and adaptable. The adaptable system allows user to change certain system parameters as per need of the user. The adaptive system, on the other hand, adapts to user's need automatically. The web and multimedia technologies have to provide for adaption based on learning style, motivation strategies, current level of domain competence, and feedback methodologies. Research community has started addressing these issues but no major breakthrough has been reported.

The term learning styles or cognitive styles has been widely used by educational theorists over the years. Learning style manifest as a preference for the method by which one acquires, retrieves and retains information, which is independent of intelligence. Garger and Guild (1984) described learning style as " Stable and pervasive characteristics of an individual, expressed through the interaction of one's behavior and personality as one approaches a learning task". There have been many characteristics of learning style preferences.

One theory, first popularized in the 1960s, claims that each brain hemisphere is specialized for a different mode of thinking: the left for linguistics, analytical and sequential tasks and the right for autistics, creative tasks (lateral thinking). Another way of looking at learning examines it from the perspective of visual, auditory and kinesthetic/tactile preferences. Education theorist believes that each of these preferences is used at a different level of cognition: perception, organization and retention. The Mayers-Briggs Type Indicator (MBTI) categorizes students according to their position on scale based on Jungs theory of psychological types. The types being extroverts/introverts, sensors/intutors, thinkers/feelers, judgers/perceivers. Kolb learning style model classifies people along the scale of preference for concrete experience or abstract conceptualization (how information is taken in), and active experimentation or reflective observation (how they internalize information). The Hermann Brain Dominance Instrument (HEIDI) uses the theory about the specialized functioning of areas of quadrants of the brain to classify students learning preferences by left and right brain dominant and cerebral and limbic.

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Felder (1996) proposed a model of classification of learning and teaching styles integrating the results of Jung, Kolb, Myers-Briggs Type indicator, Herrman's Brain Dominance Instrument and others. This model considers learning as two-step process. The first step involves reception and selection of inputs from internal and external sources. The second step is processing of selected inputs. Some students tend to focus on facts, data, and algorithms; others are more comfortable with theories and mathematical models. Some respond strongly to visual forms of information, like pictures, diagrams, and schematics; others get more from verbal forms-written and spoken explanations. Some prefer to learn actively and interactively; others function more introspectively and individually. Felder-Silverman learning style model, which classifies students as:

- *Active learners* or *reflective learners:* Active learners learn by trying thing out and working with others, whereas reflective learners learn by thinking things through and working alone
- *Sensing learners* or *intuitive learners:* Sensing learners are concrete, practical and oriented towards facts and procedures whereas intuitive learners are conceptual, innovative and oriented towards theories and meanings.
- *Visual learners* or *verbal learners*: Visual learners prefer visual representations of presented material like pictures, diagrams, flow charts whereas verbal learners prefer written and spoken explanations.
- *Sequential learners* or *global learners*: Sequential learners are linear, orderly, and learn in small incremental steps whereas global learners are holistic, systems thinkers and learn in large leaps
- *Inductive learners* or *deductive learners:* Inductive learners prefer presentations that proceed from the specific to the general whereas deductive prefer presentations that go from the general to the specific.

Many educators and researchers found Felder's model very useful and used them for research and betterment of teaching (Felder 1996).

Bostrom et al. (1988) had extended the work of Kolb's work and proposed a theory that combines the characteristics of learning and problem solving processes. Individuals learn and solve problems by progressing through a four-stage cycle: concrete experience (CE) followed by reflective observation (RO) which leads to the formation of abstract concepts (AC) which in turn leads to the testing of hypotheses through active experimentation (AE). The cycle continues recurrently. The direction of learning is governed by an individual's goals and objectives.

The Experiment

We have conducted an experiment to investigate the relationship between learning styles and methods of instruction with learner's performance and behavior on online multiple-choice self-evaluation test. The experiment had been conducted with students enrolled for the university course CS402 Data Structures using C. Students participating in the experiment were classified into different learning styles based on Felder-Silverman Index of Learning Style (ILS).

Participants

Students of B.Tech (Computer Science and Engineering, Information Technology) and Master of Computer Applications are required to take-up a course on Data structures. This course is named, as CS402 Data Structures using C. Total number of students taking this course is around 200. Due to limited number of available resources, we have selected only

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100 students as the population for this study based on the Cumulative Performance Index (CPI) in previous year. This criterion of selection was employed with a belief that students would belong to more or less the same cognitive state, if their CPI were of same order.

Learning Style Instrument

We have assessed the learning styles of all the students based on index of learning style questionnaires developed by Soloman and Felder to determine their learning styles prior to the start of instructions (Soloman and Felder, n.d.). This tool tested students along four axes and grouped them into eight separate categories. Inductive and deductive style had been excluded from the test because it has been examined by (Felder 1988) that best approach for teaching students is always inductive. The result of the learning style test has been recorded for all participants.

Methods of Instruction

Participants of the course were evenly divided in three groups such that the average CPI in each group was approximately equal. Each group contained students of different learning styles, assigned to one of the three methods of teaching. First group was taught in the conventional classroom environment using blackboard and chalk. Second group was taught in the machine assisted classroom session but using the slides on the same topic. The third group was provided with web-based online learning material. All the lecture sessions, irrespective of methods of instruction was conducted under the controlled environment. No student had been allowed to cross the activities of the group in which they belong.

The topic was divided in four sessions of one-hour duration for first and second group, whereas for the third group the session was of two hours in order to provide them flexible self-learning environment. Course materials used by the instructor for the conventional and slide-based methods were the same as of online method to maintain consistency.

Course Structuring

A chapter on “Stacks and Queues” from the textbook recommended by the university was chosen as the learning material for this experiment. The course was new to the student, so interface from prior knowledge was not a concern. The chapter was structured as a series of four sessions of independent, self-contained knowledge units, which could be taught and examined independently. Different knowledge units for the different sessions were as follows:

Session 1	Introduction to Stack and implementation
Session 2	Queue and its Implementation
Session 3	Evaluation of Expression
Session 4	A Mazing problem, multiple stacks & queues

We had developed web-based online learning material for the third group. The online course material consisted dynamic web pages. Each page was organized to include explanatory text, figures, diagrams, summary and examples. The page also contained link to more detailed explanation, to questions to promote thinking and to hints for answers to theses questions. The various components of the web page were intended to satisfy the learning need of the learners of different learning styles. For example, figures and diagrams were included to assist visual learner, whereas detailed explanations were for verbal learners. For the sensing and intuitive learner there was blend of concrete information (facts, data, examples) and abstract concepts (principles, theories) on the web page. Summery and links to the self-

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thinking questions were included in web page to assist intuitive learners. (Felder and Silverman 1988).

Self-evaluation Questionnaire

Students of different groups were given an online multiple choice, self-evaluation test immediately after the completion of a learning session. We had designed four sets of online questionnaires, for testing the performance and behavior of the students of all the three groups. Each set of questionnaires had ten questions. Each question had four alternative answers and only one was correct. The wrong options were designed to reflect the extent of lack of understanding of the topic. The questions were knowledge questions as they tested recalling of facts, terms and concepts as suggested in Bloom's taxonomy. In case of wrong answer, student could select another choice from the same question and check the answer. All the selection (i.e. selecting the wrong option as well as right option) of the students was recorded with the timestamp and session id.

The performance of students in this self-evaluation test was measured in terms of number of attempts made by the student to reach right answer. We believed that the number of attempts leading to incorrect answers were a better indicator of the extent of learning and of the behavior of the learner in discovering the solution.

Analysis and Results

Analysis of the data was done in two phases. In the first phase, we had analyzed data collected through on-line self-evaluation test. In the second phase, we analyzed the log data containing click log, mouse log, and scroll log to access the browsing behavior of the student on the online learning material developed by us. These log data were captured during use of online material by the third group.

Analysis of Self-evaluation Test Data

A one way single factor Analysis of Variance (ANOVA), with alpha level set to .05 was used to analyze data collected through online self-evaluation test. Both selections of the right answers as well as wrong answers were considered for the analysis. Independent variables of the analysis were learning styles and the methods of instruction. The dependent variable was learner's achievement in terms of performance in the self-evaluation test.

- *Methods of Instruction*: First analysis was done to test effect of methods of instruction on the average performance of students. Performance was not measured directly in terms of correct answer. Performance in this context was derived from the total number of clicks on the right choice and total number of clicks on the wrong choice. Here the independent variable was methods of instruction. The results of the analysis shows that there was no significant difference in number of clicks on the wrong choices between different groups of student, where grouping is done on the basis of methods of instruction on which students are taught. There was no significant difference in the average performance of the student belonging to different group. However, from the results we observed that the group whose methods of teaching were online had a less number of clicks on the wrong answer.
- *Learning Styles:* We have analyzed the performance of students grouped according to their learning styles. In this case the independent variable was learning style. In order to analyze the performance of different groups (based on learning styles irrespective of the method of teaching) on the online self-evaluation test, we found highly

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significant difference in selection pattern of wrong and right answers. Students of reflective learning style selected lesser number of wrong answers. Students with visual learning style explored many alternatives and made more mistakes. The performance of sensing and intuitive learners was almost same. Students with sequential style attempted less number of questions and also committed fewer mistakes.

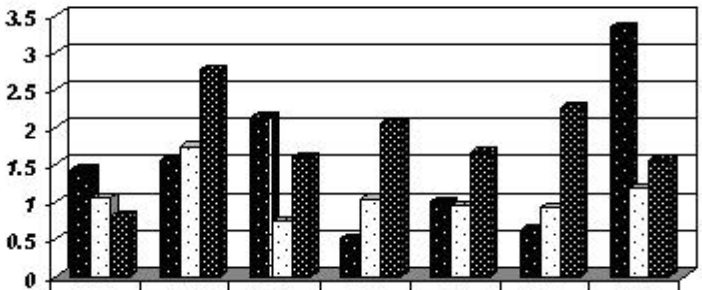
- *Learning Styles* and M*ethods of Instruction*: Analysis showed that the students belong to conventional methods of instruction with sensing learning styles excel. They committed fewer mistakes by selecting wrong options. Intuitive learners were selecting more wrong answers. Sequential learners were attempting very less number of questions also committing more mistakes per question. In the slide based method of instruction intuitive learners performed better. In the case of online method of instruction the statistical analysis showed that the ratio of right attempts and wrong attempts were higher for reflective, intuitive, visual and sequential kind of learners. It is shown in (Figure1). For active learner the ratio was minimum in online method of instruction. The biggest difference was in sequential type of learner whose performance was significantly better in the online method of instruction. Reflective learners were more consistent in all the three methods of instruction in click patterns. Since no student from the population of our experiment had shown the verbal style of preference, it was not included in the figure.

Analysis of Log Data

In the second phase, analysis was done on the various log data generated while browsing on the online course material by the third group. We had only analyzed scroll log and click log data. For the analysis of scroll log we had used a procedure to identify relatively homogeneous groups of cases based on selected characteristics, using an algorithm that can handle large number of cases. The characteristics considered for this was scrolling pattern on typical online course material. We had used K-means clustering algorithm using a statistical package SPSS.

- *Analysis of Scrolling pattern:* We observed, after the analysis that most of the visual learners have exhibited the similar kind of scrolling pattern on the typical online course material. The student who had both visual and sensing learning preferences, showed the tendency of frequent scrolling. Rate of scrolling of students with both sequential and reflective learning styles were less. In fact, reflective learners had scrolled minimum. All the students with both visual and sensing styles have shown same kind of scrolling pattern.
- *Analysis of clicking data:* We had recorded the clicking pattern of user as a sequential data per user. We used a matrix-based algorithm (Xiao et. al. 2001) to cluster students such that they were closely related with respect to the similarity measure in terms of their sequential clicking pattern. The analysis of the clusters showed that students of sensing and visual style had the same clicking pattern. All the students with sequential learning styles, irrespective of their other styles had the same clicking pattern except those who had active style in addition with sequential. The entire reflective learner had the same clicking pattern. Though, we had got differences in clicking patterns of different users, we were not able to derive the behavior out of this.

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	ACT	REF	SEN	INT	VIS	SEQ	GBL
Conventioanl	1.42718	1.56098	2.13043	0.5	0.99585	0.61765	3.33333
Slide based	1.04706	1.73171	0.73853	1.03922	0.94704	0.91304	1.18182
Online	0.7967	2.7619	1.59459	2.05556	1.66115	2.26316	1.5614

Figure1: Comparison of the ratio of right attempts and wrong attempts for different learning styles in different methods of instruction.

Pedagogical Implication of the Study

Considering the findings of the study, one may conclude that online learning system does not have much impact on the student's achievement. However, we observed high positive reactions of the participants towards the flexibility of online learning system. Therefore, it is plausible to integrate online learning activity as a supplement to conventional classroom teaching and see the effect on all the learners of different learning styles. While it is tremendously difficult to meet the need of all learners, all the time in classroom, online learning system has the potential to personalize the content and presentation suitable for different learning styles. Pictures, videos, sound recordings, animations, text, deep explanation, self-thinking questions etc. would help learners with different preferences for studying. We have observed during the study that learning and retaining the information is not only based on the learning system, but also the attitude and perception of the usefulness of the learning material and methods of instruction.

Conclusion

We have obtained promising results, which indicate that the performance of a student is not affected by the methods of instruction, whereas their behavior and performance are related to their learning styles. There is a significant difference in performance of the student of different learning styles in different methods of instruction. The analysis of pattern of reaching the right answer after attempting possibly several wrong answers may provide a possible indicator for identifying cognitive state.

As learning styles are a significant contributing factor in terms of student progress, it is required to create a pedagogical environment in which this can be accommodated. One possible approach is to implement it as online education system, designed in a way that it can identify individual student's learning preferences, learning goal and interest and changes its behavior according to that. This is termed as adaptive online learning system. Our research is an attempt to examine some of the critical variable, which may be important in the design of an adaptive online learning system based on student's learning style and cognitive state. The

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cognitive state indicates how much the student has mastered the specified domain of knowledge.

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Education innovations in first-year engineering

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***Abstract**: First-year engineering education is of particular importance because so much is new to the students: few have any friends in the same course, few have any familiarity with important engineering terms and concepts, and few have a clear idea of what engineering actually is. The majority of first year engineering students are therefore confronted by several barriers, both social and technical, that need to be overcome to allow the learning process to start. Failing to address these issues will typically result in poor progression and high attrition rates. First year is also the place to start students working on employability skills such as team-work, communication and problem-solving.*

First year engineering students at Flinders University, with degree specialisations in electrical & electronic engineering, computer engineering and biomedical engineering, take two topics in first year (one quarter of their studies) that start their technical education in electrical and electronic circuit theory. Since 1996, these topics have been coordinated and substantially taught by the authors. This paper describes the teaching philosophy that has been developed, discusses issues in its implementation and evaluates its effectiveness. The philosophy centres on integration, in many senses, and an inclusivity and empowerment of the students. The importance of assessment in motivating student learning is acknowledged. Implementation details look at the arrangement of lectures, tutorials and practicals, the use of topic handbooks, WebCT, formalised groupwork, quizzes and an exam. Over eight years, an improvement in progression rates and a significant reduction in attrition have been observed. The later student cohorts are demonstrating a greater acquisition of group learning skills throughout the rest of their studies.

***Keywords**: First-year, integration, cooperative learning*

Introduction

First year engineering students, with degree specialisations in electrical & electronic engineering, computer engineering and biomedical engineering, undertake two technical engineering topics in first year, Circuits and Devices 1 and Digital Logic Design. They provide both theoretical and practical skills in the analysis, use and design of electrical circuits, both analogue and digital, based on the operation and properties of their constituent electrical devices. This gives the students a detailed level of knowledge of many of the basic

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building blocks of our modern technological society. Since 1996 the authors have been the sole academics involved in teaching these topics, assisted by technical and casual staff. Class sizes have varied between 50 and 100 students. Each of these topics has two components, “theory” and “workshop”. The theory component uses lectures, tutorial and laboratories to develop an understanding of basic electrical circuit theory. The workshop component, taught by the engineering laboratories manager, provides essential practical skills and knowledge in measurement, laboratory equipment, soldering and electronic circuit construction.

There are many difficulties associated with teaching first year engineering students. Only those students who have some previous experience of electrical engineering, either through significant personal endeavour, through the workplace, or through TAFE or similar technical education, have any familiarity with many important engineering terms and concepts. The new students’ understanding of what engineering is can also be an issue. Another significant difficulty is the lack of any friends in the same course, leading to a sense of isolation in the university environment. These barriers need to be overcome before substantive learning can be achieved. Failure to do so results in a student that does not engage in the learning process. Depending on the extent of this, they are likely to miss classes, not submit work on time, not realise that withdrawing is worth considering, not attend the exam and, in the end, fail.

Integration

One major aspect of our teaching philosophy is the integration of theory with practice. This is most clearly seen through the complementary components of both topics. For example, the theory component of Circuits and Devices 1 introduces the ideal resistor, details the electrical laws it obeys, and examples of its use are worked through. Tutorials and laboratories are used to explore these ideas from different directions. In parallel, the workshop practice component examines real resistors, explains the colour coding used to identify their value and rating, and teaches the procedures for soldering them into circuit boards and testing them as part of a useful circuit. The two components do not simply sit side-by-side, as the workshop practice component discusses the “theory” of manufacturing processes involving resistors, and the theory component contains “practicals” requiring the construction of circuits containing real resistors. This integration and complementarity is stated succinctly in the topic aims for Circuits and Devices 1: "to introduce students to the concepts of basic circuit theory and reinforce this knowledge through practical means", and to provide "a practical introduction to understanding electrical instruments and laboratory equipment."

The content of the topics has been arranged to ensure that the material covered in lectures is promptly revisited in both tutorials and the laboratory. Both topics have a one-hour tutorial and a one-hour laboratory each week to facilitate the integration of the material across the different teaching forums. A further integration occurs within the laboratory, where both computer simulation and actual circuits are used and compared.

Comments from student evaluation of teaching (SET) reinforces the idea that teaching theory in isolation is far less successful than integrating it with hands-on experience in the laboratory. The question "What were the best aspects of this topic, and why?" is most frequently answered with some positive comment about the practicals. Some examples are "The practicals, because you see the theory go to practise", "Workshop, allowed implementation of theory, and hands on experience", "Workshop pracs - finally some hands-on stuff", "The practical classes gave a better insight".

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One part of the workshop practice component is a project where groups of students cooperatively construct new electronic laboratory equipment. Past projects have produced battery rechargers for the robotics systems laboratory, PIC microcontroller systems board for teaching use, and a patchboard for electronic systems design. This construction exercise is performed in teams of three students, and encourages an interdependence on colleagues that will be found in the workplace.

The workshop practice component is one of the highlights of these topics. The approach of using experienced technical staff to teach this component is significant in its success. The students gain many benefits from this approach, such as:

- Familiarity with components discussed in the theory section
- Hands-on learning about component structure and identification, tolerances, and current manufacturing processes used within industry
- Testing procedures, including an appreciation of the role of Australian Standards and OH&S issues
- The importance of design for issues beyond correct function, such as form, safety, compliance etc
- Opportunities to put theory into practice
- An appreciation of the role of engineering technologists and associates in the engineering team
- Enhanced motivation for their engineering course.

Using assessment to encourage deep-learning

While a learning strategy plays an important part in the education process, it needs to be supplemented with a suitable assessment package in order to be more effective. How students perceive the nature of the assessment task will determine the approach they will adopt to learning (Biggs, 1999). We were keen to adopt an assessment strategy that would discourage a surface approach to learning, as this would result in poor knowledge retention. Empowering students with a desire to learn and making them actively involved in understanding the material will lead to a deep approach to learning (Brockbank and McGill, 1998).

In 2001 the modes of assessment were reviewed and other modes were investigated to determine the most effective scheme for teaching first-year engineering. The assessment methods were examined to ensure that they met certain criteria for effectiveness such as reliability and validity, cost-effectiveness, ease of administration, perceived fairness, and information leading to improvement. The chosen assessment scheme included short weekly tests, group assignments, laboratory reports and a final examination, encased within a cooperative learning strategy (see the bulleted summary on the next page). All of these components were in practise elsewhere, but the review and the particular combination chosen as appropriate for our set of topics is not based on any existing model.

We reasoned that giving students weekly short tests in tutorials not only encouraged continuous learning, but also provided prompt feedback to both the student and the staff member on each section of the topic. In this way, students could monitor their own progress within the topic. Weekly tests helped to spread student workload throughout the semester and thus helped students in the retention of the material taught. Most students learn best when they receive frequent evaluation combined with feedback to correct and improve their work (Wankat and Oreovicz 2000). The more frequent the tests, the more frequent both students

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and teachers can get feedback. The other benefit of short tests to the teaching staff is that they are easy to administer and mark. With these tests, we can get a feel for how students are coping with the material taught, and we can address, in the lectures, any problems faced by the general student population. One student, writing in their SET, valued this form of assessment as the best part of the topic: "Quizzes, made you learn weekly"

Assignments play two important roles in the whole assessment package. Firstly, the assignment questions themselves were made more complex and challenging than the weekly tests, comparable to the examination questions that students faced at the end of the semester. In this way, students were more prepared for the type of questions seen in the examination. Secondly, assignments were worked upon by each cooperative learning group on the premise that working out these complex questions together as a group would help students to maximise their learning.

Another practice we considered carefully related to the summative feedback provided with each assessable piece of work. Engineering students tend to be marks-focussed, and determine how well they must do in the exam to pass or achieve some other standard. This distracts them from learning. To discourage the practice, we have adopted a policy of returning all marked work with a grade only, no mark. There have been no negative comments from the first years, perhaps because they have not identified a standard procedure for marking at university. Interestingly, there was considerably protest against the practice when introduced by one of the authors in a final year elective class. This suggests that a form of conditioning had occurred, and that students who are used to marks feel the need for them.

The weightings of the various assessment components have changed over the years, but indicative weightings are given below. The assessment components for laboratory and workshop activities not discussed in this paper. The merits of the cooperative learning strategy are also summarised.

Assessment components

- Weekly group tutorial homework (1-2 questions prepared for the tutorial, 10%)
- Weekly quizzes (short, 10 minute, questions - test basic analytical skills, 10%)
  - low-stakes, creates less student anxiety
  - easy to administer and mark
  - prompt feedback
  - can address common student problems in lecture
- **Group assignments** (peer-learning group work, 10%)
  - more complex and challenging questions
  - help students prepare for the final examination
- Examination (40%)
  - integration of material covered throughout the semester
- Workshop & Laboratory work (30%)
  - logbook and formal reports

Cooperative/Peer Learning Strategy

- small groups (2-4 students)
- work together to maximise their own and each other’s learning
- motivate student learning
- each member held accountable for the complete final outcome
- positive interdependence

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Implementation

Implementation of a teaching philosophy immediately strikes the tension between doing what is best for the students and what the teachers are capable of achieving in a reasonable time and with sparse resources. With only limited time available for revising and improving a topic each year, our approach has been one of iterative improvement, rather than wholesale change. Each year, or over several years, some aspect of the course has received particular attention, and some change or changes introduced.

Engagement / Inclusivity and empowerment

Weekly contact is used to engage the students frequently and regularly. This takes many forms, notably quizzes, group submission of a tutorial question and personal submission of a laboratory logbook. All of these submissions are returned promptly (within one week), providing both a grade and critical feedback on each submission. The group submission of tutorial questions and assignments encourages the students to work in teams and so become more involved with fellow students: cooperative learning.

Cooperative learning

The rationale of cooperative or peer learning was to implement a pedagogical approach of cooperative peer teaching in order to create an active learning environment where students become the "producers" of their learning rather than the passive "consumers" (Boud, 1995). Boud showed that students learn more by doing than by watching or listening, and that they should have opportunities to practice the steps of any procedure they are learning.

Cooperative learning (CL) is an instructional methodology whereby students work together in small teams in order to maximise their own and each other's learning (Johnson, Johnson and Smith, 1991). According to the California Department of Education (2000), CL is successful because it involves small heterogeneous teams working together towards a group task where each member is individually accountable for their work and group members are positively interdependent. Each member of a team is responsible not only for learning what is taught but also for helping teammates learn, thus creating an atmosphere of achievement (Balkcom, 1992). Positive interdependence is important to the success of the group because students learn the importance of "give and take". This will help them to realise that cooperation with team-members will lead to the success of the group. Rivera (1996) believes that CL is highly effective because it helps to reduce peer competition and isolation while helping to promote academic achievement and positive interrelationships. This strategy directly addresses a problem identified with the Circuits and Devices topics: difficulty in learning the material. The students regard the topics as difficult, with a lot of material covered at a fast pace. By providing them with incentive (assessable work worth marks) to learn together, we have encouraged students to take more control of their own and one another's learning.

The procedure involved is as follows: At the beginning of the semester, students in each tutorial class were instructed to form groups of two to three members, choose a name for their group, and a meeting time of at least one hour (each week) which was convenient for all group members. Every week, each group had to prepare and submit their solutions to one or two tutorial questions. This would encourage groups to meet before each tutorial to discuss and attempt to solve tutorial questions. In this way, the students could identify for themselves their own weaknesses or lack of understanding and thus could ask for assistance from within the group. Any problems that the group could not solve could then be brought to the tutorial for discussion. It was envisaged that having a CL group would be a great support system for students and would help to motivate their learning.

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To evaluate the effectiveness of the CL strategy, the team carried out its own SET, an example of which is provided in the appendix. This survey consisted of nine questions; seven asking the students to respond on a seven-point scale and the last two asking "what were the best aspect of working in a cooperative group and why" and "any other comments on working in a cooperative group". The results of the survey are shown in Table 1.

Survey Questions	Mean	Std
Working in a cooperative group helped to improve my understanding of the material covered	4.9	1.4
My cooperative group worked well together	4.6	1.3
All group members contributed equally to the assignment solutions	4.6	1.8
I preferred working on the assignment solutions as part of a group rather than an individual	5.0	1.2
It was easy to find a time for all group members to meet	3.3	2.0
Sufficient guidance was provided in how to work in a group	4.6	1.3
My ability to work in a team has been increased	4.7	1.2

Table 1: Results of the survey on cooperative groupwork

A summary of comments made by students regarding the best aspects of working in a cooperative group include: "… it makes students exchange ideas, plus help each other …", "… working in a cooperative group meant we could compare answers and help each other with things we didn't understand …", "… everyone can help each other understand …", "… you can find out how to do the questions …".

From the results in Table 1 and comments by students, CL is seen to be endorsed by students. The feedback indicates that students generally like to work in groups. They do not feel isolated and have a network of support to help them better understand the subject material. We believe that we have revolutionalised the way students tackle learning difficult material. By working together students can pool knowledge and resources to help one another. The benefits of this are far-reaching. Students develop teamwork and leadership skills, which are essential parts of every engineer's professional working life. Some of the other issues brought out in the survey included timetable concerns, guidance on how to work in a group, and accountability of work handed in.

Another measure of the effectiveness of the CL is that it has substantially reduced the proportion of students who have been enrolled in the topic but not engaged in it. In the past these topics have had high rates of failure (typically 25% including many "did not attend"s) and academic supplementary exams (10%). In 2001 less than 10% of students failed, and no academic supplementary exams were awarded in Circuits and Devices 1. This suggests a far higher level of interest and engagement amongst the enrolled students.

Topic handbooks

After three years teaching the first-year topics, the teaching material was consolidated into a consistent electronic format and published as topic handbooks. Due to the quantity of material, there are two handbooks for each topic, utilising the natural division of the topic into the theory and workshop components. The handbooks contain all the lecture notes (with the deliberate omission of some block diagrams, the details in some worked examples etc), all the

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tutorial questions, all the laboratory exercises, and a timetable outlining what happens each week. In addition, the theory handbook also contains the statement of assessment for the topic and a copy of the previous year's examination paper. Refinements of the material and its format have continued with all subsequent editions of the handbook.

There are clearly many advantages to providing the teaching material in a coherent and convenient form. From a student learning point-of-view, the coherency and clearly visible structure to the topics is a significant boon. It also reduces the chances of a student transcribing incorrectly from the whiteboard or projector screen. In technical topics there are many opportunities for a minus sign to be slipped in or out, resulting in the wrong results in the analysis and difficulties for the student in learning the material. From a lecturing point-of-view, the extra burst of work required before the start of the semester is more than compensated for by the reduced administrative workload before and during classes. In addition, each student will always have all the material to hand, which results in almost no requests for copies of lecture notes, tutorial questions etc (even more so with the advent of WebCT, as discussed later), and almost no excuses along the lines of "I didn't bring those laboratory instructions today". A problem with supplying comprehensive lecture notes is non-attendance (either in body or mind). The use of deliberate blanks allows examples to be interactively worked through in the class, facilitated by the lecturer. This engagement of the class helps to stimulate their interest in the topic in a situation which might otherwise let them be quite inattentive.

Informal comment and discussion with students provides anecdotal evidence of the success of the handbooks. Most notably, several students who had completed the topics before the handbooks were produced have approached us requesting copies for their use as a reference. The students' valuation of the handbooks has also been measured through SET, particularly comparing the value of the handbooks as opposed to the recommended reading. The "recommended reading" in these topics are not always popular because of their expense!

WebCT

WebCT, or Web Course Tools, is a commercial integrated e-learning system or, from an alternative viewpoint, an online course management tool. Flinders makes use of WebCT in every topic, to a greater or lesser extent. We use it as an additional and alternative means of delivery of the class material, but with some additional benefits and content. The provision of all lecture, tutorial and laboratory material on WebCT complements its presence in the handbooks and further reduces requests for extra copies of course material. In addition, assignment questions and solutions have been published at appropriate times, and feedback on other assessment exercises such as formal reports. All grades for all assessed work are also provided. All this material is not new for the web, but provides an alternative way of accessing the material.

The medium-specific benefit of the Circuits and Devices WebCT sites is in the gallery of external links that has been collected to provide alternative descriptions of important concepts, supported by features such as java applets to animate the presentations constructively. A particularly useful link that can be used to pique a student's interest points to the part of the Britney Spears official website that describes the physics of semiconductor devices and lasers. Another particularly important set of links point the student to websites related to the textbooks. Some of these are large and well-maintained and provide substantial additional benefits to the students. For example, the text on semiconductor devices used in Circuits and Devices has a website which contains a battery of multiple choice questions that

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cover the topic material and can be used by the students to gauge how well they understand each part of the topic.

Conclusion

This paper provides an overview of education innovations undertaken in the two first-year engineering topics at Flinders University. It illustrates that an integrated approach to teaching together with a pedagogical approach of collaborative peer learning, creates an active learning environment which empowers students to be the drivers in their own journey of learning. This has led to an improvement in progression rates and a significant reduction in attrition.

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Appendix

The Flinders University

Student Evaluation of Teaching
In

CIRCUITS & DEVICES 1 – COOPERATIVE GROUPWORK

This questionnaire seeks information about your experiences of this topic. Please circle the number which most closely corresponds to your own view about each statement. If you feel that you cannot answer a particular question, circle the 'Not Applicable' category. Your responses are anonymous. Please print your comments to preserve your anonymity.

The Topic

		Strongly agree			*Undecided*			*Strongly Disagree*	*Not applicable*
1.	*Working in a cooperative group helped to improve my understanding of the material covered*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
2.	*My cooperative group worked well together*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
3.	*All group members contributed equally to the assignment solutions*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
4.	*I preferred working on the assignment solutions as part of a group rather than an individual*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
5	*It was easy to find a time for all group members to meet*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
6.	*Sufficient guidance was provided in how to work in a group*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*
7.	*My ability to work in a team has been increased*	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*x*

8.	*What were the best aspect of working in a cooperative group, and why? (*print your comments*)*
9.	*Do you have any comment on working in a cooperative group? (*print your comments*)*

Thank you for answering this questionnaire

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Addressing inequities in engineering sketching skills

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Abstract: *All engineers need to be able to create, read, and sign-off on technical drawings prior to production of designs. From listening to the debate and disappointment amongst colleagues teaching in engineering courses, it seems that it is often assumed that students who enrol in an engineering undergraduate degree program have good technical sketching skills and can move quickly on to computer aided drawing packages. It may also be assumed that they are familiar with CAD packages. This paper presents preliminary research that investigates the familiarity with, and skills in, technical sketching by first and second year students enrolled in engineering at the University of Technology Sydney (UTS). The authors discuss why inadequacies in technical sketching skills can arise in some students as a result of subject progression at school and lack of time spent developing confidence in technical drawing at university. We describe a mini-course in technical sketching that is being trialled through the Engineering Communication subject at UTS.*

Keywords: *technical sketching, visual communication, engineering communication skills*

Introduction

All engineers need to be able to create, read, and sign-off on technical drawings prior to production of designs. It is also well documented that engineers need visual/graphic skills to be able to communicate their ideas (Tufte 1997 and Field 2003) to non-engineers like clients, workshop staff and other professionals as well as to other engineers.

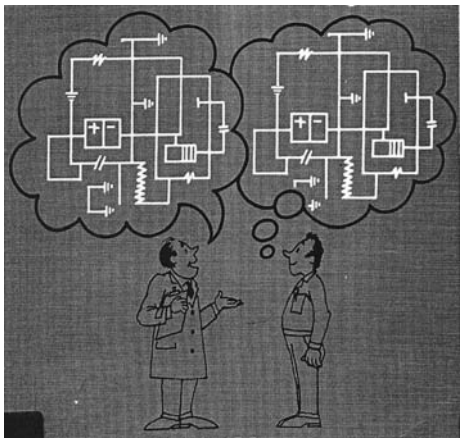


Figure 1. The cover of "Communicating Technology"

Kardos (1997 p. 1) states that "Engineering drawing ... is the language of the engineer. It is their means of developing and recording their ideas, and conveying them to others. Every engineer will be using and referring to some form of drawings almost daily." Glegg (as cited in Kardos 1997 p. 1) says "words are not the natural language of engineers. Drawings are their prose, mathematics their grammar and differential equations their poetry." Figure 1 shows the cover of "Communicating Technology" (Morgan

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1983). In this one cartoon she acknowledges the absolute necessity for technologists to be able to communicate visually as well as verbally.

Graham (2004 p. 2), in an article summarising many contributions to one particular newsgroup, points out "while the capability to sketch effectively is not needed by **everyone** in your organization, it's essential to have **someone**. This is a tool, just like CAD – and you would think it is essential to have CAD expertise somewhere." He discusses the need for dimensions on designs and that while some engineers can draw easily and quickly in CAD, others "generally sketch on the [whiteboard, chalkboard, pad, envelope, napkin – pick one] before even turning the computer on. But ... software encourages attention to detail and working by hand encourages awareness of the big picture." Petroski (1997) also refers to the engineer's first sketch as often being on the back of an envelope and regularly forms the basis for final drawings.

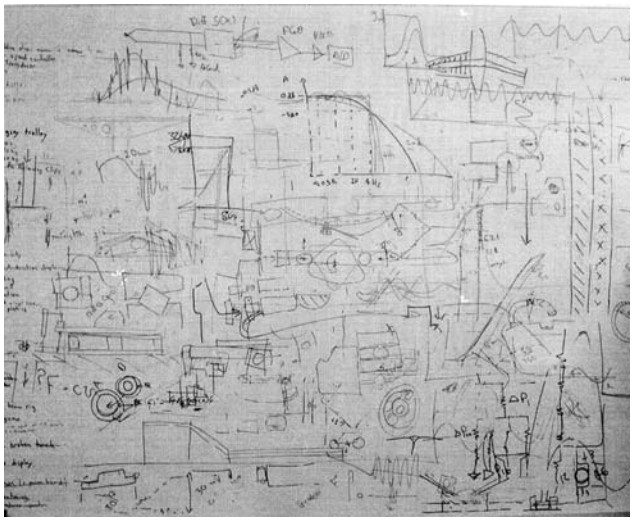


Figure 2. An engineer's whiteboard.

A quick tour of engineering labs and offices will soon provide evidence of such technical sketching being used throughout the design process and in any available space (Figure 2).

The particular skill we are concentrating on in this paper is hand sketching or what we have called "technical sketching".

What types of technical sketching are used in engineering?

Graham (2004 p. 3) outlines three major types of hand sketches used by engineers. They are:

- **thinking sketches –** that clarify ideas
- **prescribing sketches** – that add scale, ensure repeatability, eliminate discretion of workshop staff
- **talking sketches** – that guide discussion of ideas, e.g. improvements and ambiguities.

This freehand sketching skill is needed in all engineering fields of practice and at all stages of the design process.

Throughout the design process engineers need to use technical drawings to better clarify their ideas to themselves and communicate their ideas to others with whom and for whom they are designing. Sketches and other graphics are generated by hand and/or computer software at various stages through the engineering design process. Students should learn that these graphics are an integral part of designing and should be developed and embedded throughout the process and not seen as an annoying add-on, something to be created in a perfect form just before handing in a project. In fact, many design texts reinforce this latter view that communication and documentation only occurs at the end, for example "Communicating the design to others is the *final*, vital step in the design process" (italics

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added, Shigley and Mischke 1989 p. 8) and "Subsequent to many iterations, the process *ends* with the vital step of communicating designs to others." (italics added, Ugural 2004 p. 7)

Figure 3 contrasts two models of communication and documentation during the design process. In the first flow chart, typical of those found in many introductory engineering design texts (Shigley and Mischke 1989, Ugural 2004, Eide *et al.* 1998, Burghardt 1999), all documentation is shown as occurring at the end of the process. The second, proposed by the authors, shows that documentation and communication is, or should be, more integrated throughout the process.

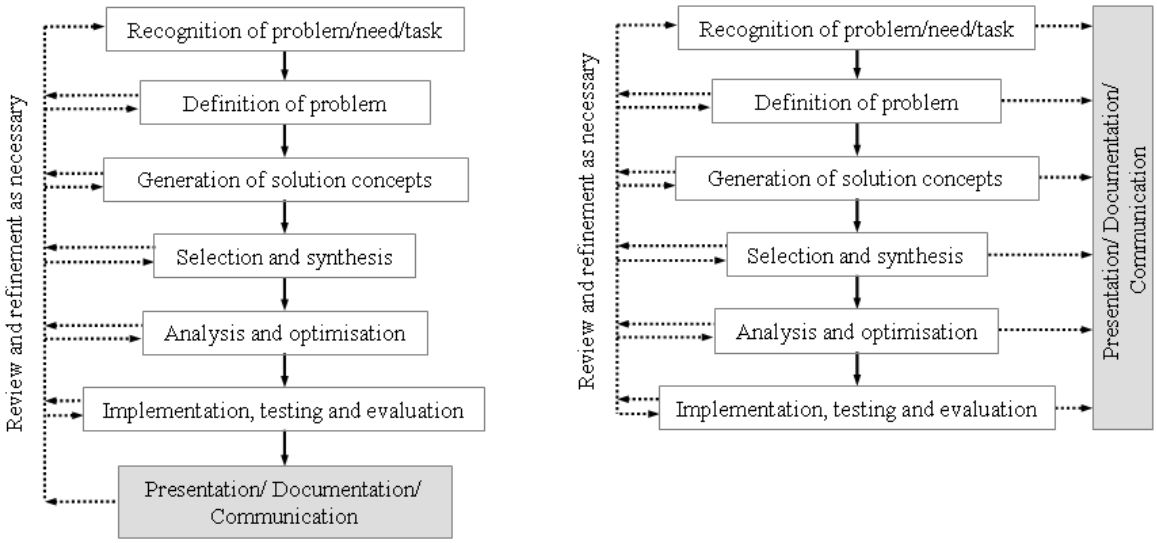


Figure 3 Where does communication and documentation fit in the design process?
a) the 'common' model b) the integrated model

In supporting the development of freehand sketching skills throughout the design process Lueptow (2000) states that "sketches often act as stepping stones to refine and detail the original concept or generate new ideas. Many great design ideas are first sketched on the back of an envelope or in a lab notebook."

While all engineers and engineering academics agree that these skills are important and are not present, this is not accepted by our undergraduate students who cannot see the need or relevance of such skill. Therefore, it was necessary for us to make explicit for each field of practice where these skills were required. To do this we developed the list in Figure 4.

Advantages of having good technical sketching skills

Graham (2004 p. 2) summarises three advantages for engineering students of good technical sketching skills:

- drawing by hand **can reinforce fundamental skills** like the selection of appropriate coordinate systems, understanding of spatial and mass relationships and prediction of inferences,
- hand drawings are **cross-cultural, cross-gender** and understood by others **regardless of educational background**,

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- hand drawings are easily passed around for comment or annotation or to elicit further ideas.

In a study by Alias *et al.* (2002) it was also found that spatial visualisation was significantly improved in engineering students who were given sketching activities as well as their standard class work.

Because graphic communication often needs to occur during meetings of engineers with a variety of other people when there are limited tools and materials at hand, the 'technical sketching' skill that allows this to happen is an important one for our students to develop.

Figure 4. Some areas of need for technical sketching

Mechanical engineers may need to create hand sketches:
- to communicate to others effectively, concisely and unambiguously such things as dimensions, shapes, layouts, etc of mechanical systems and components;
- of Free Body Diagrams for analysis of design options, to teach/explain concepts or design issues to junior engineers e.g. the engineers whiteboard seen in Figure 3; and,
- to help generate ideas and to quickly communicate them (while brainstorming for example) and to document them (in journal or notebook for example).

In the **Civil engineering** fields sketches of structural elements are important. In surveying, engineers need to be able to draw a sketch plan, i.e. the view from above, so that field notes and measurements can be added while on site in a reasonably accurate way.

Electrical engineers should develop the ability to hand sketch:
- equipment interconnection layout diagrams for laboratory work,
- schematic representations of the same lab circuits,
- graphs that summarise measured results in order to verify trends,
- waveforms (sinusoidal, square, triangle) as seen on a CRO,
- transfer characteristics that describe component or circuit functions.

At UTS the electrical engineering program sets an assessment task (compulsory - but with no marks) for students to sketch the main meter box or distribution board in their house or dwelling. The students are then walked through their sketch, identifying various components, and analysing them with regards to their function as part of domestic metering, protection and distribution. The final outcome is a schematic representation of the same.

Computer Systems and Software engineers must be able to visualise their often virtual systems in terms of 2D and 3D images and metaphors like the Mississippi metaphor Bentley (2000, Column 7) uses when discussing 'back-of-the-envelope' scribbles that were effective in pinpointing design faults with software systems for the Atlanta Olympics. He goes on to say "the idea ['back-of-the-envelope'] is standard fare in engineering schools and is bread and butter for most practicing engineers. Unfortunately, it is too often neglected in computing."

Telecommunications engineers need to be able to sketch timing diagrams, wave forms, operating systems and block diagrams.

Technical sketching skills of our students

From the results of some of the work in the hand-graphics activities in the Introduction to Mechanical and Mechatronics Engineering subject at the University of Technology Sydney (UTS) it has been found that some students have particularly poor skills in this area. During our Australasian Association for Engineering Education conference in Melbourne 2003 we heard despair from colleagues about lack of ability in these basic skills. Discussions with colleagues within UTS and from other universities and comments from papers and presentations at various engineering conferences also support our hypothesis that **many engineering students come with poor hand-graphic skills. Good skills are expected of them throughout the course and little opportunity and guidance is provided for improving these basic skills**.

Given that technical sketching is so important to engineers we felt that the apparent lack of confidence and skills observed in our students needed investigation.

Investigating issues that affect technical sketching skills

Time allowed for development of skills and confidence

In Mechanical Engineering the process of producing accurate 2D detail drawings begins with a rough sketch. A CAD solid model is then produced from which the 2D detail drawings can be generated automatically. In Civil Engineering the process may also begin with a sketch

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either on site or in the office and then detail drawings are produced using AutoCAD, for example. Instead of spending hours, days, weeks, months producing detail drawings with perfect line work using T-squares, set squares, compasses ..., engineers now produce these drawing quickly using a variety of CAD packages.

As a result, university courses in engineering drawing often quickly gloss over hand-sketching and drawing skills and move onto computer-aided drawing skills. Because the requirement for engineers to be able to produce accurate 2D detail drawings by hand is no longer as necessary as it was in the past, we no longer need to devote an entire subject to technical drawing by hand as we once did.

Thus students are not given the extended experience or practice of drawing by hand that equips them with skills and confidence to produce the less formal types of hand sketching and drawing required later in their courses and careers.

Given that we do not spend as much time on technical drawing as in the past can we assume that the students have mastered technical sketching skills prior to entering university?

Assumptions of prior knowledge

To answer this question it is important to understand the path of subjects students may have taken to enter university engineering programs.

In NSW, secondary students in Years 7/8 do **Visual Art** in which there is much experimentation with materials and styles of art. It is not like the drawing classes of a century ago. They may touch on perspective, they may be taught various techniques of wrist, elbow and shoulder movement, they may even be given opportunities to draw from still life. However, these experiences will be short and without the rigour required for 'technical drawing'.

All students in Years 7/8 complete the **Mandatory Design and Technology** subject in which they may encounter some technical drawing experiences. However, this will depend entirely on the design projects they are required to complete and the competency of their teachers in technical drawing. Some design areas of food, textiles and computer-based projects provide little opportunity for engineering-style technical drawing skills.

All students in Years 7-10 must do **Maths** in which some geometry is studied and diagrams are generated. In compulsory **Science,** diagrams to accompany project work or 'experiments' are required. However, in both these subjects, although diagrams are required, the results are either good or poor and little instruction is given about the 'how to' of technical drawing. This experience then carries through to the Maths and Sciences in Years 11/12.

These experiences and opportunities for development of technical drawing skills is all we can assume from our students when they enter engineering courses at university. In NSW, universities no longer have 'prerequisite subjects' but 'assumed knowledge' and these are Maths, Physics and English at HSC level.

However, some of our students will come to us with much more than the vague and basic skills developed through the compulsory subjects discussed above.

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Elective subjects in Years 9-12 allow students, who so choose, to study Technical Drawing through specific subjects. These subjects include Technical Drawing (Technology – Graphics) (9/10), Technology – Industrial (wood and metal options) (9/10), Technology & Design (9/10), Design & Technology, Industrial Technology, and Engineering Studies. These students should be quite advanced in their hand technical drawing skills and also familiar to a beginners level with at least one CAD software package.

Analysing technical sketching skills

To test our assumptions about prior knowledge and skills of technical sketching we presented students in our 2nd Year Engineering Communication class with a relatively simple technical drawing exercise (Figure 5 Part 1.), and a more complex drawing exercise (Figure 5 Part 2). Results of the sketching exercise were submitted in hard copy to the authors for assessment and formative comment.

We also presented students in our 1st Year Introduction to Mechanical and Mechatronics Engineering subject with an online non-assessable questionnaire about their prior experiences in technical drawing. The pre-test was run via our UTSOnline web-based learning platform. The UTSOnline software tracks who has accessed the material and their results.

From the following photograph:
1. create a freehand sketch by copying the item
2. create an orthographic freehand sketch of the item (if you do not know what this means, say so in the box below)
Your drawings should be submitted in hard copy.



Figure 5. The Engineering Communication pre-test.

In both the pre-test and the questionnaire the initial return was quite small. Nevertheless, the results (see below) give credibility to our assumptions of prior learning.

Results of Pre-Test

The pre-test shows that most of the students tested required some development of their technical sketching skills. They are from 30 students from the entire range of engineering majors. A range of these submissions is included in Figure 6. It is interesting to note that many students did not know what an ‘orthographic drawing’ was. There was even one English-speaking student who did not know the term ‘freehand sketch’.

Some excellent drawings were submitted for this task demonstrating excellent to adequate technical sketching skills. Some examples are included in Figure 6a.

Other submissions demonstrated a lack of 3D thinking, use of boxing and guidelines and even line drawing skills. Some of these sketches needed to be enhanced so that they could be scanned adequately for this paper. Some examples are included in Figure 6b.

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It is also worth noting that it was very difficult to get submissions from students who thought they 'could not draw' and most of the drawings received from these people were only received under pressure. For a more comprehensive range of evidence of the skills of our students it would be necessary to make the pre-test both compulsory and assessable. This is to be trialled in Spring semester 2004.

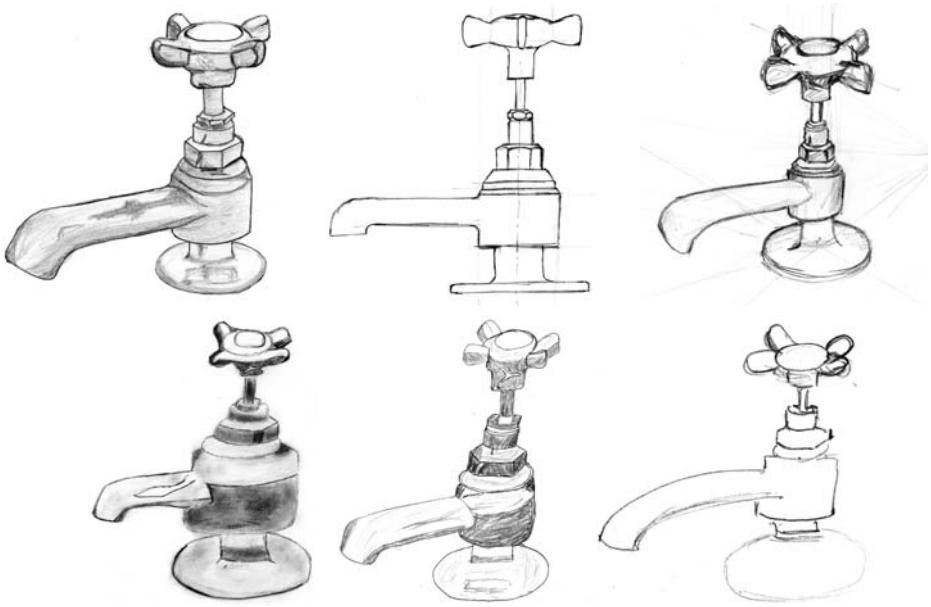


Figure 6a. Results of the pre-test – some better examples.

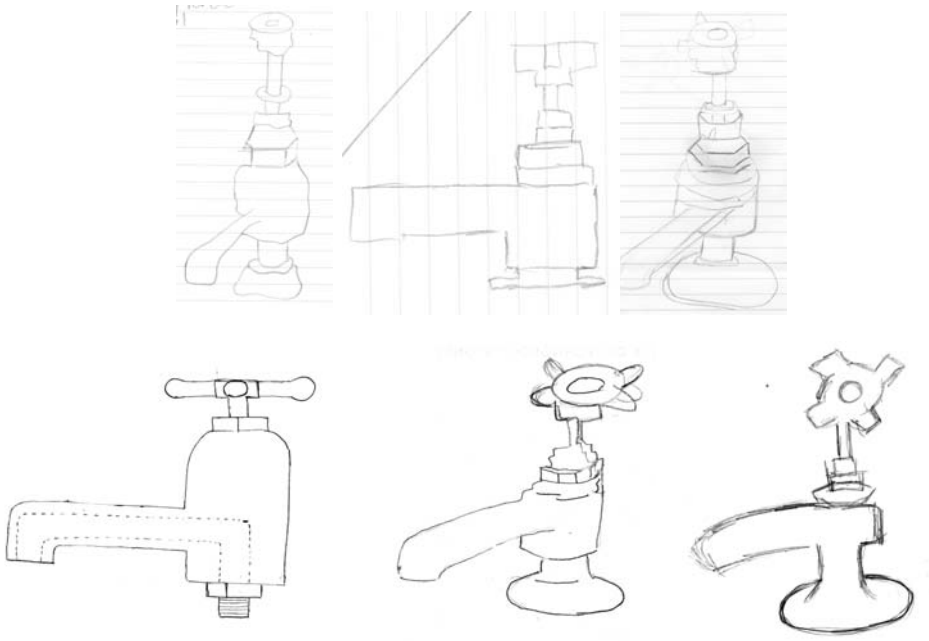


Figure 6b. Results of the pre-test – some poorer examples from students who may need support to develop their technical sketching skills and spatial relationship skills.

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Results of questionnaire

It is important to note that this was also a non-compulsory and non-assessable task. The number of students who attempted the questionnaire was 67 (out of 120), an excellent return. There were no unanswered questions from these students.

From the results shown in Figure 7 it is obvious that our assumption of prior knowledge and skills in technical sketching and even hand drawing is correct. More than half of the respondents feel that they have had a very small amount of training in technical sketching.

It would be easy to assume that school students are moving on too quickly to CAD programs at the cost of sufficient technical sketching skill development, but from the results of questions 2 and 3 this does not seem to be the case.

This deficiency in technical sketching skills needs to be addressed early in the university courses of engineering undergraduates.

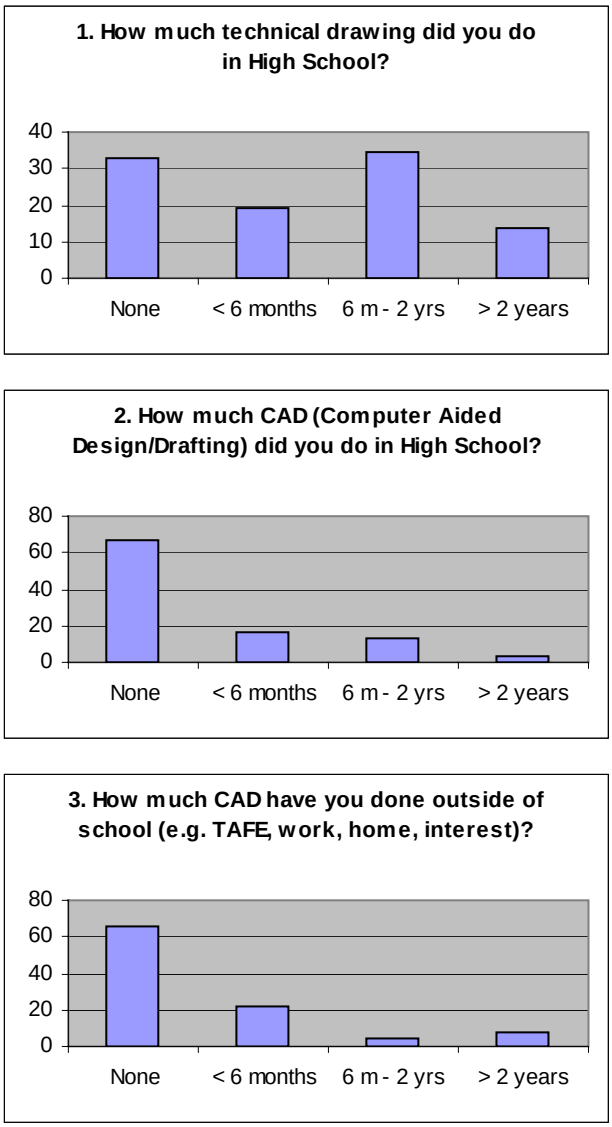


Figure 7. Results of the questionnaire shown as % of total returns.

Addressing inequities of technical sketching skills – the mini-course

At UTS students in their first year do many subjects in common but also encounter the first of the specialist subjects in their particular major. Students in Computer Systems, Mechanical, Mechanical & Mechatronics, and Electrical Engineering must complete a subject called Introduction to Mechanical and Mechatronics Engineering. Students in other majors can also choose this subject as an elective in their course. In this subject only one week (6 hours) is spent on instruction in hand graphics before moving on quickly to computer-generated graphics through a CAD software package. However, students are required to submit several hand sketched assessable items, mostly integrated into a design project. Civil Engineering students and Telecommunications Engineering students are not given this opportunity to develop their technical sketching skills.

At UTS, all students (usually in their second year) complete a subject called Engineering Communication that focuses on their communication skills in an engineering setting (Jacobs & Griffiths 2004).

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In the earlier design of our Engineering Communication core subject a decision was made by the development team that 'Engineering Communication should concentrate on developing generic visual communication capabilities' and that it was 'inappropriate ... to teach sketching and drawing skills' that were specific to any one field of practice (McGregor, Mack & Jarman 2002 p. 249). In other words, students should learn **about visual literacy** rather than how to **do** specific technical sketching tasks.

While the authors appreciate this decision, we have found that minimum levels of graphic communication skills are assumed and students do not necessarily have these skills. However, the development of this skill in our students suffers from the 'Whose job is it? – everybody, somebody, anybody, nobody' syndrome and thus 'falls through the cracks'.

This year the authors have begun to address this technical sketching issue and skills of visual communication, not only through visuals in presentations and reports but also by offering an opportunity for students to improve their hand technical sketching skills. This is achieved via a mini-course run in parallel with other activities in Engineering Communication for students who do poorly on the graphics pre-test discussed earlier. Currently it is a completely voluntary program but from Spring 2004 students with poor skills will be able to gain bonus marks for the subject by submitting their Portfolio of Technical Sketching that is the outcome of this mini-course. At the time of writing this paper, these students were progressing through the exercises with some success. For this mini-course, students work at their own pace through a series of 12 basic sketching exercises that develop skills in drawing straight lines and boxes, curves and circles, lettering, boxing and guidelines, thumbnails, dimensioning then progresses to exercises in orthographic projections and perspective views. Figure 8 includes some pages from the mini-course booklet developed.

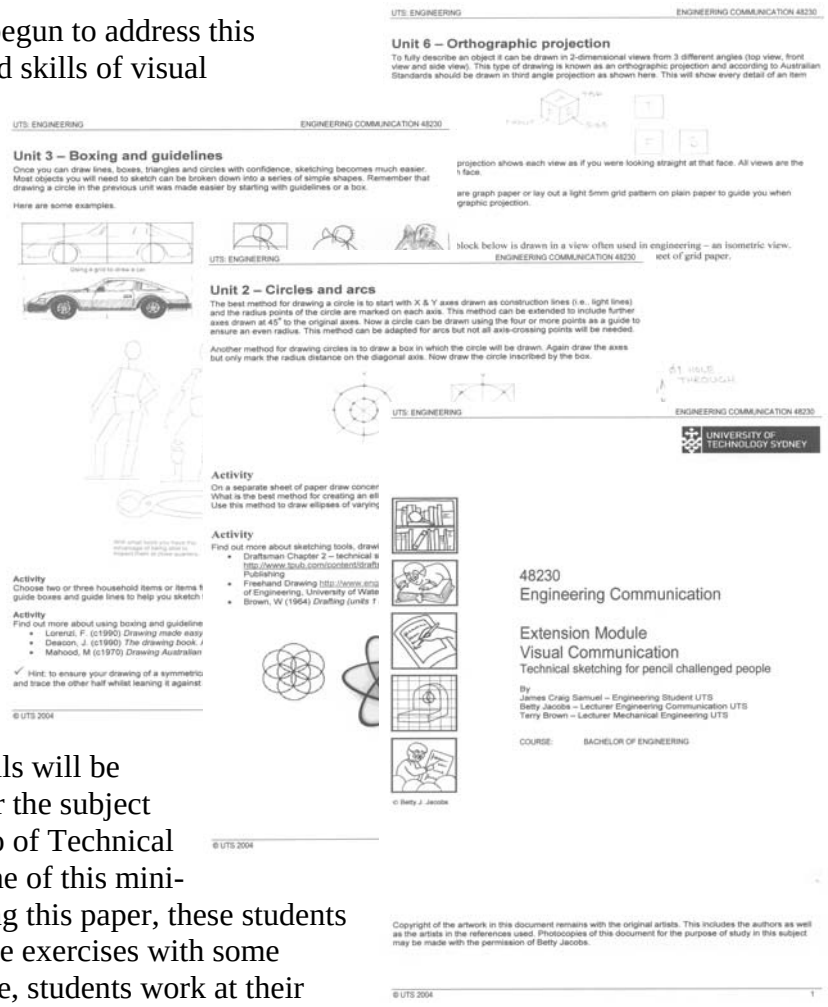


Figure 8. Sample pages from the mini-course booklet.

The pre-test and mini-course have been developed by the authors, in conjunction with an undergraduate mechanical engineer working in an engineering drafting office. This student has worked on this project as part of an elective subject run through the Faculty of Engineering called Professional Service Project. This subject gives students the opportunity to

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find a 'community' project that requires their **engineering expertise** and has a **communication outcome** (Jacobs *et al*. 1999).

Where to from here?

As this semester progresses results of the pre-test and mini-course will allow us to modify our strategies for developing competent technical sketching skills in our students who need help.

It is obvious that universities must come to terms with the discrepancies between assumed and actual prior knowledge of our students. It is not appropriate to assume that the skills of the best students are the skills of the whole cohort, or that those without the skills have been lazy or stupid in their schooling. We must realise that many students who enter engineering courses have not had the opportunity to acquire the skills we assume they have.

Perhaps we need to be more explicit in describing to our First Year students the skills that we assume they have, the benchmark from which we will begin their education as engineers, and provide them with pathways to develop these skills if they do not have them. This issue has been addressed in many engineering maths and physics courses with the provision of bridging courses and slower-paced foundation courses for those in need. Our solution this year for technical sketching has been to provide a mini-course. This is just a beginning. Is there opportunity to recommend a course from another faculty or TAFE that can be used as an elective subject for our students? Should the Engineering Communication subject extend its already full curriculum to include technical sketching as well as visual and textual literacy? Is there a need for a 'standards document' outlining standards for 'technical sketching'?

The authors look forward to opening and continuing the debate about these issues and to finding solutions to the problem of technical sketching for our students.

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Incorporating and developing graduate attributes via program design

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Abstract: *Universities around the world have become increasingly aware of the need to be able to demonstrate, in a quantifiable manner, the skills and attributes that their graduates are imbued with during their learning experience. Engineering schools, similar to other professional program providers, have been aware of this need for over a decade and it is a requirement of accreditation that engineering schools must be able to demonstrate that their graduates possess the nominated Engineers Australia (EA) attributes to a substantial degree. This paper describes how the School of Engineering in Tasmania has been able to incorporate and develop graduate attributes by good course design and how it validates that it achieves the required EA graduate outcomes. The paper also refers to the recent guidelines for accreditation of engineering programs in the United States of America and the United Kingdom.*

Keywords: *accreditation, graduate attributes*

Introduction

The features of the Engineers Australia (EA) accreditation process are generally well known in Australia and details are readily available (EA 2004). To refamiliarise the reader, EA states its primary objectives in the accreditation process to be *"the maintenance of internationally benchmarked standards, the promotion and dissemination of best practice and the stimulation of innovation and diversity in engineering education*". EA then identifies the parameters listed below as the foundation on which engineering program accreditation is founded. The EA accreditation processes promote an holistic approach to engineering education.

- The teaching and learning environment
- The nature of the academic program
- The exposure of students to professional engineering practice

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- Quality systems and processes in place

The accreditation process is the responsibility of the Accreditation Board, which is appointed by EA Council and chaired by the National Vice-President Education and Assessment. The Board in turn relies on voluntary accreditation expert panels to visit institutions and make recommendations for accreditation of engineering education programs within any particular engineering school. The review cycle is nominally 5 years but delays can push out the process to 6 years or even longer. Shorter periods of accreditation may be specified based on the review outcomes and in rare cases accreditation may be declined and closure of the program(s) recommended.

One feature of the accreditation process that has proven to be of great interest in the last few years is the need for the school being reviewed to demonstrate how it imbues its graduates with what has been termed desirable "graduate attributes". This need to measure and validate the attainment of attributes has stemmed from two recommendations from the Review of Engineering Education (IEAust 1996) that indicated that engineering courses must have clearly stated goals and outcomes and must equip graduates for lifelong learning. Under Recommendation 3.2 of the Review the now widely known attributes are listed. It is also stated that *"engineering schools demonstrate that their graduates have the following attributes to a substantial degree"*. Recommendation 3.3 sums up the present accreditation process, stating that *"that the accreditation of Bachelor of Engineering courses is based on demonstrated development of graduates with these attributes"*

The 1996 Review (IEAust 1996) encouraged Engineers Australia and engineering educators to lead the charge across the nation in incorporating graduate attributes in teaching programs. This trend has gradually spread and all universities in Australia now publicly espouse the attributes that they expect (or hope) their graduates to possess. The Generic Attributes of Graduates of the University of Tasmania (2004) are provided in Table 1 as an example of information published by universities. As might be expected the EA graduate attributes can be easily matched against the UTas exemplars listed for knowledge, communication skills, problem-solving skills, global perspective and social responsibility (Table 1). This matching of EA graduate attributes against a home university's generic attributes is very important if the engineering school is to satisfy both masters (EA and the teaching and learning body at the home university) and to minimise duplication of the large amount of reporting and paperwork required by both bodies.

Accepting the status quo, the issue for engineering schools now becomes how they can truly demonstrate that their graduates have the desired EA (and home university) attributes to a "substantial" degree. One approach is of course to "map" how the various graduate attributes are embedded in individual units and programs. This would require developing individual unit matrices, using information that should form part of the unit outlines/synopses routinely provided to students. Such matrices of course need to link learning outcomes with graduate outcomes via assessment methodology. Outcomes from individual units are then integrated across each program and the overall outcome evaluated.

Comparison to the United Kingdom and United States of America

The Engineering Council of the United Kingdom (ECUK)

The ECUK has recently developed new accreditation criteria to be used for the accreditation of engineering degrees in the UK (2003). The proposal is that graduates must achieve five learning outcomes although it is also intended to allow for program designers to compensate

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between the elements of each of the five outcomes. The compensation is intended to promote diversity by allowing program designers to focus on the strengths of their universities and schools and thereby produce graduates with special attributes unique to that program. The five learning outcomes are listed below. The ECUK provide detailed content under each of the five learning outcomes, however only the components of the last outcome are provided here and the reader is referred to the ECUK (2003) for detailed content of all outcomes.

1. Underpinning science and mathematics, and associated engineering disciplines.
2. Engineering Analysis.
3. Design.
4. Economic, social, and environmental context.
5. Engineering Practice. This can include:
    - Knowledge of characteristics of particular equipment, processes, or products
    - Workshop and laboratory skills
    - Understanding of contexts in which engineering knowledge can be
    - Understanding use of technical literature and other information sources
    - Awareness of nature of intellectual property and contractual issues
    - Understanding of appropriate codes of practice and industry standards
    - Awareness of quality issues.
    - Working with technical uncertainty

The USA Accreditation Board for Engineering and Technology - ABET

ABET is recognised in the United States of America by the Council for Higher Education Accreditation as being responsible for the accreditation of educational programs leading to degrees in engineering, engineering technology, computing and applied science. The reader should also refer to the full details provided from documents on the ABET website (2004). The ABET criteria are very broad with the coverage of basic information being considered more important than offerings of specific courses. Evaluation is via a self-study report supplemented by an on site visit and the overall evaluation is used to verify that the program under review is in compliance with the appropriate accreditation criteria. Its list of accredited programs is widely recognised by many organisations such as the National Council of Examiners for Engineering and Surveyors. ABET accomplishes the accreditation by commissions including the Engineering Accreditation Commission (EAC). Some points on the criteria for accrediting engineering programs follow, however the reader should also refer to the full details provided by ABET (2004).

- The EAC accredits programs leading to the professional practice of engineering.
- All engineering programs must have the word “engineering” in the title.
- Programs are accredited at a basic or advanced level.
- The same general criteria apply for all basic and advanced level engineering programs.
- Additional program criteria apply for specifically named engineering programs.

The most interesting of the eight criteria listed for basic level programs to the authors is Criterion 3 “Program Outcomes and Assessment”, as this criterion relates to what EA term, graduate attributes. The EAC list the following under, “Engineering programs must demonstrate that their graduates have”:

(a) an ability to apply knowledge of mathematics, science, and engineering.
(b) an ability to design and conduct experiments, as well as to analyse and interpret data.
(c) an ability to design a system, component, or process to meet desired needs.

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(d) an ability to function on multi-disciplinary teams.
(e) an ability to identify, formulate, and solve engineering problems.
(f) an understanding of professional and ethical responsibility.
(g) an ability to communicate effectively.
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context.
(i) a recognition of the need for, and an ability to engage in life-long learning.
(j) a knowledge of contemporary issues.
(k) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

ABET also requires that the teaching institution has a program assessment process with documented results and that the assessment process must demonstrate that the program outcomes are being measured (ABET 2004).

Linking EA, ECUK and ABET (EAC)

The link that connects the engineering professions in the three countries is the Washington Accord, which is an agreement between all signatory bodies of engineering education accreditation processes (Washington Accord Secretariat 2004) that provides for mutual recognition. The Accord is based on each member of the group having confidence in the accreditation processes of the other countries, thus leading to the mutual recognition of all accredited engineering degree programs. In practical terms the Accord means that in general a graduate from any course is exempt from the education requirement for practising engineering in all the signatory countries.

While the accreditation EA and ABET accreditation processes are very similar, the accreditation of courses in the UK is not carried out directly by the ECUK and instead individual Engineering Institutions are licensed by the ECUK to accredit courses which meet academic standards for admission to the register (ECUK 2004). The graduate outcomes for EA, ABET and the ECUK are broadly equivalent although expressed in different formats. This is not surprising given their links via the Washington Accord. Both the EA and ABET are voluntary for the teaching institution, both accreditations are completed by volunteers, the outcomes from the accreditation processes are recognised by the relevant professions and both bodies stress the importance of demonstrated graduate outcomes. There is however a very important difference between the two, in that ABET exists for the sole purpose of accreditation while accreditation for EA is a very minor part of its activities. This difference is of course very important to universities who sometimes perceive that EA places too little resources into its accreditation activities and does not provide adequate information to its clients regarding the accreditation process. A visit to the two websites will very quickly verify the perception of relative importance.

Mapping Graduate Attributes

Waters (2003) reviews the current situation in Australia and the UK with respect to how various universities have produced mechanisms for students to map, track and assess the development and/or acquisition of graduate attributes during their studies. Some universities provide self-assessment or portfolio building tools for students while others have developed specific units or skills programs to equip students with the desired attributes. The University of Tasmania has opted for the explicit embedding of appropriate skills and attributes into each course. Waters concludes that it would be unwise to invest in software or mechanisms that

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"merely mapped notional graduate attributes rather than those that students actually had achieved". The authors' experience has shown that the embedding of graduate attributes into courses should be driven by schools and faculties, with administrative areas, such as teaching and learning units, facilitating the process by provision of simple tools and good advice.

ATTRIBUTE	DESCRIPTOR	EXEMPLARS (extract)
Knowledge **(EA equivalent attributes a,c,j)**	*Graduates will have an in-depth knowledge in their chosen field of study and the ability to apply that knowledge in practice. They will be prepared for life-long learning in pursuit of personal and professional development*	▪ Apply technical and information skills appropriate to their discipline or profession;. ▪ Use a wide range of academic skills (research, analysis, synthesis etc); ▪ Understand the limitation of, and have the capacity to evaluate, their current knowledge; ▪ Identify, evaluate and implement personal learning strategies; ▪ Learn both independently and cooperatively; ▪ Learn new skills and apply learning to new and unexpected situations;
Communication Skills **(EA equivalent attributes b,f)**	*Graduates will be able to communicate effectively across a range of contexts*	▪ Demonstrate oral, written, numerical and graphic communication; ▪ Present well-reasoned arguments, using technology as appropriate; ▪ Access, organise and present information, particularly through technology-based activity;
Problem-solving Skills **(EA equivalent attributes d,e)**	*Graduates will be effective problem-solvers, capable of applying logical, critical and creative thinking to a range of problems. Developed competencies in information literacy*	▪ Identify critical issues in the discipline or professional area; ▪ Conceptualise problems and formulate a range of solutions; ▪ Work effectively with others; ▪ Find, acquire, evaluate, manage and use relevant information in a range of media.
Global Perspective **(EA equivalent attributes f,g)**	*Graduates will demonstrate a global perspective and inter-cultural competence in their profession*	▪ Demonstrate an awareness of the local and global context of their discipline or professional area; ▪ Function in a multicultural or global context.
Social Responsibility **(EA equivalent attributes h,i,j)**	*Graduates will act ethically, with integrity and social responsibility*	▪ Acknowledge the social and ethical implications of their actions; ▪ Appreciate the impact of social change; ▪ Demonstrate responsibility to the local community, and society generally.

Table 1. Generic Attributes of Graduates of the University of Tasmania (2004)

As in most Australian universities a university wide approach at the University of Tasmania to map graduate attributes, while under development, is yet to be fully realised. The School, faced with an imminent accreditation visit, opted to comprehensively map its 6 engineering specialisation programs. This required developing new unit outlines for all 60 plus units taught by the School and linking assessment-outcomes-graduate attributes in matrices especially developed by the School (for the EA accreditation visit). Table 2 provides an example of a unit matrix, for KNE313 Geotechnical Engineering 1, a unit taught in the third year of the civil engineering specialisation.

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KNE313 Geotechnical Engineering 1	Graduate Attributes				
	a) Ability to apply knowledge of basic science and engineering fundamentals	c) In-depth technical competence in at least one engineering discipline	d) Ability to undertake problem identification, formulation and solution	e) Ability to utilise a system approach to design and operation performance	f) 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
Estimated % Split	**35**	**35**	**10**	**10**	**10**
Nature and properties of geological materials	Assignments Examinations	Assignments Examinations	Field Trip		Geology Project Report
the processes which work to modify landscape, materials, and modify properties of earth materials	Assignments Examinations	Assignments Examinations		Field Trip, Laboratories	Geology Project Report
the geological (and geophysical) methods which might be used to derive essential information on distribution of materials and rock	Assignments Examinations	Assignments Examinations			Geology Project Report
the methods used to classify engineering soils in a systematic and unified manner	Assignments Examinations	Assignments Examinations	Laboratories		Laboratories
how water enters and flows through soil and influences the strength parameters of soils	Assignments Examinations	Assignments Examinations	Assignments		
the methods used to predict the behaviour of soils under consolidating loads	Assignments Examinations	Assignments Examinations		Laboratories	Laboratories
Presentation:	Lectures, tutorials, laboratories, field trips				
Assessment:	Assignments, laboratories, practical examination, theory exam, field trip and project reports				

Table 2. Example of a graduate attribute matrix for a teaching unit/subject

In order to create this matrix the unit designer estimates to what extent each graduate attribute is addressed in the unit. Such an approach may be seen as being rather mechanical in nature and perhaps a somewhat imprecise measure of delivery of graduate attributes within a single unit. However, when aggregated over all 32 units in a School specialisation, a reasonable estimate of delivery of graduate attributes throughout the program is obtained. An example of such information is shown in Table 3, which provides the summary of graduate attributes addressed for all the School's teaching programs.

To support successful student development of the desired attributes, the School has adopted a strategy of making it explicit to students just which graduate attributes are developed in each unit, and how they are addressed. Accordingly, every unit outline now makes explicit the relevant graduate attributes and the unit's intended learning outcomes. In particular, there is an explanation of how each assessment item in the unit will assist the student to develop specific graduate attributes. In this way, the likelihood of students completing a course without being aware of their development of the desired graduate attributes is substantially diminished. Students are able to achieve relevant learning outcomes in each unit and to track their development of graduate attributes. The mapping process for each unit, taken in the context of making graduate attributes and learning outcomes explicit, provides a good indicator of graduate attribute outcomes for all the School's engineering disciplines. It is important to note here that the School uses the overall graduate attribute data to make

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decisions if a program requires fine-tuning via adjustment of a few units, a minor revision within a Year or even a major course review.

EA Generic Graduate Attributes and Summary									
Discipline	a	b	c	d	e	f	g	h	i
Civil	30%	7%	17%	16%	4%	10%	3%	4%	2%
Comp. Systems	34%	6%	12%	19%	9%	12%	3%	3%	2%
Elec. & Comp.	33%	5%	12%	19%	9%	13%	3%	2%	2%
Elec. Power	32%	5%	13%	18%	9%	14%	3%	2%	2%
Mechanical	32%	5%	13%	18%	7%	10%	3%	5%	2%
Mechatronics	31%	6%	13%	19%	9%	12%	2%	3%	2%
Average	**32%**	**6%**	**13%**	**18%**	**8%**	**12%**	**3%**	**3%**	**2%**

Table 3. Mapping the Degree Programs for Graduate Attributes

Verifying Outcomes

While a school may believe that it has demonstrated that it has achieved the goal of demonstrating that it is graduating students imbued with the EA attributes, such claims are meaningless unless validated by the school's end clients – industry and the profession. The School thus conducted a statewide survey of employers and of its graduates in 2003 to evaluate graduate outcomes both from attributes and learning experience aspects. The questions in Table 4 were posed in a survey to 50 employers across the State with a total of 23 responding. The employers were asked to indicate on a scale of 1 to 5 their level of agreement/disagreement with the posed questions. The information in Table 4 is simple summation of those responses received from employers of the School's recent graduates. The School is well pleased with the responses received, especially the very good overall employer ranking of 4.1/5.0 for graduate quality. Typical of the many supportive comments received is the following example, from an engineering company that employs UTas engineering graduates, and more are available from the authors.

"Students have invariably exhibited a good knowledge of basic science and engineering fundamentals. In most cases students have produced clear reports that exhibit the ability to identify problems, formulate solutions and communicate these to others. Whilst this type of employment provides limited scope for students to display leadership qualities our experience is that they have the ability to operate well in a team environment. In general students that have undertaken employment with this organisation have displayed sound knowledge, the ability to work with others and an awareness of their professional responsibilities".

At the same time the School conducted a survey of its recent graduates to evaluate their learning experience in the School. The questions in Table 5 were posed to 85 recent graduates (within 3 years) from the School and 47 responses were returned. The graduates were asked to indicate on a scale of 1 to 5 their level of agreement/disagreement with the posed questions. The data in Table 5 is a simple summation of those responses. The graduate survey outcomes were very favourable, with an overall course satisfaction level of 3.6/5.0. The best outcome was that students indicated that they were able to develop their problem solving skills well throughout their studies (4.1/5.0). It was also noted however that graduates considered that the workload "inflicted" on them as students was somewhat excessive,

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returning a poor ranking of 4.0/5.0. The following quotes are samples of graduate feedback on their time in the School of Engineering:

"Enjoyed my time at Uni of Tas and gained skills that have allowed me to successfully enter the workplace. No hesitation in recommending BE (Civil) to anyone considering it as a future career."

"I like the way the school is including modern developments as they become available, such as robotics & intelligent systems."

1 is disagree very strongly, 5 is agree very strongly						
Aspect	**1**	**2**	**3**	**4**	**5**	**WM**
Good knowledge of basic science and engineering fundamentals	0	0	4	13	4	4.0
Able to communicate effectively, with colleagues and the general community.	1	1	7	10	3	3.6
Good Discipline related technical competence	0	0	5	13	4	4.0
Able to understand, identify problems and formulate solutions.	0	0	8	11	4	3.8
An appreciation of using systems approach to design and operational performance.	0	2	8	11	2	3.6
Able to act as an individual and leader in multi-disciplinary and multi-cultural teams.	0	1	5	12	4	3.9
An awareness of the principles of sustainable design and development and professional responsibilities.	0	2	10	7	2	3.4
An understanding of the professional and ethical responsibilities and a commitment to them.	0	1	9	10	2	3.6
An awareness of the need to undertake life long learning, and a capacity to do so.	0	0	7	11	3	3.8
Overall level of satisfaction with recent engineering graduates from the School of Engineering, UTas	0	0	3	14	5	4.1
Results of 23 Companies	1	7	63	112	32	3.8

Table 4. Summary of employer survey

The **WM** is the weighted mean response for each attribute. The data under the ranking for each question is the number of responses received at that level.

One benefit from the mapping exercise and employer graduate surveys was that the School could compare claims to reality and thus be able to state with some confidence how employable its graduates are and what special attributes it believed its graduates to possess. For example the School could claim that, "*The School of Engineering graduates students who are well received by industry, imbued with excellent discipline technical skills and who possess knowledge of the role and importance for teamwork and leadership in their profession*".

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1 is disagree very strongly, 5 is agree very strongly						
Course Aspect	**1**	**2**	**3**	**4**	**5**	**WM**
The course developed my problem-solving skills as I progressed through my degree	0	1	8	20	15	4.1
The staff attempted to understand difficulties I might be having with my work and normally gave me helpful feedback	1	7	15	21	1	3.3
The course progressively sharpened my analytical skills and readied me for employment as an engineer	2	2	9	25	7	3.7
There was a lot of pressure on me as a student in this course due to the high workload.	1	0	9	21	12	4.0
The course helped me develop my ability to both work as a team member and to be a team leader.	0	4	13	19	9	3.7
My course helped me to develop the ability to systematically plan my own work	0	6	11	20	9	3.7
The course improved my skills in written communication and report preparation.	2	9	10	13	11	3.5
I had developed a good understanding of engineering fundamentals and felt able to cope with my new job.	1	2	10	12	11	3.8
The course made me aware of the responsibilities of a professional engineer.	5	7	7	8	6	3.1
I gained an awareness of the need for sustainable design and development.	3	4	18	11	8	3.4
The course made me aware of the importance to undertake ongoing professional development and learning.	2	11	12	15	5	3.2
Overall, I was satisfied with the quality of my learning experience in engineering at UTas	1	6	8	23	5	3.6
Overall Response	18	59	130	208	93	3.6

The **WM** is the weighted mean for each attribute. The data under the ranking for each question is the number of responses received at that level.

Table 5. Summary of graduate survey

Discussion – Where to from now

Engineering education naturally does not remain static and must change with the requirements of the profession and the needs of modern society. The most recent development in Australia, the USA and the UK has been the role of the accreditation bodies as they have moved from reviews based on prescriptive course content to graduate outcomes. Thus in general there has been a significant reduction in what is often termed technical course content (science and engineering) in engineering programs, as they become ever broader. The findings of a review carried out in 2003 by the National Council of Examiners for Engineering and Surveying (USA) (NCEES) (10) are of interest at this point.

ABET moved fully to its new graduate outcome based engineering criteria in 2000 (termed EC-2000). Prior to 1997 (1997 to 2000 was a transition period) accreditation was more prescriptive requiring a minimum of 0.5 years of social science and humanities, 1.0 year of mathematics and basic science (including specified content) and 1.5 years of specified engineering topics. A much less prescriptive engineering curriculum is now required with only the 1.5 years of engineering topics being retained, but without specifying content. A

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general education component that complements technical content is required, along with a year of college level mathematics and basic sciences appropriate to the discipline. This relaxation has apparently concerned some practitioners and the licensing community, especially the possible loss of *"physics based core units that traditionally have formed the basis of an engineering education"* (The National Council of Examiners for Engineering and Surveying 2003). The ABET requirements for more non-technical content, which have led to a reduction of core science/engineering units, appear to have helped galvanise a concept that increasing USA degree programs from 4 to 5 years (equivalent) is desirable. The extended time would allow retention of both the important broad base material and reinstate the important technical content.

These trends are of interest to Australia given the similarity of developments in the two countries. On one hand engineering schools are continually pressured by EA and their universities to diversify their programs to enrich the students' learning experience. On the other hand they may be hounded by employers and the profession who want to ensure that graduates have an excellent grounding in the sciences and also possess the required technical skills to take their place within their (discipline) profession.

Conclusions

In the current Australian accreditation atmosphere engineering schools must be able to verify that their graduates possess the desired and claimed EA graduate attributes. Demonstrating graduate outcomes can be done via a thorough and explicit mapping process of graduate attributes, which in turn will very likely require a full review of all units in all programs. This is an onerous task that requires significant and dedicated resources.

While an explicit mapping process may satisfy quality assurance issues, external validation will still be required to support the school's claims. The validation that a school's graduates possess the desirable graduate outcomes requires involvement of both employers and graduates. One relatively simply means of validating is to conduct an industry and graduates survey to correlate expectations with demonstrated skills and performance.

The international trend in accreditation bodies has been to move away from specification of course content to specifying graduate outcomes. However some registration bodies and individual professionals are now becoming concerned that this trend has resulted in an excessive loss of technical content and basic engineering science in programs. There is a view held by some in the USA that it would be wise to increase engineering programs from 4 years to 5 years duration to allow for reinstatement of engineering related content.

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The contribution of work placement to generic skills development

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Abstract: *This paper presents findings from Stages 4 and 5 of the Griffith Graduate Project, which compared the perceptions of graduates from the Schools of Microelectronic Engineering (MEE), Environmental Engineering (EVE, and Engineering (ENG) in relation to the development of generic skills and abilities at university, during work placement and in employment after graduation. MEE graduates had the benefit of work placement during their degree through the Industrial Affiliates Program (IAP), whereas graduates from EVE and ENG did not. This enabled conclusions to be drawn regarding the perceived value of work placement on the development of graduate skills and abilities.*

Keywords: *Generic skills and abilities, work placement, work-integrated-learning*

Introduction and background

Griffith University's School of Microelectronic Engineering introduced its first group of final-year students to the Industrial Affiliates Program (IAP) in 1994. Since that time, 400 students have passed through the program and the present enrolment in the program is around 60 students per year from the Microelectronic Engineering degree, combined degrees with Microelectronic Engineering (Commerce, Science and Information Technology) and students from Electronic Engineering at Griffith's Gold Coast campus. Graduates from the IAP were involved in Stage 4 of the Griffith Graduate Project from July 2001 through June 2002. The Industrial Affiliates Program represents a structured work placement of 15 weeks minimum full-time in an industry environment, usually undertaken in the student's 7th semester, with an 8th semester of course work. The IAP represents 40 of the year's 80 credit points in assessment.

The Griffith Graduate Project had three prior stages "designed to raise awareness of generic skills, collect data on current levels of their implementation, embed them into the curriculum and develop ways to assess, monitor and record progress in improving generic skills development in students of Griffith University" (Crebert, *et al*, 2004a). Stage 4 of the project examined the relationship between undergraduate programs, which include components of work placement, and graduate's perceptions of their generic skills development in the three contexts of university, work placement and subsequent employment. Stage 5 of the project (July 2002 through June 2003) examined

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perceptions of graduates from similar disciplines who did *not* have a work placement component as part of their undergraduate requirements, and hence their perceptions of their generic skill development could be compared with those of graduates surveyed in Stage 4.

Griffith University, together with all Australian universities, recognises the importance of generic skill development in its graduates, with its statement of graduate skills and attributes taking prime place in its Strategic Plan, 2003-2007 (http://www.gu.edu.au/ua/aa/plans/docs/strategicplan2003-2007.pdf). Numerous reports have recognised the need for a broad set of skills in addition to disciplinary content knowledge for a graduate to be well placed in obtaining employment after graduation. (E.g., Business/Higher Education Round Table ,1991, 1992, 1993; Coopers & Lybrand, 1998; Sausman & Steel, 1997; The Association for Graduate Recruiters, 1993, 1995, and A.C. Nielsen Research Services, 2000). A.C. Nielsen's report on Employer Satisfaction with Graduate Skills in particular notes the following "skill deficiencies in new graduates: creativity and flair, oral business communication and problem solving." The report also cites employers as reporting that graduates have a "lack of communication skills, interpersonal skills and an understanding of business practice." Of particular interest to engineering is the finding that "Graduates of engineering are perceived to be poor in many skills, particularly at problem solving and oral business communications and interpersonal skills." Engineering schools generally believe their graduates have a good grasp of problem-solving skills, however these skills are tied up in a discipline-based knowledge context and graduates are not skilled in being able to transfer these discipline-based skills to a wider variety of contexts. Research has shown that students' ability to integrate and demonstrate generic skills is linked to the development of confidence in their application to new and different contexts, including the workplace (Harvey, *et al*, 1997; Te Wiata, 2001). Getting students and new graduates to think "outside the square" was an important issue for employers of Griffith engineering graduates in our study. As one commented:

> [Engineering graduates tend to think] "'a+b+c' – that's the rule – and if you put 'd', you're wrong, but in the real world it doesn't work like that, because the weather was dark, and therefore the answer was 'b.'. [They] come out thinking there is only one answer, and it has to be 'y' … but the real world is more like 'Which way was the wind blowing?" Stuff happens."

Of particular interest in Stages 4 and 5 of the Griffith Graduate Project was the examination of whether the inclusion of a structured work placement, such as the IAP, would make a difference in how graduates were able to reflect on the development of their generic skills and their ability to transfer those skills into the context of paid employment and in particular, whether graduates with a work placement component in their degree believed they had an advantage in the development of generic skills during their undergraduate degree. Harvey, Moon and Geall's study (1997) found that "respondents overwhelmingly endorsed work-based placements as a means of helping students develop attributes that would help them to be successful at work," and Coll, Zegwaard and Hodges (2002) report that some of the generic competencies sought by employers "may be obtained in the classroom on campus; others are best developed in the workplace via the work-based learning that forms an essential part of cooperative education programs." Another study reports that:
Co-op graduates reported faster rates of gaining employment following graduation and a much higher satisfaction with the jobs gained…The experience gained by the co-op graduates during their work placement was reflected in the significantly higher proportion who had previously worked for

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their current employer or with another employer in the employer's history. (Edwards & Jancauskas, 2003).

Methodology

A total of seven schools participated in the Griffith Graduate Project, Stages 4 and 5. Of these seven, the responses from three in particular will be examined in this paper. In Stage 4, 41 graduates from the School of Microlectronic Engineering responded to the survey. In Stage 5, 30 graduates from the School of Environmental Engineering and 11 graduates from the School of Engineering responded. Graduates of Engineering and Environmental Engineering were selected as comparisons to the Microelectronic Engineering graduates, which created a total of 41 students who had the experience of a structured work placement during their degree, and 41 students who did not have that experience. All graduates who responded to either the Stage 4 or Stage 5 survey completed their degree between 1997 and 2000. Graduates from these three schools are all engineering students, from four-year engineering degrees, and all need to complete 12 weeks work experience to be qualified to graduate. While Microelectronic Engineering graduates are the only ones with the experience of a structured work placement, they too have to complete 12 works work experience in addition to the IAP. Within Griffith University, these three schools offer a similar type of undergraduate experience, making any comparisons of the development of generic skills with and without work placement particularly valid. It was an intentional design aspect of the research project that students would have been in the workplace for several years before answering the survey. This ensured that the survey respondents would understand the real requirements of the world of work in relation to the application of generic skills.

As part of Stages 4 and 5, focus groups were held where employers and graduates were asked to comment on the data arising from the survey and to answer a number of questions. During the focus groups, employers had an opportunity to comment on the performance of graduates they had employed who had work placement experience and graduates who did not have work placement experience. In general, they made very positive comments about the performance of those who had, e.g.,

> "I have found a better success with Griffith graduates than with those from other universities, and it principally relates to a realistic view about work and a capacity to become more useful more quickly. I suspect it is in part to do with things like the IAP, but I think there is something more to it. The Griffith people are much more practical, I think." (MEE graduate employer)

The survey instrument had six sections with a total of 32 questions, with three of the questions requiring complex prioritising through entering rank-ordered numbers and the remainder being made up of demographic data and five point Likert scales, or check box responses. The generic skills that comprised the Griffith Graduate Statement adopted by the University at the time, and which formed the basis of the questionnaire and the focus group interviews, were:

- Oral and written communication;
- Problem solving;
- Analysis and critical evaluation;
- Information literacy;

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In addition, a number of generic abilities were included in the Statement:

- Undertake independent lifelong learning;
- Initiate and lead enterprises;
- Work effectively as a member of a team;
- Assume responsibility and make decisions;
- Undertake employment or further study nationally and internationally;
- Combined with high ethical standards.

Focus group participants were divided into employers and graduates, and were asked questions on identical topics, with only slight variations depending on the participating cohort. They were asked questions about what generic skills are best developed at university and in a workplace context; how these skills can be better developed in both contexts; what skills are necessary for new graduate employees to possess at the start of employment; how industry and the professions can best contribute to the further development of these skills; what employers value most in a work placement student and in a new recruit; when work placements should occur in the program; whether workplace supervisors should contribute to the formal assessment of work placement students; and their overall expectations of Griffith graduates. Findings from the focus group discussions have been reported elsewhere (Crebert, *et al*, 2004a; 2004b) and will not be discussed in detail in this paper.

Research findings and discussion

Of the wealth of information available in the research findings, seven of the questions will be examined here, broken into two contexts; awareness and opportunities for generic skills development while at University (including the IAP), and recognition of the continuing value of generic skills development importance in employment.

	MEE **n 41**	**EVE & ENG** **n 41**
i. University teaching staff made me aware of the importance of generic skills and abilities for my future career.	57.5%	39%
ii. At University it seemed more important for career prospects to acquire content knowledge than generic skills and abilities	43.6%	63.4%
iii. My University undergraduate degree did provide sufficient opportunities to develop generic skills and abilities	87.5%	51.2%

Table 1: Awareness and opportunities for generic skills development while at University

Of interest in the above figures is the fact that at the time the students represented by this survey were at university, there was little overt awareness raising of the need for generic skills development

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done by academic staff, and certainly not in the MEE program. However MEE graduates did have the advantage of a full semester's work placement, which exposed them to the professional environment of engineering where generic skills are applied. In their response to Question ii, MEE graduates demonstrated a higher level of awareness that generic skills played an important role in comparison to discipline-content knowledge.

Further analysis of the research data will reveal information about specific generic skills and their development while at university for each engineering cohort. All students are in a four-year (or five-year combined) degree, each of the degrees is applied in nature, and all students have to complete 12 weeks of work experience. Assuming, therefore, that there is no peculiar reason why MEE academics would be more inclined than EVE or ENG academics to build awareness of generic skills in the university-based aspects of the curriculum, it may be proposed that the difference in these figures between MEE graduates and other engineering graduates, especially in relation to Question iii, is the exposure to the development and application of generic skills during the structured IAP work placement, including preparation for the IAP and reflection on the experience at the close of the program.

Of particular interest is the response to Question ii, where MEE graduates were more able to recognise the value of acquiring generic skills during their degree in addition to content knowledge.

	MEE **n 41**	**EVE & ENG** **n 41**
iv. Employer creates sufficient opportunities to further develop generic skills and abilities in the workplace after graduation.	82.8%	82%
v. The workplace was so different from university that it was hard to transfer generic skills and abilities when I started employment.	74.2%	53.6%
vi. Development of generic skills and abilities during university work placement gave me a definite advantage when it came to finding employment, OR A university work placement would have given me a greater advantage in finding employment after graduation.	56.5%	60.9%
vii. Participation in work placement contributed (or, would have contributed) to advancement in career.	71%	82%

Table 2: Recognition of the continuing value of generic skills development importance in employment.

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This set of questions shows reasonably common agreement that, once in employment, graduates can easily recognise the value of generic skills and abilities. This creates an interesting comparison with the undergraduate experience of those students without work placement who did not as easily recognise the need for their development during their degree. Responses to questions vi and vii can only reflect the perceptions of EVE and ENG graduates in relation to the added advantage that work placement may have had in relation to finding and advancing in employment, and the literature on the role of work placement in career advancement is divided (Gillin, *et al*, 1984 and Rowe, 1992 cited in Edwards & Jancauskas, 2003) However, a study by Harvey, Moon and Geall (1997) found that respondents who included strategic managers, line managers, graduate and non-graduate employees in 91 organisations "overwhelmingly endorsed work-based placements as a means of helping students develop attributes that would help them to be successful at work", and anecdotal evidence from MEE graduates confirms that the role of the IAP is significant in job interviews.

Another debatable issue in the literature relates to the transferability of skills learned in one context to another context (Clanchy & Ballard, 1995; Atkins, 1999). However, as work placement replicates, to a great extent, the context of employment and the context for the application of the content-based knowledge acquired at university, the figures in Question iv would indicate clearly that MEE graduates found transferability of skills less of an issue that did other Engineering graduates. This finding is supported by the work of Tennant (1999) who proposes that transfer occurs when learners are exposed to opportunities to experience and reflect on a variety of experiences.

Conclusions and implications

The findings from Stages 4 and 5 of the Griffith Graduate Project support the inclusion of work placements in undergraduate degree programs generally. The focus of this paper on the responses from Engineering graduates can only echo the findings that the development of graduates' generic skills and abilities is greatly enhanced through the provision of a structured work placement during the degree program. It should be noted that the graduates involved in this research completed their degrees between 1997 and 2000, when the work of the Griffith Graduate Project had not commenced, or had just commenced. Students graduating in the last few years, and in years to come will be much more aware of the need for generic skills development and will be even more demanding that their undergraduate program provide opportunities for the development of those skills. A structured work placement is one opportunity that can be provided for the development of those skills in context, but this should not negate the need for inclusion in the everyday curriculum of opportunities to develop a wide variety of generic skills and abilities, that are so highly valued by employers, e.g.:

> [The graduates] "we've had from Griffith in recent times have far more of a team approach. Some graduates we've had from other universities, particularly those with a Science background, seem very focused on the 'me,' You know, 'I can do this', or 'I want to do this', and they take the information and almost filter it solo around themselves. But the two we've had from Griffith have been really focused on taking the information and sharing it, getting feedback and working more as part of a team." (MEE graduate employer)

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A design framework for developing technical competence, professional skills and identity

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Abstract: *Recent work by Scott, Yates & Wilson (2001) suggests that the most successful and valuable recent graduates are those who know what to do when things go wrong. Habermas (1996) suggests that persons can be most effective when they achieve a balance between three different ways of knowing about the world—technical, practical and personal ways of knowing. This framework can be used to classify the ten IEAust generic graduate attributes into three areas—ability to apply discipline knowledge and skills, ability to work productively, ability to act responsibly and transformatively. This paper explores the application of these ideas to the teaching of a project-based learning course at the beginning of second-year when students first encounter advanced technical knowledge. It uses Habermas' ideas to provide a framework that can be used to support teachers' personal reflection on the teaching experience and on the use of this framework to improve and accelerate learning.*

Keywords*: generic attributes, portfolio assessment, course design*

Introduction

Traditional design of university education for professional engineers was based on explicit definition of the structure and sequence of discipline content and access to facilities required to develop an understanding of technical knowledge and skills. Experience of staff and students at Central Queensland University (CQU) in the early 1990s (and similar experiences at other universities) suggested that this traditional discipline knowledge and skills approach produced graduates who were ill-prepared for professional employment (Aldred, Aldred, Walsh & Dick, 1997). Investigation of this problem at CQU led to development of a cooperative education scheme in 1994 in which students spent two six-month periods in paid employment during a four and a half year Bachelor of Engineering program. It soon became evident that while introduction of the cooperative program had a positive effect, many students remained poorly prepared for their cooperative placements (Howard, Jorgensen & Nouwens, 2003). Thus CQU became involved with other universities and IEAust to develop a new program design framework based on a more holistic description of the desirable capabilities of graduate engineers. IEAust has defined ten generic attributes for graduate engineers in its accreditation process, and takes a learning-centred approach to accreditation, one that requires universities to show that students are able to demonstrate these attributes on graduation. In 1998, in response to these developments, CQU added to its cooperative

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program a hybrid project-based learning, program structure that supported holistic development of science/ engineering fundamentals, discipline specific technical competence, and other necessary discipline knowledge and skills.

During each of the seven terms that students spend on campus, students complete 24 credit units of study. The program is structured so that project-based courses are allocated 12 credit units, the other two 'traditional' courses in each term have 6 credit units each.

The first year of the program develops basic knowledge of "Maths" and "Physics" and in each term students take a 12 credit unit "Engineering Skills" course that builds professional and basic workplace skills (e.g. capacity for personal reflection, teamwork, verbal and written communication, time-management and a host of other professional skills) (Jorgensen & Howard, 2001; Wolfs, Howard, Vann & Boyd, 1998). The course "Embedded Processor Systems Design" (the focus of this paper) is a 12 credit unit, project-based learning course offered in the first term of the second year. As the first year is not discipline specific, Embedded Processor Systems Design is the first course encountered by the students which includes discipline-specific technical content in addition to the professional skills requirement. As such, it becomes important to design this course well, as it sets the pattern for all following project-based courses in the electrical stream.

The course "Embedded Processor Systems Design" has had a history of development prior to a major review in 2002. Originally the technical content of the course was divided into two separate project areas, microprocessors and programming. Awareness of the possibility of collaborative student activity and synergy that could be developed between the use of discrete digital devices and programmable devices resulted in a merging of these two technical areas. Prior to 2003 however these two areas could still be clearly differentiated in the structure of the course.

The review of the course in 2002 had recognised the negative impact on student learning that this differentiation had caused. For the 2003 offering a much more integrated approach was adopted covering the same content. The portfolio assessment structure (Biggs, 1996) was retained, but additional activities to support learning and assist student development were added. Linkages between the different components of the course are now more obvious to the students and overlapping of the projects allows the students to see the relationships between all areas of the course. This structure provides additional mechanisms for the students to show their learning at all levels of development.

Within the overall process of development of professional skills in the BE program, this course was required to provide opportunities for learners to build their capacity to work in teams, manage multiple team projects and to show their capacity to communicate effectively in the context of team-based analysis, design, construction and documentation of embedded systems to perform tasks according to sets of client specifications.

The challenge for teachers is to devise a course that achieves an appropriate balance of technical discipline knowledge and skills the IEAust nominated professional knowledge and skills, and some measure of personal 'transformation' reflected in development of a professional attitude in students. Such a course design process would benefit from a coherent theoretical framework, one that balances the requirements for technical competence, generic professional skills and development of learners' commitment to the professional identity promoted by the IEAust.

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Theoretical Perspective

A great deal has been written about generic/professional attributes (DEST, 2002; DETYA, 2000; Coopers & Lybrand, 1998).)), however much of the literature is focused on surveying interest groups and describing skills and attributes. Holmes (2000) argues that in most cases, the survey methodology is poor and does not focus on developing an understanding of the pedagogical processes by which professional attributes are developed. Some recent studies such as those at University of Technology, Sydney (Scott, Yates & Wilson, 2001) have begun to develop more robust descriptions of the attributes of successful recent graduates. It is of interest to note that employers interviewed in their research suggest that the best graduates are those who know what to do when things go wrong. While that may be the proof of the pudding, it is no recipe.

The curriculum design literature recommends processes for designing traditional, objectives-based educational programs with a focus on content knowledge and skills (Lovat & Smith, 1995). Little literature was found that addresses the need for a curriculum design framework that would enable learners to develop the generic attributes specified in the IEAust accreditation documents. However Lovat & Smith offer a framework based on the work of Habermas, that can be adapted for design of engineering programs.

Habermas (1996) developed an epistemological framework that suggests people use three different kinds of knowledge to guide activities—technical, practical and emancipatory knowledge. Authoritative knowledge for each of these 'ways of knowing' is produced by its own methods, and each is learned and is taught, and is assessed by different methods. Traditional engineering education has focused explicitly on development of 'technical ways of knowing' but 'practical' and 'emancipatory' ways of knowing have remained implicit, largely invisible to learners and lecturers in the educational process. The increasingly complex, global and dynamic nature of our world, and the need to better educate a greater proportion of the population at a lower cost per student requires that programs explicitly address development of practical and emancipatory knowledge. This is reflected in the IEAust generic attributes specification whose development requires course and program designs that make explicit the approach used to develop in learners all three ways of knowing.

Technical ways of knowing relate primarily to the two IEAust defined generic attributes, 'apply knowledge of basic science and engineering fundamentals', and 'in-depth technical competence in at least one engineering discipline'(IEAust, 1999, s.2.2). According to Habermas, a technical interest in knowledge is important because it seeks a shared, rational, predictable understanding of our physical and cultural world so that humans can develop a capacity to manage their world. This kind of knowledge is based on social conventions and on hypothetical/deductive methods of inquiry that use scientific reasoning to decide what counts as valid, 'objective' knowledge. To allow this method of inquiry to advance unhindered by arguments about ends and means, questions about the value of knowledge are put on hold during the inquiry process. Such technical knowledge is developed and maintained in the scientific community and within the communities of practice of the engineering disciplines. These communities are the authorities for what counts as legitimate technical knowledge. Education into technical knowledge is the process of introducing learners to the authoritative body of knowledge. For this kind of knowledge, the role of the teacher is to act as an authoritative representative of the discipline (Perry, 1988). The learner's role is to reproduce or reconstruct that 'objective' body of knowledge in their own minds. In assessing learning the teacher seeks correct answers, assessment is often summative. Because it focuses on

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'objective' knowledge that has been accepted by the discipline, such learning can be achieved using resources designed in advance, like textbooks and media, or by using primarily 'one-way' communication such as is found in traditional lectures. However dialogue remains necessary for dealing with misconceptions students may have about technical knowledge.

Habermas identifies a second **practical way of knowing** with different intents and methods of inquiry. This knowledge relates to what he calls 'practical' interests, that is, interests in promotion of shared productive human activity. It relates to many IEAust (1999, s.2.2) generic attributes, most obviously to teamwork and communication that are the professional skills focus of the "Embedded Processors" course. According to Habermas, the key to this kind of knowledge emerges from the subjective processes by which humans make and share meaning and construct their social reality. Language is at the centre of this meaning-making process. Knowledge is legitimate if the evidence and arguments used are convincing for the people affected. Disciplines function as communities of practice that help participants articulate and apply the rules and methods of good argument. The role of teachers changes from being the 'content' authority (for technical knowledge) to a person who guides learners, negotiates and shares authority (Perry, 1988), and supports learners to develop better answers rather than the correct answer. Through practice and interaction with others, learners obtain feedback about the quality of their performance, and develop practical knowledge and skills. Assessment tends to be qualitative and formative, requiring good argument or good performance rather than correct answers.

The third kind of interest humans have in knowledge is '**emancipatory ways of knowing'** (Habermas, 1996). This kind of knowledge is personal, closely linked to each person's self-understanding and commitment (Perry, 1988). In an engineering program, this type of knowledge is associated with development of each student's identity as a responsible person committed to acting professionally and maintaining that capacity to act professionally. This kind of knowledge relates to IEAust generic attributes like commitment to professional and ethical responsibilities and a capacity to undertake lifelong learning (IEAust, 1999, s.2.2).). The method of inquiry that makes emancipatory knowledge legitimate is based on critical self-reflection on one's experience. Here 'authority' lies not in the discipline or the teacher, or the quality of argument or performance—authority for what counts as knowledge lies with each individual learner. The teacher cannot be considered to be 'in control' of this kind of learning, only the individual learner can be responsible for developing this kind of knowledge. The teacher must observe the work of the learner and ask the learner to provide evidence that they are developing knowledge of this type. Many learners are reluctant to enter onto the difficult and discomforting path of critical self-reflection and emancipatory learning, the teacher and other students often need to provide a learner with support and with a 'press' to struggle with, reflect on and transform their understanding of the world. Assessment must be based on each learner's story of their struggles and self-reflections and on their behaviour during these struggles.

Lovat & Smith (1995) argue that any holistic education program requires a balance of technical, practical and emancipatory ways of knowing. To live and work, people should have reliable technical knowledge about the world, they should have the capacity to live and work productively in society and in the workplace, and they should have the capacity to act autonomously and responsibly to transform their world. Lovat & Smith suggest that emancipatory knowledge is critical because it is required to ensure that individuals use technical and practical knowledge responsibly. How education programs should develop emancipatory knowledge is an area of growing interest related to development of graduate

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attributes. Holmes (2000) argues that employers are not interested in whether an interviewee for a professional position has particular generic skills, an employer will make a holistic judgement based on their perception of the interviewee's sense of professional identity. Scott, Yates & Wilson (2001) suggest a similar assessment based on employers' notions that the best graduates are those who understand what to do when things go wrong.

Thus in addition to conveying traditional technical knowledge, the "Embedded Processors" course has been designed to develop learners' 'practical' knowledge, the ability to make and share meaning in collaborative groups, and to provide learners with structured and supported opportunities for self-reflection to develop the skills learners need to become autonomous and responsible professionals.

Course Development

The development of the course has become an iterative process which itself includes many of the practices required of the students in their program. The first step is to consider the desired outcomes for the students in this course. Following this a structure can be developed, which will guide the students towards those outcomes. The outcomes must reflect a balance of the different "ways of knowing" described by Habermas, as these are now explicit in the course, rather than implicit as in the case of more traditional teaching approaches. Finally, an assessment structure is required, which allows assessment of student learning towards these outcomes and captures the process of learning, student experience and the development of student identity, rather than just the technical outcomes. As these different aspects of the course are interconnected, it is necessary to constantly review and reflect on the course as it develops and try to maintain alignment between outcomes, delivery and assessment (Biggs, 1999). Critical reflection on different approaches then allows improvement towards a "better" outcome.

Course Outcomes

The course outcomes must be defined broadly, to give students space to explore the region of the outcomes. Within the framework of the IEAust generic attributes, employers have indicated that they seek graduates with strengths in different generic skills to fill requirements of different engineering roles (ISCAN, 2003). Students, on the other hand, have different innate capacities to develop generic attributes. This challenges the students to both reflect on the requirements of the profession and to define their own interests in responding to the outcomes.

Course Delivery

The delivery of the course must enable student development in the different "ways of knowing". There should be several different sets of activities that link together to develop the technical, practical and emancipatory knowledge of the student. According to Vygotsky, some scaffolding is required to build a foundation for the students to begin, but then the scaffolding should be gradually withdrawn for the students to take control of their own learning (Driscoll, 2000, p.251). The delivery of the course can be defined by three main types of activities:

- Workshops
- Projects
- Team Meetings

The **workshops** are heavily structured in the early stages of the course. Students must rapidly develop a technical foundation to use within the course. These early workshops seek to

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support accelerated development of technical knowledge, but within an experiential framework. The workshops were structured to make use of learning-centred activities, rather than lecturer-centred activities. The typical workshop format consists of an introductory activity in which the students are required to build something. This introductory activity defines a context for the information which will be delivered in the workshop.

As the term progresses, the workshop structure is modified so that the student experiences in other parts of the course can be discussed and expanded. Towards the end of term, the workshops tend to become a forum for discussion on the projects, where the students have developed a strong experiential base. The student confidence increases through this experience and they are better able to confidently engage in discussion on higher level topics.

The **projects** address the experiential knowledge of the students in a greater way. The projects have been selected such that the students are challenged to link together many small bits of knowledge, that they have gained through the workshops, and develop a working prototype. Throughout this process, they make mistakes and choices which are not the best in terms of a technical outcome, but which begin to develop a rich experiential, diagnostic framework to guide their decisions. In addition, the projects are delivered in teams of 3 students. Team based projects were selected to allow students to develop their personal interaction skills and an understanding of others. The students are also challenged to develop their own identity within the teams and to take on different roles to challenge themselves personally.

Initially, two projects were decided upon within this course to practice and extend team management skills developed in Year 1. The two projects schedules were deliberately overlapped, to challenge students to manage both projects together and develop strategies to work on multiple projects simultaneously. The first project has the same definition for all teams and this encourages a certain amount of competitiveness amongst the teams. At the end of the project, teams are required to present their designs informally to the class. The different solutions to the same problem are then compared and discussed to highlight the strengths and weaknesses of each.

The second project has a different definition for each team. In the process of development, different teams are exposed to different experiences. The final presentation by the teams then allows each team to share its experiences with the other class members and justify the approach taken by answering class questions. In this way, students may benefit from being exposed to the experiences of others. Often, these experiences can be linked back to experiences the student has had in their own team.

Within this framework, a monitoring and feedback process or what Laurillard (1993, p.104) calls the ‘conversational framework’ of academic dialogue becomes important, so that the students’ learning may be guided in the appropriate direction. The teaching staff have regular **weekly meetings with each team** to discuss their progress in the projects and their progression in the course. The team meetings allow the students to demonstrate development of their practical and emancipatory knowledge, and to begin to take responsibility for their own learning as they share their understandings of team performances and reflect upon and develop a personal professional identity as a team member. The team meetings also allow learners to voice problems with technical knowledge associated with the projects. Feedback on their progress allows the students to reflect on their practices, on their successes and failures, and to improve. As there is no “right” outcome, the students are always challenged to

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improve. There are no circumstances in which the facilitator can say "That's good, you can stop there".

To demonstrate reflection and assist with assessment and feedback, students are required to keep a reflective journal. The reflective journal should discuss, review and reflect on the following areas:

- The activities the student has performed
- Where these activities (and the information contained in them) fit into the desired course outcomes
- The learning obtained from those activities (particularly in the context of the course outcomes)
- What learning student has yet to demonstrate
- What strategies they did use and will use to improve their knowledge
- How effective those strategies were
- Their own performance and the performance of their team members towards the projects

The reflective journals are reviewed throughout the term so the teaching team can be aware of the progress of individual students and provide appropriate feedback. Also, the reflective journal gives an indication of the team performance and allows intervention if the team dynamics are beginning to fail. Such failures are often turned into powerful learning experiences for team members and facilitators (Denning, 2002). This has been found to be a critical task of the facilitator, and if neglected there can be negative learning consequences.

Assessment

The assessment structure used in this course is portfolio based with the students also nominating the grade they believe they have achieved. The portfolio itself must address the course learning outcomes and provide evidence of the student's own work throughout the term to justify claims made. The students must include the following pieces of work in their portfolio:

- Reflective Journal
- Reflective Paper
- Workbook
- Self and Peer Assessment

The portfolio preparation is itself is a reflective process for the student and, as they prepare the portfolio through the term, they must think about their changing individual commitment, contributions, knowledge and learning. As the students are requested to nominate their own grade they must also think about their place in the larger picture. In this manner, the assessment of the course does more than just demonstrate what the student has achieved. The self-assessment becomes a further learning vehicle, reinforcing the technical and practical knowledge, and extending the emancipatory knowledge.

The assessment of the portfolio is assisted by an interview with the students following submission. After all of the portfolios have been reviewed by the facilitators and an initial grade is given, the students are interviewed individually. In the interview, students are given an opportunity to reinforce their grade nomination and then given feedback on their portfolio and their performance throughout the term. Each student is then advised whether the nominated grade is supported or not and the reasons for this decision.

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Reflections

This course was offered as described in this paper in the 2003 offering and again in 2004. The facilitators have made some general observations about the student learning which will now be shared.

The most significant observation is the level of student engagement with the content. In earlier lecture-centric offerings of similar courses, it was noted that students did not engage with the course content until very late in the term, except for the bare minimum required to do the assignments. One result of this is that students have very little time to digest the information and reflect on it. In this offering of the course some students begin to engage as early as week one and many students have begun to engage by week two or three. One disadvantage of this has been that students who lack confidence can see their peers moving ahead at a high rate and this can negatively impact on their own progress. It has been an important task of the facilitators to identify this as it occurs and take some steps to address it. It is not uncommon to see students staying on in the class to finish a difficult task that they were unable to complete during the workshop. This is particularly true from about weeks 2-6.

The presentation of the first project in week six is a highlight for many students. Teams are able to critique each others designs and identify the strengths and weaknesses. The reflective journals also seem to indicate that they are able to identify the strengths and weaknesses of their own design after seeing a number of other ways to approach the same problem. One thing that is particularly of note is that the designs in the 2003 offering were all completely different, allowing much sharing of ideas after the presentation.

The second project offers a wide choice of challenges as each team has a different topic. In a similar fashion to Project 1, students are able to critique the designs of others. In addition to critiquing, students are exposed to the challenges other teams have faced, challenges which are often quite different from their own. Students' personal project experiences provide a firm experiential foundation upon which to interpret and attach the experiences of their peers.

Students appear to have been more able to demonstrate the links between the various content components of the course. Rather than compartmentalize each component, students were able to see and describe the links in their reflections, portfolio and the final interview. This demonstrates that students gained a deeper understanding than has been previously seen in courses covering this content. The depth of understanding that students achieve is often evident in the confidence displayed and their ability to discuss and share their knowledge with others. This is not surprising as Biggs (1999, p.4) shows that as teaching methods become less passive (traditional lectures) and more active (e.g. project-based), even weaker students become more engaged in learning and begin to perform at higher cognitive levels.

The 2003 offering of the course also gives some less positive experience to reflect upon. It is instructive to review the things that went wrong as a critical understanding of failures instructs both teachers and learners. As a result of reflection on experiences in 2003, some modifications have been made for the 2004 offering.

During the 2003 offering, the students bought a problem to the attention of the course team. They felt that certain outcomes could not be achieved within the projects and activities. The way in which these outcomes could be met was to simply going off and read some other texts. Clearly, this indicated a lack of alignment (Biggs, 1996) between the specified learning

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outcomes and learning activities. This allowed alignment of the learning outcomes/activities to be improved for the 2004 offering. However, it is important to note that the students were raising this issue at around week 8 of the term. This indicates that some of the students were thinking about the relationships between the activities and the assessment well before the assessment was actually due. Students identified concerns about the course and felt they had the skills and the right to voice these concerns demonstrating their growing practical and emancipatory knowledge that is an important element of professional responsibility.

During the 2003 offering, it was noted that students take some time to recognise the need for good record keeping and so their early activities tend to be poorly documented in journals or finally written up much later than the original activity. To assist students during this learning phase, the workshop structure and content has been formalized a little more. By setting specific text book problems as a benchmark, students can complete some of the introductory work required as evidence in their portfolios. Thus, some of the workshops will be run in a more tutorial style during the first few weeks to provide scaffolding for students and accelerate learning. This integration of more traditional teaching methods with the use of project based learning is consistent with a growing realisation within the Faculty (BE Forum, 2003) that Habermas' different ways of knowing (technical. practical, emancipatory) require different approaches to teaching and learning and that traditional approaches like lectures and tutorials can be effective in certain circumstances for teaching technical knowledge provided the lecturer and students are clear about the desired outcomes.

Finally, it is important that all of the facilitators in the course team have a common goals and agreed outcomes for the course and a common understanding of pedagogical approaches required to achieve those goals and outcomes. If there are different approaches, then the students sense this and become confused. In the 2003 offering, one member of the teaching team still had a lecture-centric style and this affected the workshops structure, turning some of the workshops into de-facto lectures. Under this structure the students quickly reverted to sponges and did not interact with the facilitator or the class. In the 2004 offering it was necessary to modify the teaching team to reduce the occurrence of this.

The teaching of this course has also proven to be a very positive experience for the teaching staff. Increased levels of enthusiasm from the students tend to further enthuse the staff. Although there will always be students whose performance disappoints, the general feeling of students is more positive than with a lecture-centric approach. The development of the student as a professional is more obvious and leaves staff with a sense of pride in the development of the students. Finally, the delivery of this course has been a lot more fun than previous lecture-centric courses with similar content.

Conclusion

This paper has presented a framework for the development of courses which encompass the three "ways of knowing" as proposed by Habermas (1996). This framework has been linked to the IEAust graduate attributes and it has been shown that these ways of knowing can be incorporated explicitly, rather than implicitly as in traditional course design. An example of course design, "Embedded Processor Systems Design" has been used to illustrate the use of this framework and reflections and observations of the teaching team are presented. Overall, this framework is seen to be valuable by the teaching team involved in this course. Within the program structure at CQU, this framework is already being used to develop other project-based courses in all three discipline streams.

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Processes in Distilling Course Capability Profiles

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***Abstract**: This paper describes the evolutionary processes employed to profile the development of student capabilities as they are progressively developed within the Bachelors of Engineering (Civil, Electrical and Computer Engineering, Mechanical) courses at the Queensland University of Technology (QUT). The outcomes of these processes informed the formulation of new course objectives, formerly a set of value-centred principles, to ones of a student centred framework. The framework's graduate capability statements were developed in a manner encompassing Engineers Australia's requirements, and QUT and Faculty teaching and learning objectives, in consultation with academic staff from within and beyond the disciplines. They relate discipline specific knowledge and skills, critical, creative and analytical thinking abilities, abilities to communicate, life long learning capacity, independent and collaborative working abilities, responsible professional practice, and self-reliance and leadership capabilities. The three engineering degree courses were examined on a unit-by-unit basis in terms of developing students' graduate capabilities, both discipline specific and generic, and linking these against the framework's objectives. This structure allows units to be refined and better integrated to improve the course's development of student graduate capabilities, and facilitates an investigation into elements of the course that could be enhanced, or better achieved, through an enhanced work integrated learning program.*

***Keywords**: AAEE2004, work integrated learning, learning outcomes, graduate capabilities*

Introduction

The Faculty of Built Environment and Engineering (FBEE) at the Queensland University of Technology (QUT), in Brisbane, is currently engaged in a University Large Teaching and Learning Grant entitled, *Integrating Workplace Learning and Professional Education:*

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Implementing a Student Centred, Objectives Driven and Outcomes Focussed Framework (Boles et al, 2002). The following section of the introduction outlines the objectives of the project and establishes the foundation for the topic being presented in this paper.

The QUT-FBEE Work Integrated Learning (WIL) project addresses the objectives, structure, development and evaluation of workplace learning, focussing on integrating workplace learning with the academic curriculum. The intended framework and implemented system purposely centres on the students, their learning environment and outcomes, and utilises the flexibility provided by the advances in educational technologies in an increasingly knowledge based and learning economy (Lundvall et al, 1994).

The most important goal of this project is to enhance students' learning outcomes from the workplace components of their courses. This will be enabled by the identification of workplace learning objectives specifically linked to, and derived from, the learning objectives of the targeted courses. The achievement of the project's goal will also be facilitated by the design and integration of assessment approaches targeting the evaluation of students' attainment levels of the set objectives.

The project focuses on the three large engineering courses offered at QUT, but with a view to facilitate its extension to other courses in the Faculty. On the operational level, the achievement of the project's goals requires, for each course, the identification of specific objectives that are best achieved through workplace learning and the integration of appropriate assessment with the teaching and learning. The project team, in conjunction with QUT's Teaching and Learning Support Services (TALSS), will complement the components developed through other Faculty projects by building a web-based package that provides and facilitates linking of these components, and enables their integration within the framework targeting the specific objectives of this project.

The distinctive goal of the project is to enhance students' learning outcomes from the workplace components of their courses, thus supporting a change in students' position from detached observers to involved performers. This paper describes the process engaged in to extract and articulate components of course objectives that are best achieved through work based learning. The process is broadly summarised as follows.

1. Examination and alignment of course objectives with Faculty, University and professional body objectives, and QUT graduate capabilities.
2. Distilling discipline-specific objectives for each course and mapping the progressive development of such towards attaining the published objectives.
3. Mapping the contribution and progressive development of objectives and graduate capabilities from specific units within each course. (*Units* are the fundamental academic teaching entity at QUT and are generally equivalent to *subjects* at other institutions.)

The following sections describe the processes and outcomes of these stages in the context of the WIL project with general implications in course continuous improvement cycles.

Examination and Alignment of Course Objectives

The identification of graduate engineer workplace skills, which provides a basis for the structure of the undergraduate course curriculum in the Faculty of Built Environment and Engineering, can be found from a number of sources. Both the technical and generic skills

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required in the workplace are defined by the Engineers Australia (EA) in general terms and also in specific terms for different engineering disciplines (The Institution of Engineers Australia, 1999). Similar competency standards have been adopted at various levels throughout the University. These are the: *QUT Graduate Capabilities* document (QUT, 2001); *Faculty of Built Environment and Engineering Teaching & Learning Philosophy*; *Course Objectives* for each course within the Faculty; and *Employability Skills* framework developed by the Department of Education Science and Training (DEST) and the Australian National Training Authority (DEST, 2002).

While the workplace generic skills expected of a newly graduated engineer are very well and fully described in all frameworks and standards referred to (although not necessarily articulated the same way), engineering technical skills tend to be more discipline aligned and their articulation typically less pronounced other than course level objectives and capabilities. However, in reviewing or developing new course curricula, it is important that the full gamut of relevant technical and generic skills is defined and integrated within the course structure.

The EA "National Generic Competency Standards" provides a good starting point for obtaining both generic competencies and fields of technical competencies in different discipline areas.

EA Generic Skills	QUT Graduate Capabilities (MOPP)	BEE T&L Philosophy	Employability Skills Framework	Course Objectives BE(Elec&CompEng)
Ability to apply knowledge of basic science and engineering fundamentals.		Provide our students with opportunities to develop knowledge and skills that are relevant and applicable to current and future real world situations.		To ensure that all graduates are provided with a sound appreciation of the fundamentals of their discipline as well as a knowledge of "state of the art" techniques so that they may adapt themselves to scientific, technological and social changes.
Ability to communicate effectively, not only with engineers, but also with the community at large.	Effective communication in a variety of contexts and modes; written and oral with discipline specialists and on-specialists in cross cultural contexts.		Communication skills that contribute to productive and harmonious relations between employees and customers: oral, written, negotiation, numeracy, persuasion, network, share information, LOTE.	To develop the ability of students to communicate at al levels with their colleagues, in industry, and with other professionals, verbally and in writing.
In-depth technical competence in at least one engineering discipline.	Knowledge and skills pertinent to a particular discipline or professional area: theoretical and practical knowledge in at least one discipline, and technological skills appropriate to the discipline.	Offer courses that are at the forefront of technological advances, flexibly delivered, responsive to the varied backgrounds of students and to the needs of society.		To produce technically competent graduates with an awareness of the "managerial" requirements of industry who can take their place within the profession initially in junior positions with a foundation necessary to progress to senior positions.
Ability to undertake problem identification, formulation and solution.	Critical, creative and analytical thinking, and effective problem-solving: critique current paradigms and contribute to intellectual inquiry; exhibit creative and analytical ways of thinking; identify, define and solve problems.		Problem-solving skills that contribute to productive outcomes: develop creative and practical solutions, show independence and initiative, solve problems in teams, apply a range of strategies to problem solving, use mathematics including budgeting and financial management to solve problems, test assumptions relative to context of data and circumstances.	To develop in students a creative problem-solving approach to practical engineering situations, including the investigation, design, construction and operational phases, working either as an individual or as a member of a specialist or multi-disciplinary group.

Table 1: Generic skills and capabilities associations (extract)

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Distilling Discipline-Specific Objectives

Whilst a number of course objectives are relatively generic and can, to some extent, be decoupled from specific engineering disciplines, it is recognised that a number of objectives will be discipline specific and, in-part, provide a distinction between the three engineering courses examined. The following descriptions outline the approaches used in distilling the discipline specific objectives of the three engineering courses. The approaches do vary and, in doing so, illustrate a richness of historical, cultural and philosophical underpinnings used to achieve a common outcome.

Course Objectives Framework

Following the "whole of WIL" examination and alignment of course objectives with each organisations' criteria, discussed above, the requirements of a BE(Civil) course objectives framework were identified.

Prior to the WIL project, a set of 10 broad objectives existed for the BE(Civil) course. Examples of these objectives include:

- To produce competent and effective Civil Engineering graduates of national and international standing, capable of adapting to and meeting the challenging demands of the future community;
- To maintain high quality teaching and develop and implement innovative teaching approaches;
- To foster a safe and equitable working environment for all students;
- To produce graduates who are technically competent in the fundamentals of civil engineering with an opportunity for specialization…

Upon reflection, and in the context of the WIL project, this set of objectives was considered a blend of organizational objectives for the School itself, and student-related objectives that were not focused towards an audience of students or external stakeholders such as employers. It became clear that the existing set was inadequate to serve the needs of the WIL project and further development was required in relation to defining teaching and learning outcomes.

To inform development of a student-centered course objectives framework a "skills matrix" was first developed, which mapped each unit and the development of capabilities across the course. A "1 to 4" scale was used, which broadly reflected the year of study or depth of skill development. Although extremely informative to the project and academics, this skills matrix was not suitable as a new course objectives framework, as it was too detailed to be informative to students or outside stakeholders, and was not readily comparable to frameworks of other courses of QUT or other institutions.

Providing coverage across seven sub-disciplines, the BE(Civil) course is considerably broader than the other two engineering courses, and many other courses offered at QUT. A model course objectives framework was sought, which would suit this broad disciplinary nature while satisfying each organisation's criteria, in particular QUT's graduate capabilities framework. This meant that the framework could not be too technically specific; rather, it needed to cater for technical breadth but leave the sub-disciplinary specific depth to a lower layer of articulation as discussed later.

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These graduate capabilities were adapted in order to re-define BE(Civil) course objectives as summarized in Table 2 below. For brevity some criteria pertaining to some of the capabilities have been abbreviated.

Demonstrate that they possess the **knowledge and skills pertinent to the Civil Engineering discipline**, sufficient for entry to the profession, including: • Sound theoretical and practical knowledge across the discipline • Comprehensive theoretical and practical knowledge in one or more areas of specialization… • Ability to adapt to, and apply, technologies and processes used routinely in the discipline area
Demonstrate that they possess **critical, creative, and analytical thinking abilities** pertinent to the Civil Engineering discipline, including: ▪ the ability to effectively identify, define, and solve novel problems using the disciplinary knowledge and skills.. ▪ the ability to critique current paradigms and contribute to intellectual enquiry in the discipline area
Demonstrate that they possess the capacity to **communicate effectively and appropriately** with Civil Engineering discipline specialists and non-specialists in professional contexts, and in a variety of modes, including: written documentation, graphical presentation, oral conversation, oral and visual presentation
Demonstrate their capacity for **life-long learning** in context of the Civil Engineering discipline, in particular the ability to: ▪ search and procure pertinent information… ▪ critically evaluate information for application… ▪ appreciate the importance of participation in continuing professional development activities… ▪ set and maintain their career goals; and plan and act to enable development of their career…
Demonstrate their ability to work **independently and collaboratively** in a multi-disciplinary context, in particular the ability to: ▪ set goals and objectives for their activities, and observe them during the course of those activities ▪ define and prioritise tasks and manage time and resources to achieve stated objectives of an activity ▪ define and address resource implications in the consideration of problems and their potential solutions… ▪ work cooperatively and productively as a team member, or leader, in order to achieve activity objectives…
Demonstrate that they **act responsibly in their professional practice** towards environmental, social, cultural and ethical aspects, in particular: ▪ possessing an understanding and appreciation of perspectives of those from varying cultures… ▪ the capacity to identify, and be considerate of, all members of the community who may be affected… ▪ the capacity to identify, and be considerate of, realms of the physical environment that may be impacted… ▪ the propensity to value and promote truth, accuracy, honesty, accountability, and codes of practice… ▪ the capacity to contribute to intellectual, social and cultural endeavours
Demonstrate that they possess characteristics of **self-reliance and leadership** including: ▪ the propensity to take the initiative ▪ the capacity to embrace innovation in a responsible manner ▪ the ability to manage change productively

Table 2: Graduate capabilities from BE(Civil) course objectives framework

The model course objectives framework selected was the *graduate capabilities development* model developed by the School of Design and Built Environment at QUT for the Bachelor of Architecture course, as it enabled all organisations' criteria to be encapsulated, and provided the ability to map development of professional capabilities over a year-by-year course structure. This Architecture framework is a two dimensional matrix, with each row representing a QUT graduate capability and each of three columns a course stage. Stage A represents a foundation level (year 1), Stage B a sub-professional level (years 2 and 3) at the end of which para-professional graduation occurs, and Stage C a professional/ graduate level (years 4 and 5) which includes an industrial practice year (Table 3). It is noted that the graduate capabilities development incorporated technical skills and knowledge as well as those capabilities widely considered to be professionally generic.

A four-year staging of professional capabilities development was defined for the BE(Civil) course objectives framework, as is presented in Table 2. This table is an excerpt of the full framework documenting development of the first mentioned graduate capability over the four years of the course.

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Graduate Capability	Foundation Year (Engineering)	Foundation Year (Civil)	Sub-specialist Year (Civil)	Specialist Year (Civil)
Demonstrate that they possess the knowledge and skills pertinent to the Civil Engineering discipline, sufficient for entry to the profession, including: • Sound theoretical and practical knowledge across the discipline • Comprehensive theoretical and practical knowledge in one or more areas of specialization within the discipline • Ability to adapt to, and apply, technologies and processes used routinely in the discipline area	Demonstrate awareness of the range and scope of knowledge and skills pertinent to civil engineering across a range of core curriculum areas: • materials • physics • eng maths • elec/computer eng • eng drawing • eng communication Demonstrate basic theoretical and practical knowledge within a civil specialization area: • structures	Demonstrate basic theoretical and practical knowledge within a limited range of civil specialisation areas: • structural • geotechnical • environmental • municipal • transport • construction practices • construction eng mgt • hydraulic • eng surveying • U&R planning Demonstrate basic ability to use a limited range of technologies and processes used in the discipline area	Demonstrate sound theoretical and practical knowledge across a number of civil specialisation areas: … Demonstrate sound theoretical and practical knowledge across core curriculum areas: … Demonstrate ability to apply technologies and processes used routinely in the discipline area…	Demonstrate sound theoretical and practical knowledge across a number of civil specialisation areas: … Demonstrate comprehensive theoretical and practical knowledge in at least one area of specialization: …

Table 3: Row excerpt from BE(Civil) course objectives framework

Unit Formation of Graduate Capabilities

It is recognised that graduate capabilities are formed and developed in units as students progress through their degree. Further to the broad course objectives framework established for each of the three engineering courses examined, and illustrated with BE(Civil) above, units that contribute to the development of each capability are linked within the framework. It is not necessarily an expectation that any one unit contributes solely to a particular capability or learning outcome. More typically, units progressively engage in the development of a number of capabilities such that a sequence of units develops capabilities throughout the four year courses. Of further note, it is significant that capabilities to which units contribute, are embedded within the curriculum of each unit and form part of the assessment process.

For efficient mapping across the course objectives framework, the code of each unit that addresses each objective is displayed adjacent to that objective. Table 3 illustrates this mapping and how units contribute toward the formation of each graduate capability and discipline-specific technical capability in the case of BE(Elec&CompEng) (as an example). Unit codes are given which are not expected to have particular significance to the reader per se, however they do illustrate the sequencing and formation of graduate capabilities.

In the case of the BE(Elec&CompEng) illustrated, generic and broad technical capabilities are developed through units in the *Foundation year [Engineering]*, *Foundation Year [Electrical]* and *Sub-specialist year [Electrical]*, and the *Specialist year [Electrical]* units largely align with EA published electrical engineering sub-disciplines (eg, Instrumentation and Control as shown in Table 3.

This auditing process, applied to the three engineering degrees, provides deeper insight into certain areas of the course structure, which provides a basis for iterative refinement of the course objectives framework. Conversely, it provides insight into shortcomings of certain unit outlines in how their stated objectives address the graduate capabilities being developed in that unit.

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Graduate Capability		Foundation Year (Engineering)	Foundation Year (Electrical)	Sub-Specialist year (Electrical)	Specialist Year (Electrical)
GENERIC GRADUATE CAPABILITIES:					
Ability to apply knowledge of basic science and engineering fundamentals		All 1st year units	All 2nd year units	All 3rd year units	All 4th year units except EEB781
Ability to communicate effectively, not only with engineers but also with the community at large		CEB109,BNB007		EEB584,EEB612, EEB684,EEB686	EEB781,EEB889, various electives
Ability to undertake problem identification, formulation and solution		All 1st year units	All 2nd year units	All 3rd year units	All 4th year units except EEB781
Ability to utilise a systems approach to design and operational performance		CEB109,BNB007	EEB411	EEB511,EEB584, EEB612,EEB682, EEB686	EEB781,EEB889
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		CEB109,BNB007	EEB311,EEB312	EEB512, EEB584, EEB612, EEB684, EEB686	EEB889
Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;		BNB007	EEB311	EEB650,EEB686	EEB781
Understanding of the principles of sustainable design and development;		BNB007	EEB311	EEB650,EEB686	
Understanding of professional and ethical responsibilities and commitment to them;		BNB007		EEB684,EEB686	EEB781
Expectation of the need to undertake lifelong learning, and capacity to do so		BNB007		EEB584,EEB612, EEB684,EEB686	EEB781,EEB889
TECHNICAL GRADUATE CAPABILITIES:					
demonstrate that they possess the knowledge and skills pertinent to the Electrical Engineering discipline, sufficient for entry to the profession, including: • sound theoretical and practical knowledge across the discipline • comprehensive theoretical and practical knowledge in one or more areas of specialisation within the discipline • ability to adapt to, and apply, technologies and processes used routinely in the discipline area		• demonstrate awareness of the range and scope of knowledge and skills pertinent to the foundations of Electrical engineering across a range of core curriculum areas	• demonstrate basic theoretical and practical knowledge within a limited range of Electrical specialisation areas • demonstrate basic ability to use a limited range of technologies and processes used in the discipline area	• demonstrate sound theoretical and practical knowledge across a number of Electrical specialisation areas • demonstrate ability to apply technologies and processes used routinely in the discipline area, to which they are introduced, to undertake basic tasks	• demonstrate sound theoretical and practical knowledge across the discipline • demonstrate comprehensive theoretical and practical knowledge in at least one area of specialization • demonstrate ability to adapt to, and apply, technologies and processes used routinely in the discipline area
Instrumentation and Control	Process Plant		EEB311		
	System Engineering		EEB311,EEB411	EEB511	
	Mathematical Modelling	EEB212,EEB340	EEB411,EEB440	EEB511,EEB584, EEB640,EEB650	EEB961,EEB976
	Computer Engineering	EEB112,EEB212			EEB976
	Communication Engineering		EEB340	EEB560,EEB641	EEB961,EEB976
	Control Systems		EEB311,EEB411, EEB412	EEB511	EEB911,EEB976
	Energy Conversion	EEB212	EEB311,EEB411		EEB911,EEB976
	Software Techniques	EEB112,EEB212	EEB411,EEB412	EEB511,EEB560	
	Computer Interfacing		EEB412	EEB512	EEB976
	Digital Signal Processing		EEB440	EEB511,EEB640	EEB941
	Transducer and Activator Engineering		EEB311		
	Local Area Network Engineering		EEB311	EEB560	

Table 4: Unit formation of graduate capabilities (excerpt)

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Levels of Capability Development within Units

Having established the broad framework in which units contribute toward satisfying course objectives, and developing graduate capabilities, an extensive audit was conducted to identify how particular units contribute to such.

As discussed earlier, the graduate capabilities as listed in the framework and contained within the objectives section of each unit outline broadly cover technical skills and knowledge development. Generally, this is limited to stating the depth and development of coverage by sub-discipline. They do not detail specific technical skills or knowledge pertaining to the sub-discipline, which may be covered in the unit, such as "shear force and bending moment diagrams of simply supported beams". This deeper layer of detail is left for stipulation as *technical objectives* within each unit outline.

Prompted by an audit of units within the BE(Elec&CompEng) course during a regular course review process, it was possible to establish unit-by-unit contributions toward the progressive development of graduate capabilities, both technical and generic. The audit identified the expected skills and levels expected of students entering the unit, the topics studied to further develop those skills and the expected skill level outcomes for students having successfully completed that unit. The skill levels used are adopted from Blackketter (2002), developed to address ABET 2000 criteria at the University of Idaho, and are summarized in the following extract (Figure 1).

PERFORMANCE LEVELS - DEFINITION

Level 1: INFORMATION
This level is typical of 1st year students. This level person has developed a knowledge base, with specific skills within a specific context. Can be referred to as a **Trained Individual or Engineer in Training**.
Attitude: Must have explicitly defined rules, procedures, and policies
Cognitive: Need to be told what to do
Social: Need constant supervision and monitoring of performance

Level 2: COMPREHENSION
This level is typical of 2nd and 3rd year students. This level person has acquired a broad base of general knowledge and can apply it in related contexts. Can be referred to as a **Learned Individual or Engineering Intern**.
Attitude: Are willing to accept challenges within their areas of expertise
Cognitive: Can perform low level problem solving within base of experience
Social: Accept feedback better on "what they produce", better than "how they perform"

Level 3: APPLICATION
This level is typical of 4th year students. This level person has developed skills and motivation to apply and self-direct learning in limited contexts. Can be referred to as a **Lifelong Learner or Entry Level Engineer**.
Attitude: Seek out new challenges in related areas of knowledge
Cognitive: Are able to apply previous problem solutions to new situations
Social: Accept and use feedback based on their performance

Level 4: PROBLEM SOLVING
This level is typical of those in, or beyond, graduate school. This level person has highly developed skills and actively seeks knowledge and opportunities for application. Can be referred to as an **Enhanced Learner or Project Engineer.**
Attitude: Seek to push the boundaries of their performance
Cognitive: Seek out greater challenges, responsibilities, and problems to solve
Social: Are willing to manage a team effort and mentor fellow team members

Figure 1: Definition of Expected Student Skill Levels

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It would then be expected that one could follow how the skill developments connect and grow through threads of units studied. An example of technical skill development is given in Table 5 below for a single unit *Introduction to Telecommunications*.

Unit	Expected Technical Capabilities	Level	Broad Topics	Developed Technical Capabilities	Level
EEB340 - Introduction to Telecommunications	Complex Arithmetic	1	Classification of Signals	Mathematical Description of Signals	2
	Differential Equations	1	Fourier Series & Transform	Fourier Analysis	2
	Integrals	1	Impulse Response & Transfer Function	Relationship Between Signals & Systems	2
	Fourier Series	1	Convolution	Understanding of System Response	2
	Basic Signal Theory	1	Frequency Response, Filters	Design of Basic Filters	2
	Basic Circuit Theory	1	Components of a Communications System	Reasons for Matching to Channels	1
	Matlab Fundamentals	1	Amplitude Modulation(AM)	Spectrum, Shapes Bandwidth	1
	Operation of Desktop Computer	1	Angle Modulation (FM, PM)	Spectrum, Shapes Bandwidth	1
			Simple Modulation Circuits	Circuits for Modulation & Demod	1
			Introduction to Noise	Sources & Effects of Noise	1

Table 5: Technical Skill Development

Outcomes

The processes engaged in and described above produced a number of outcomes relevant to this paper.

Work Integrated Learning

The initial and primary goal of the course level objective distillation and unit audits was to identify opportunities in which WIL could be used to maximise learning outcomes. The most intricate mapping produced from the previous processes provides the ability to articulate the precise developmental stage of a student undertaking one of these three courses. Students can identify where they are within the developmental path of stated graduate capabilities, and to what depth they have developed these capabilities. This allows them to, firstly, articulate their skill level to a prospective employer/industry mentor, and secondly, to identify particular capabilities that can be targeted and developed within a workplace environment in agreement with both academic and industry supervisors. To facilitate such a process, a web-based interface is to provide support mechanisms as discussed below.

Web-Based Integrated Learning

A web interface is being designed based on constructivist principles which engage students in ways which requires reflection and demonstrated knowledge construction. The project team has a clear goal of creating a flexible, web based system applicable across a range of courses and work based experiences from site visits to work placements. The web interface is planned to offer students access to a range of resources while also providing self-paced training for both academic and industry staff in the areas of consultation and negotiation; experiential learning design; supervision and mentoring; and workplace assessment. This work has been presented in another paper submitted to AAEE2004.

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Objective Course Linkages

A secondary benefit of the course objectives distillation and unit audit processes is that it provides a process for quality control for course development and revisions. Capabilities should be seamlessly and progressively developed towards fulfilment of graduate capabilities. Any gaps or deficiencies can be readily identified through these processes.

This process coincides with course reviews soon to be embarked on, for instance, BE(Mech). The opportunity was seized upon to draw upon this course objectives framework to a more student centred perspective. An example of a suitable course objective would be:

> *The Bachelor of Engineering (Mechanical) aims to produce graduates:-*
>
> > *"who can demonstrate a sound knowledge of the fundamentals of science and engineering, and their applications, understanding the principles of sustainable development while valuing ethical and professional responsibilities"*

Conclusions

The primary motive for the work presented in this paper was to provide a mechanism whereby students' skill levels and capabilities could be identified at any point within their course and targeted for further development in a workplace environment. They could then enter into a workplace learning agreement established in consultation with their prospective industry supervisor and faculty. This prompted an in-depth examination of course objectives and testing of their alignment against institutional objectives and desired graduate capabilities. A process was then developed which systematically mapped and facilitated the alignment of unit (or subject) level contributions to the progressive development of student graduate capabilities. Whilst some of the outcomes achieved were engineering discipline specific, the overall process is applicable to any course in any discipline. This process has application in students pursuing workplace integrated learning opportunities and a quality control mechanism for course development and continuous improvement

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Recognising and supporting a scholarship of practice: Soft skills are hard!

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***Abstract**: Modern professional practice requires not only recognised 'technical' skills, but also high-level generic or 'soft' professional skills. Recent professional negligence claims suggest that technically well-qualified professionals with deficiencies in these generic skills may fail to effectively identify and satisfy client requirements, contributing to the professional indemnity insurance (PII) crisis which has developed in the last few years. In 2003, the Federal, State and Territory attorneys general agreed to introduce legislation to address the PII crisis. The NSW Professional Standards Council (PSC) now has national responsibility for reviewing current CPD (continuing professional development) programs and improving their effectiveness. As a first step, the PSC commissioned a discussion paper, followed by a forum reviewing its findings. In this paper we review the PSC paper and forum, with a focus on their relevance to engineering education. We explore four central areas for action that we believe need to be addressed by engineering educators: integration of CPD with undergraduate programs; attention to broad ethical and futures issues, including sustainability; clarification of the nomenclature describing these skills; and the importance of internships to the development of generic competencies. We also challenge two widely held assumptions about professional practice. The first is that the generic skills essential to successful professional practice can be readily acquired after graduation through professional induction and CPD programs. The second is that these 'soft' practice skills are somehow less demanding and less academically challenging than the 'technical' skills which are the almost exclusive content of most professional qualifications, including those in engineering. We argue that the investigation of generic professional practice skills and their development is a critically important area of scholarship that must be incorporated into engineering research and teaching.*

***Keywords**: Professional practice, Continuing Professional Development (CPD), Internships, Life-long Learning*

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Introduction

Increasingly, professional engineers practice in turbulent global and local contexts, confronting problems that need to be framed and addressed by teams incorporating a variety of disciplinary perspectives. All team members need to be competent in their own specialisations, and comfortable working with people from other disciplines. Indeed, all professionals now need the professional skills and attitudes involved in recognising other perspectives and valuing diverse contributions. Nieragden (2000) suggests that broad professional skills can be grouped into four areas: self-management; interaction; communication; and organization. Deficiencies in generic professional skills are even considered to be a factor in the increasing number of professional negligence claims (Professional Standards Council 2004). For many years, Peter Miller has been exploring professional negligence issues in 'Miller's Tales', a regular and well-respected column in *Engineers Australia*. Miller regularly demonstrates how difficult professional practice can be, and how important these broad skills are to establishing and maintaining effective working relationships between professionals and clients. However, the typical expectation in engineering is still that broader practice ('soft') skills such as communication and management will be developed after graduation, as part of a graduate development process in a workplace context.

The almost exclusive emphasis in most engineering undergraduate programs is on de-contextualised technical areas of practice has serious implications that affect the development of generic practice skills by graduates. This narrow focus has been challenged by Australian and overseas reviews of engineering education, and accreditation requirements for engineering undergraduate programs now include attention to contextual issues, including 'sustainable design and development' (Johnston and Eager 2001). However, current economic trends are reinforcing 'back to basics' moves within engineering faculties to cut back on this material in undergraduate programs. The obvious absence of generic skill material in the curriculum can be read by students as an indication that these skills and abilities are much less important than the technical content. This perception is commonly reinforced by technically-focused academics who frequently challenge or undermine any attempts to broaden the curriculum (Vanderberg 2000). In the short-term, this failure to value 'non-technical' areas trivialises the broader social and ethical program content required by accreditation requirements. In the longer term it fosters a narrow approach to professional responsibilities and inhibits the development of generic practice skills, skills that are essential to identifying client needs and providing appropriate levels of professional service.

The authors have been involved with the cooperative education of professional engineers for over 25 years and have published widely on professional issues, including seminal texts on engineering and society and professional communication (e.g., Johnston, Gostelow and Jones 1999: Mohan, McGregor, Saunders and Archee 1997, 2004). This paper aims to refocus on the importance of including the development of generic professional skills as part of the undergraduate curriculum. The publication of a report by the Professional Standards Council has provided the springboard for discussion of these issues and their significance to engineering practice.

Professional Standards and Professional Indemnity Insurance

Failures associated with professional services can have serious economic and human consequences. Professional Indemnity Insurance (PII) was developed to address the personal

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and professional implications of such failures. In recent years, the size and frequency of claims have escalated. Particularly since the demise of HIH, which was a major provider, insurance is no longer available for many areas of work and, even where it is available, the cost of PII has increased steeply (Ryle and Hardwicke 2004).

In order to ensure the continuing availability of socially-important professional services, Professional Standards schemes have been developed, aimed at improving both professional performance and mechanisms for resolving consumer claims. For the professionals who join them, the schemes would cap liability for economic loss or property damage (but not for personal injury or death). To join a scheme, a professional is required to meet a range of initial and ongoing professional competency criteria, and to have PII at a level which will cover consumer claims. Schemes are state-based, and only currently in force in NSW and Western Australia. However, during 2003, the federal and state governments agreed to introduce consistent national Professional Standards legislation. The first schemes under the legislation are expected to be in place in early 2005. As the basis for its professional standards scheme, Engineers Australia (the new working title for the Institution of Engineers Australia, IEAust) decided to set up a new Technical Society, using the existing national engineering registers as the standard of competence for engineers to be included under the scheme. Professional standards arrangements are expected to be coordinated by the NSW Government's Professional Standards Council on behalf of all other State and Territory governments (Ryle and Hardwicke 2004).

As part of its ongoing program to improve the quality of professional practice in New South Wales, the Professional Standards Council (PSC) recently commissioned a report on continuing professional development (CPD) aimed at improving practice skills (Field 2003). The report is directed particularly at professional associations. It challenges these associations to recognise the importance of 'soft skills' to professional competence and to develop programs to increase proficiency in these areas. Publication of the paper was followed on 24 March 2004 by a forum in Sydney. Forum participants came from a range of disciplinary areas, including accounting, building, law and engineering. The PowerPoint presentations to the forum and a summary of the discussion are available from the Council's website (Professional Standards Council 2004). The Council has also developed a website to encourage and inform debate on soft skills issues, and to support the creation of alliances across business, industry, government and higher education, TAFE and other training providers.

In this paper, our goal is to highlight the important issues from the PSC report and to focus on their relevance to engineering education. In our response to the report, we argued that the discussion initiated by the Council needs to be expanded to include initial professional formation as an important part of the continuum of professional development. Our responses to the Council's initiative focused on four key issues: 1) nomenclature, 2) undergraduate formation, 3) the value of internships and 4) ethics and social responsibility. In the remainder of the paper we have located these responses in the context of an outline of the discussion paper and the forum associated with it.

Soft Skills: The Current Environment

The discussion paper (Field 2003) starts with an analysis, based on interviews with six PSC associations, of the current environment in which continuing professional development (CPD) activity takes place. CPD is defined (p5) as:

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'…the systematic maintenance, improvement and broadening of knowledge and skill and the development of personal qualities necessary for the execution of professional and technical duties throughout the practitioner's working life.'

The paper refers to the non-technical skills and personal qualities required for successful professional practice as 'soft skills'. It also acknowledges the inadequacy of this term, in that it could suggest that these were:
'…skills, which are somehow easy, light, and not to be taken seriously. Nothing could be further from the truth. Numerous studies have highlighted the importance of soft skills to the work of professionals and the value that employers place on soft skills.' (p5) Other possible terms suggested for these skills include 'non-technical skills', 'general skills', 'generic skills', 'essential skills' and 'employability skills'. The paper outlines the scope of these skills. They include information handling skills like learning, thinking communicating and problem solving. They include organisational skills like planning and managing projects. They also include interpersonal skills like leadership, working with others and in teams. The paper makes the point that the way these skills are exercised in the workplace depends very much on personal values and attributes, including integrity and business and technical competence. It also emphasises that whether a skill (for example, 'planning and co-ordinating') is technical or not depends significantly on the context.

The authors find it interesting that skills in posing and framing problems were not mentioned specifically in this part of the paper. It seems to us that this omission highlights a key problem with most models of the design process (in engineering and other disciplines), which assume that 'the problem' is somehow 'out there' and simply needs to be discovered. Work by scholars like Bucciarelli (1994) shows that deciding on the nature of the problem and framing it so that it can be addressed can be at least as challenging as any other professional task.

Nomenclature: Soft Skills vs Generic Professional Skills

As acknowledged in the report (p5) the term 'soft skills' is problematic. While the Notes to the paper list a variety of alternate terms, the choice of soft skills indicates some preference for this descriptor. We would argue that the nomenclature to describe the suite of skills and abilities that are referred to in the report should be changed. Logical and more useful alternatives, even in a paper that is issued to discuss the issues, would be generic skills or generic professional skills, since these terms suggest the basic commonality across all professional areas, while implying contextual differences.

In technical and professional writing it is preferable to choose the most accurate descriptors. The term 'soft' seems to be the least accurate of those proposed. The choice of the term 'soft skills' also seems likely to impede the realisation of the objectives expressed in the report. In our experience, these aspects of professional work are much more difficult to learn and practice than many of the so-called 'hard' skills. The use of this term is misleading and denigrates both the importance of these skills and their complexity. There is a parallel in the use of the term 'soft systems' as an alternative to hard systems engineering. Even in this field, terms like 'socio-technical systems' have evolved as more accurate descriptions of the study of the more complex systems that involve human interaction.

Discussion during the Forum also focused on the negative aspects of the term 'soft' skills. Although the use of the term has certainly caused a reaction, so stimulating discussion, the

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authors suggest that the term 'soft' skills be avoided and recommend 'generic professional skills' as a more appropriate and accurate descriptor of the required competencies.

Improving Soft Skills CPD

The paper discussed a range of soft skills improvement strategies: promotion; E-learning; experiential learning; mentoring; alliances; and evaluation. The study explored the extent of the gap between the current situation, and an ideal one, with ready availability of suitable opportunities for professionals and others to develop their soft skills. The paper noted that: 'associations generally don't endorse the value of soft skills' and suggested that associations should acknowledge their importance in newsletters and websites, as well as in: '…material relating to professional quality service delivery and risk minimisation, and statements of association values and perspectives on CPD'.

In both the paper and his forum presentation, Dr Field emphasised the importance of attitudes and values in the exercise of soft skills, adding that deficiency in soft skills was a significant contributor to negligence claims. He noted the paradox that, even though this is recognised by most professional associations, the demand for soft skills CPD was low across all the professions studied, in comparison to the demand for development of technical skills. Some of the explanations offered for this low demand for soft skills CPD included: failure by practitioners to see the need to further develop these skills; cynicism about their perceived 'touchy-feely' character; lack of professional incentive in terms of concrete knowledge; cost of time away from the workplace weighed against the perceived benefit; and a lack of clear-cut evidence of the impact of soft skills CPD and consequently a questionable return on investment. In our view, from our experience in engineering, those reasons resemble the arguments presented to reduce or eliminate professional development subjects in the undergraduate curriculum (McGregor and Saunders 2001).

At the forum, Steve Dilli outlined the approach taken in the Professional Development Program offered by Engineers Australia (Professional Standards Council 2004). Engineering Education Australia offers a range of CPD programs, with nine out of ten of these programs including some soft skills content, although (as seems commonly to be the case) the evaluation of this content was rather limited.

A problem with existing CPD is that most effort in delivery goes into large-scale seminars and conferences, approaches which are not well-suited to actual individual development of soft skills. The availability and quality of direct and indirect opportunities for soft skills development varied widely. The approach taken by particular associations to soft skills CPD was recognised as a central issue. For the range of cognitive and behavioural skills involved, effective CPD requires experiential learning (doing and reflecting on what was done) (Kolb 1984) in contrast to presenters talking about issues and behaviours. This calls for close involvement and interaction with others, including role plays and activities which bring in life experience and prior learning. AAEE has from time to time made an effort to build this sort of learning into its conferences, and the difficulties in sustaining this effort illustrate the cultural and organisational difficulties in making such changes.

Coaching and mentoring can help people to develop a number of soft skills, including listening and observing. Good mentoring can encourage attention to the issues of problem framing and problem setting, as well as problem solving. Mentoring can also facilitate a two-way exchange

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of knowledge which can be particularly helpful for senior mentors prepared to improve their information technology skills, learning from their younger colleagues. Mentoring is a powerful way of passing on the culture of an organization, so it can have a down side, and training for mentoring is important. At least some of the time spent on coaching/mentoring ought to be recognised as valid and valuable soft skills CPD.

While computer-based E-learning has a role in a range of learning and development activities, present forms appear best suited for initial information presentation and compliance training. CPA Australia uses it effectively through its web-site for presenting 'SNAPS' – packages of material that are short, relevant, accessible and practical, and aimed at meeting an immediate member need. The current relevance of this approach for personal development and building interpersonal skills seems rather limited, although innovative approaches to team building are showing promise. In the short term, at least, hybrid mediated and face-to-face programs are most likely to achieve some successful outcomes.

Associations in the same professional sector are likely to be more or less in competition, so sharing training resources is problematic. However, alliances between sectors, including the presentation of jointly-badged seminars in regional areas, may well be attractive.

In his forum presentation, Bruce MacDermott of Risk Management Services, LawCover, acknowledged that for his organization, the key driver for improving soft skills CPD was economic. Their detailed claims analysis had highlighted a particular age group of sole-practitioners for attention. For this group, better soft skills performance would have avoided four out of five claims. A modest but ongoing discount on their Professional Indemnity Insurance premiums was offered to this group for completion of a CPD program developed specifically to meet its needs. He believed that this approach had been very successful.

In the context of CPD, Field's paper (Field 2003) suggests that the least well developed area is probably that of evaluation. The relevance of evaluation to this audience is obvious. Field suggested at least six levels of evaluative data which are relevant to CPD, from participant reaction, through consideration of behavioural change and its impacts, to looking for evidence of future impacts on risk and quality. He noted that: 'Current approaches to evaluating soft skills CPD are highly inadequate and many CPD activities do not incorporate any evaluation at all.' Reasons suggested for the general failure to evaluate beyond the lowest level include an emphasis being placed on 'customer satisfaction' rather than on actual skills or workplace behaviour and priority being given to other social and professional purposes, including networking and awareness raising. In addition, the cost and effort involved in higher level evaluation was an obvious deterrent.

Possible approaches for improving evaluation include: having facilitators report changes in participant behaviour; emailed follow-ups to participants asking for comment and reflection; encouraging the use of online learning journals; short phone interviews; two-part training programs, with a second face-to-face session in which participants can discuss what they have learned and how they have applied it; and pairing participants, so that 'buddies' can liaise after the session and encourage ongoing application of new skills.

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The Way Forward

Submissions on the paper were invited, and we responded with enthusiasm because we believe it is crucial to open wide debate on this topic. Our first suggestion for improving the development of generic professional skills, both within the engineering profession and more generally, was in terms of improving the connection between undergraduate and graduate formation. Although the target audience of this report was professional associations, we see the absence of any discussion of the relationship between professional foundation study (as in undergraduate work) and continuing professional development as a major omission from this study. Generic skills, such as communication and even negotiation, are developed throughout the whole educational process from kindergarten onwards. However, when students enter an undergraduate program, and embark on their professional formation, generic skills start to be developed within the contextual framework of that discipline area. This would suggest that an additional way forward (p24) would be for Professional Associations to liaise with universities and other institutes of learning to ensure that the development of generic skills is valued and included as part of undergraduate curriculum.

The report recommended that alliances be set up (pp19/20) and we suggest that these should also include alliances of business and the PSC with tertiary education. Given that many Australian universities now specify Graduate Attributes intended to be developed during their undergraduate programs, proposals for cooperation with the Professional Standards Council along these lines seem likely to be well received. We strongly urge professional associations, universities and other educational providers to be conscious of the ways that these generic competencies are developed throughout the formal educational process. This valuing of the broader, contextualised aspects of professional work, should extend to supporting and encouraging collaborative research with professional associations, industries, and organisations working with universities to extend knowledge of these generic components of professional formation.

The role of universities in developing generic skills at post graduate and CPD level is clouded by the 'competition' between universities and professional associations at this level. While practitioners might legitimately seek their on-going professional formation through their associations, it is more difficult for these bodies to challenge the existing paradigms and thus to move discourse communities beyond their comfort zones. Our work in 'captivity' is important here (Johnston, Lee and McGregor 1996). The role of universities has always been to extend the limits. Despite the pressures of economic rationalism, it is important for universities to continue to assert their mandate to challenge and extend knowledge.

Internships

As was noted earlier, our work at the University of Technology, Sydney has involved us in cooperative education, and our third recommendation is that the value of student internships needs to be recognised and supported by governments, industries and professional associations. While the report discussed the role of experiential learning (pp12/13), we believe that an essential component of professional formation is learning how to learn. Through our work with

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the Professional Practice component of our undergraduate program in Engineering at UTS, we have identified learning how to learn through experience as one of the key learning outcomes of tertiary study. The UTS internship program is supported by a suite of subjects that help students prepare for learning through their work experience, document their learning and share and validate that learning. This educational model constantly endorses the importance of the generic skills, especially the communication skills, and clearly indicates that students develop these skills through testing theories in practice during their experience (Johnston, Taylor and Chappel 2001: McGregor 2000: McGregor and Saunders 2001).

The continuing importance of contextualising basic skills implies that further development of generic skills needs to occur throughout life. Therefore, both an understanding of experiential learning and some development of the abilities to plan, reflect, review and revise are essential career development tools for any professional. While this development can occur as continuing professional development, the value of laying the foundation through educationally sound student internship programs must be endorsed. We recommend that professional associations, industries and governments seek ways to support and encourage educationally sound student internships.

Ethics, Social Responsibility and Sustainability

We see ethics, social responsibility and sustainability as central to the leadership role of the Council, and we are deeply concerned that these topics are not raised in this report. It is our strongest belief, based on our experience with students, that a constant challenge for them is to develop a framework for their professional practice that reconciles their own personal codes of conduct with professional codes, mores and practices. (McGregor, Johnston, & Bagia 2002) We recognise the difficulty of 'learning' these skills, but would argue that the process of learning is as important as the outcome. These considerations underpin all relationships. Unless there is scope for professionals to collectively discuss, debate and develop their thinking and practice, societies cannot move forward in constructive ways. This is particularly important for multi-cultural societies such as Australia. We therefore recommend that ethics, social responsibility and sustainability be included as core areas of generic professional skills.

Towards a Theory of Practice?

The topics discussed here are central to the ongoing development of a practical understanding of professional practice, a debate in which the authors have been involved for many years, both within UTS and more widely. It would be nice to think that it would be possible to develop a comprehensive theory of professional practice, even within engineering, that would be as clear cut as the engineering science which still dominates our curricula, not to say the thinking of more than a few of our colleagues, for whom practice issues are outside the scope of the academy.

Given the complexity of practice, involving as it does human beings with their various understandings, attitudes and values, it seems to us unlikely that a comprehensive theory is likely to be possible. However, we do believe that some order can be found in the complexity, if not at the level of laws, then at the level of models, metaphors and insights. Checkland (1999) describes the development of a methodology for approaching problem situations. In this process it is essential to recognise the world view from which the model is formulated, and to spell this out explicitly in the system model. This supports the development of models based on other

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perspectives, permitting an open and multi-faceted exploration of the issues. Checkland (1999, p. A10) describes this methodology as a 'learning system'. Although well beyond the scope of this present paper, approaches along these lines could be fruitful.

Conclusion

We were impressed with the amount of information collected for the report and the forum and the detailed picture presented of the current situation with respect to CPD in NSW. We were also troubled by what we saw as a number of significant gaps in the paper. It seems to us that an excellent start has been made, a start which opens up a number of promising directions for further research aimed at improving our understanding of the situation and addressing the shortcomings of preparation for practice, both within undergraduate degrees and in the professional development that is now recognised as needing to continue throughout our professional lives.

We encourage engineering academics to consider the ways in which 'soft skills' can be developed throughout the curriculum. Professional competence involves the development of skills in posing and framing problems, which increasingly can be complex and multi-disciplinary, and need to be addressed in a global as well as a local context. The evidence is strong that both technical competence and well developed broad professional skills are needed for effective professional practice. The Professional Standards Council Report effectively endorses that vision.

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Multidisciplinary student projects develop desired skills.

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***Abstract**: Numerous reviews of engineering education have recommended broadening the focus of existing courses to develop graduates with greater skills in leadership and management who are better communicators, have greater self knowledge and control, enhanced awareness of business ethics and procedures and increased interpersonal skills.*
To achieve such skills, staff in Industrial Engineering, Marketing, Accounting and Design at Monash, developed a MultiDisciplinary Industry Project (MDIP) in 1996, in which third year students were formed into eight member consulting teams. Each team carries out a feasibility project for a local small or medium sized enterprise. It was believed that such projects would provide the intrinsic motivation for students to learn to apply their theoretical knowledge to meeting a real client's needs, while acquiring the extensive range of skills desired.
The purpose of this paper is to identify the changes recommended, the goals and organization of the MDIP and its success in achieving these goals as determined by independent observers, clients, students and graduates. The skills graduates believe they need for their current positions have been compared to those which they felt were addressed by the MDIP and while most of the major objectives appear to have been effectively achieved, a number of issues for further consideration have been identified.

***Keywords**: Generic skills, Motivation, Subject Evaluation*

Introduction

Finniston (1980) said, "Engineers have to work in teams with other relevant disciplines in which the total expertise is coordinated to achieve maximum efficiency towards the stated objective." He highlighted the need for engineers to efficiently use manpower and financial resources to make competitive products. The IEAust review, (Johnston 1996), stated that curricula should be less loaded and use alternative modes of learning along with closer ties with industry. The report also advocated enhancing "economic awareness… problem solving ability, self-directed and lifelong learning, communication, management and teamwork skills, but on a sound basis of mathematics and engineering technology."

Industrial Engineering, Marketing, Accounting and Industrial Design staff at Monash believed that a project based learning approach was essential to generate the motivation for students to achieve these goals. They established the Multidisciplinary Industry Project (MDIP) in 1996

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in which each discipline's students became members of consulting teams determining the feasibility of developing new products based on briefs from local companies.

Deficiencies in existing engineering graduates.

Both Finniston and Johnston advocated strategic changes in engineering education, but Wearne et al (1984) carried out a comprehensive survey of specific managerial skills required by engineers. A wide divergence was found in the skills graduates had developed at university as compared to those required in their professional life. Some of the skills most used by British and Australian graduates but poorest taught are shown in table 1. It is apparent that the major deficits were interpersonal, organizational and finance and accounting skills.

	UK			**Aus**		
Skill	Often required	Sometimes required	Received training	Often required	Sometimes required	Received training
Direct supervision of others	67 %	16 %	9 %	64 %	20 %	7 %
Motivate others	66	15	8	49	24	6
Plan and schedule projects	39	34	17	44	31	24
Evaluate projects	45	33	16	44	39	19
Costing, estimating	33	47	26	46	42	22

Table 1. – Essential Skills For Graduate Engineers Least Developed In Their Courses.

Williams (1988) studied Australian engineering education by surveying final year students and graduates. He found both groups advocated "increased use of problem solving strategies, … more effective opportunities for interdisciplinary activities and better development of social, communication and management skills." He stated that these skills should be facilitated by changes in teaching strategies, stating "Engineering schools review their policy - or create a policy - on the balance between individual and group research projects, and between single and multidisciplinary research projects". Sinclair (1992) surveyed Australian business CEOs and university VCs on their priorities for graduates' skills. Table 2 shows the rank and mean results, on a 1 to 5 scale, for the ten highest priority skills. It is apparent that there is a significantly difference in the views of the 2 groups. Business leaders see generic skills as significantly more important than do academics who prioritise professional theoretical knowledge and computer skills.

	Business CEOs		**University VCs**	
Skills	Rank	Mean	Rank	Mean
Communication (written, verbal)	1	4.29	7	3.26
Capacity to learn new skills	2	4.21	5	3.36
Cooperation and team work	3	4.18	8	3.24
Make decisions and solve problems	4	4.17	3	3.54
Apply knowledge to real problems	5	4.05	4	3.51
Work with minimum supervision	6	3.65	6	3.33
Professional theoretical knowledge	7	3.52	1	4.02
Use computer technology	8	3.43	2	3.65
Understand business ethics	9	3.21	12	2.24
General business knowledge	10	3.03	11	2.33

Table 2 – Perception of the Priority of Graduate Skills by Business CEOs and University VCs.

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Woods (1985) emphasized the difference in addressing real problems encountered in industry, where problems are ill-defined, multidisciplinary and information is limited, as compared to academic exercises where all necessary information is provided, the latest theory is needed to solve them and the problem is clearly defined within the context of the subject being studied. Kelley and Caplan (1993) who studied engineers' success at AT&T's Bell Labs, found no correlation between success and IQ, but found high correlation between success and Emotional Intelligence (EI). Salovey and Mayer (1990) defined the term Emotional Intelligence as "a form of social intelligence that involves the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use this information to guide one's thinking and action". Goleman (1995) identified EI as including self-awareness (self-assessment, confidence), self-management (conscientiousness, initiative, adaptability, drive), social awareness (empathy, service orientation) and relationship management (change catalysis, communications, leadership, influence, conflict management, and teamwork).

Motivation.

To impose this extensive range of additional skills onto an already crowded curriculum is a significant challenge which can only be met if students are highly motivated. Florman (1976) criticized "the stultifying influence of engineering schools where the least bit of imagination, social concern or cultural interest is snuffed out under the crushing load of purely technical subjects". Barrows and Tamblyn (1980) identified the inherent motivation of problem and project based learning in a real context as a means to develop true professionalism.

Pintrich and Schunk (1996) discussed a wide range of motivational theories pertaining to education with the following recommendations being particularly relevant to the structuring of large group projects.

1. Build on the skills each individual brings to a situation.
2. Align student and group goals
3. Help students identify multiple goals to increase motivation for greater success.
4. Ensure tasks are difficult and challenging but not excessive.
5. Enhance confidence and performance by developing real skills.
6. Assess and reward the development of real skills.
7. Allow flexibility in students' goals to change over the course of the project
8. Get students emotionally involved.
9. Ensure all team members are treated with respect.
10. Give project ownership to the students, leaving staff to facilitate and assess.

The Monash multidisciplinary industry project (MDIP).

The above recommendations can be classified into five broad areas: Personal and Interpersonal Skills, Business Awareness, Communications Skills, Leadership Skills and Project Management. The challenge to engineering educators is how to develop these skills in a restricted curriculum, with limited time and opportunities. The approach developed at Monash has been to use a large group PBL structure based on a realistic and motivating scenario involving interaction with real world companies with a real interest in the project outcomes. Authentic assessment by staff observation of weekly meetings chaired by students in turn, and by reports and presentations to staff and the company, was considered essential to the projects' success. Staff act as facilitators rather than as tutors or lecturers as project ownership by the students was seen as central to their motivation and hence the projects' success. Continuous monitoring and ongoing improvement of the program was also essential if the motivation level and achievement of objectives were to be achieved. The subject is

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compulsory for third year engineering students but is an elective for design, accounting and marketing students. Results discussed below show some discrepancies between the disciplines possibly attributable to the compulsory/elective distinction.

Stated Learning Objectives

The learning objectives Wellington et al (1996) were that students should be able to:

1. Formulate, through group interactions, solutions to business problems which require the integration of design, manufacturing and marketing solutions.
2. Separate engineering, accounting and marketing problems into solvable elements; explore solutions mindful of the influence each discipline area has on the other.
3. Demonstrate understanding of manufacturing design and the possible need for redesign;
4. Exhibit committee chairperson, secretarial and recording skills;
5. Negotiate responsibilities within a group to ensure effective project management;
6. Organise communication systems to ensure effective project management;
7. Compile, present and defend a syndicate report on the project;
8. Assess personal and peer performance in achieving individual and group objectives;
9. Value the complexity of issues and range of people affected by the introduction of new products and technology,
10. Appreciate the complexity of decision making processes in a typical industrial situation.

Project Organisation.

So as to minimize time wastage and to replicate business practice, students are allocated to teams to undertake selected projects as announced on the first day of semester. They realize that in the business situation, they will not be able to select who they work with and have little opportunity to choose their projects, and few complaints are made. In most years, 6 to 9 teams of 7, 8 or 9 students are formed. Groups are of a broad range of academic abilities but with diverse personality, ethnic and gender mixes. Close friends are put in different groups if possible, as on the occasions in which close friends have been allocated to the same group, cliques formed and overall team cohesion suffered.

The first formal meeting with students focuses on project organization and assessment, confidentiality and safety issues. In the second week, committee skills are introduced with group coordinators chairing the first meeting to provide a model. Students select areas of responsibility and one of their members is voted to be team leader. Schedules for chairing and minuting are negotiated so that each student experiences these roles, and contact details are exchanged. In week three, students begin the task of information gathering. Engineers who compose half of most teams address material and process selection, testing, packaging, safety and distribution issues and product design along with industrial designers. The engineers work with accountants to determine product costs and the accountants determine financial implications and likely profitability. The marketers carry out market research and propose marketing strategies. Staff supervisors adopt the roles of facilitator, observer and assessor, giving private feedback on team skills to individuals and to the group as a whole on the two interim reports. Final reports and a formal presentation is given to members of the sponsoring company and all coordinators at the end of semester for assessment and moderation purposes.

Authentic Assessment of Students.

Authentic assessment is assessment that evaluates students' demonstration of skills in a real world situation (Wellington 2002). Observation of chairing, minuting and contribution to meetings is 30% of the total mark; individual contributions to interim reports and a reflective report is a further 20%. The company representatives and facilitators equally award the other

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50% to the group on the basis of the final oral presentation and report. The program was developed to give individual and team performance equal weighting, with the group mark modified by a peer weighting factor based on students' perception of the reliability, initiative cooperation, and communication of their team mates. This element of assessment was seen as crucial to develop responsible attitudes and minimize the possibilities of 'passengers' as discussed by Brown Parker et al. (1997). The students evaluate their peers formatively in weeks 5 and 10 and summatively at the end of semester. This tool is designed to help students improve their group performance, ensure that all students contribute and introduces them to self and peer assessment as used in industry but coordinators feel that few students use the formative feedback effectively.

The projects.

Companies are approached during first semester by the subject coordinator and meetings are held to develop a brief and ensure that the necessary support will be given. Representatives of each company visit the campus in the first week to meet their team, discuss the project and answer questions. A plant visit is organized by week 2. The contacts are made through alumni, previous participants, staff contacts and references from local councils. To allow time for students to gain the range of experiences and develop the range of skills, projects appear to be relatively simple, although students do not generally see them as boring (see Table 3).

In one semester, 8 students have to form teams with people they do not know or may know only slightly, learn basic chairing, minuting and other committee skills, gain familiarity with technical processes and an industry of which they have limited if any knowledge. They then analyse the brief, divide the project into equal areas of responsibility, gather the necessary information, develop a design, write interim and final reports and make a presentation to the company. This is only feasible to achieve at an appropriate level of depth if the students can understand the design and function of the products quickly. Projects have included feasibility studies on moulded plastic products such as storage tanks, hazardous goods pails, even coffins, as well as recumbent tricycle manufacture, hand dryer optimization, and food processing and packaging. The relocation and development of a new hulling and packaging plant for an almond grower has been one of the most challenging and unusual. Fifty-one such teams have addressed forty-two different briefs for 20 companies in this time.

Student Motivation.

A major feature of project based learning is its intrinsic motivation. In the last 3 years, students completed surveys to indicate their attitudes to the concept of the project at the start, when they know the subject structure and their project topic but before meeting their team members. A summary of the results showing the mean responses to questions on a 1-5 Likert scale in which 5 indicates strong agreement and 1 strong disagreement is shown in Table 3.

Item	2001	2002	2003
Working on a real project will be great.	4.55	4.59	4.53
Working for a real client will be highly motivating	4.45	4.65	4.43
Working in a multidisciplinary group will be a great experience	4.45	4.51	4.24
This will look good on my CV when I go for a job.	4.21	4.49	4.10
The project topic looks boring	2.15	1.97	1.96
I do not want to assess my team mates	2.91	2.32	2.65

Table 3. Summary of Responses to Questions on Attitudes to the Projects in Week 1.

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As can be seen, initial motivation was high, especially for the reality of the project, the company and the multidisciplinary nature of the team. It was apparent from the results of a similar survey at the end as shown in Table 4, that a significant number of students find the reality does not totally meet their expectations, especially in relation to the client company. Company representatives see their roles differently – some are highly supportive providing significant amounts of information and guidance, while others want students to generate their own ideas with minimal direction. However, the best students see this as an extra challenge, and find innovative approaches to collecting information. The realization that information is not always provided in the real world as in most university assignments, and developing strategies for obtaining meaningful data, are major learning outcomes.

Question	'97	'98	'99	'00	'01	'02	'03
Working on a real project was great					4.21	4.35	4.25
Working with a real company was great					4.03	4.12	3.81
The different disciplines cooperated well	3.79	3.95	4.32	4.04	4.00	4.26	4.53
Gained broader perspective from other disciplines	3.85	4.02	4.46	3.7	3.79	3.94	4.09
The committee structure worked well.	3.83	3.69	4.11	3.76	3.55	4.15	4.12
Peer assessment was hard to do	2.57	2.85	2.46	2.7	3.34	2.76	2.98
The project topic was boring					2.63	2.21	2.09
This will look good on my CV					3.66	4.26	3.5

Table 4 – Summary of Responses to Questions on Attitudes to the Projects in week 18.

There is little loss in enthusiasm for the multidisciplinary teams over the semester and most think that they have learnt substantially from the other disciplines and that the project will look good on their CVs. Although apparently simple, the projects are not considered boring. Feedback in the early years indicated many students were negative about peer assessment, and so the number of questions was reduced from 16 to 8 to 4. There was little loss of information as the original 16 questions were grouped under 4 main headings. The results in Tables 3 and 4 indicate that peer assessment is no longer a major issue.

Enhancing the level of learning - leadership seminars and the MBTI

In the first year of the project, it became apparent that less successful teams had weaker leadership, so an elective seminar on leadership was instigated in 1997. Participants in this seminar completed Myers Briggs Type Indicator (MBTI) personality measures in advance, so that ways of organizing teams to optimize each student's contributions could be discussed and role played. Group life cycles, multicultural awareness, communications and resolving conflict have recently been supplemented by more emphasis on planning, problem definition and solving strategies and role allocation. After several different formats, the seminar is now called "Leading and Participating in High Performance Teams" and is run over two days the week before classes start as an elective activity. Attendance of twelve to twenty students ensures that each team has at least one or two students with this experience. In 2003, students rated sessions on communications, the use of the MBTI, conflict resolution and planning highly. In 2003, the MBTI results were used as part of the team allocation process, so that each team had diverse personality styles as advocated by Tyson (1998).

Evaluation of the MDIP.

The project has been evaluated via student feedback through questionnaires and reflective reports, company, external observer and graduate feedback discussed below.

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Student reflective reports.

Ten percent of student assessment is given for a reflective report which in 2003 was split into 3 sections required in weeks 4, 8 and at the end of semester, discussing the establishment of the project, data gathering and concept design, and an overview respectively. Weak students tend to record what happened, but better reports show high levels of reflection and analysis of group performance. Students not only consider the structure of the project and the team, but also recommend improvements. Comments of interest included "that this was the first time most Australian and International students had worked together" and that "most engineering decisions were influenced by marketing or cost considerations". One accounting student recommended after her plant visit that auditors of manufacturing companies should spend at least one day on site to have some understanding of the processes involved.

Feedback from independent observers

In 1996-1998, Masters of Applied Psychology students, observed and analyzed group dynamics, subsequently recommending improvements in course organization including the leadership seminars. Healy and Bankier (1996) noted

1. Minimizing supervisor intervention had a positive effect on the group dynamics
2. Interdisciplinary conflict did become noticeable at moments of tension.
3. Higher performing group members addressed the whole group more than their peers.
4. The most successful groups were the more homogeneous in terms of ability.
5. International students participated more when higher performers were absent.
6. Better performing groups minimized disciplinary differences and communicated better.

Feben (1999) found that teams with high levels of group identity, achieved higher satisfaction, commitment and cohesion, more positive attitudes to group-work, and were more successful. One unexpected finding was that the group culture showed little change after the first 5 weeks, emphasizing the importance of the induction process and early team building.

Feedback from clients.

Most companies have been impressed by the reports and presentations, with several offering projects on an annual basis. A number of graduates have been subsequently employed and many recommendations have been accepted. However, several clients have required better justification of recommendations in terms of cost analysis and market data. The engineering students were seen as needing to quantify their statements to a greater extent and explore all feasible options, not just the most obvious. Many have seen the students' greatest challenge as gathering real information to validly address the problem. Some companies indicate that the projects provide fresh insights and can provide extra motivation for their own staff.

Feedback from graduates

In 2003, the recommendations of the academic literature on educational outcomes as outlined above were reviewed. Outcomes derived were used to construct a 57 item questionnaire. This instrument was mailed to 219 MDIP graduates (1996 through 2002). Usable returns were received from 57 engineers, 19 of whom were still in full time study or seeking employment. Of the 39 employed engineers, 25 worked in teams with other engineers, 18 with accountants, 19 with marketers, 14 with designers, 5 with IT professionals, 4 with sales, 2 with production, and others with logistics, legal, finance, etc. Eleven claimed they always worked in teams, 10 frequently, 11 sometimes and 4 occasionally. Only 2 of these 39 worked only with other engineers. An exploratory factor analysis of the data revealed 5 main factors. Inspection of items loading on the factors suggested a strong alignment with those categories deduced from the review papers. Table 5 shows the questionnaire items loading most strongly on each factor to demonstrate the nature of these factors and table 6 indicates those items

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where graduates reported congruence between the importance of skills currently used in their workplace and the presence of this learning in the MDIP

Item (Learning Outcome)	Factor Title
37. Leading and mentoring	Leadership and project management
33. Allocating resources (eg, people)	
50. Appreciating regulatory impacts (eg, OHSE, tax)	
15. Using presentation media (eg, powerpoint)	Communications
16. Using communications media (eg, email)	
13. Communicating in writing	
14 Oral communication	
29 Dealing with criticism	Personal skills - self knowledge, application
30 Learning from mistakes	
57 professionalism	
48. Understanding markets	
46. Strategic planning	Awareness of business
49. Understanding customer demographics	
45 Add value for client	
26. Gaining enthusiasm and motivation for learning	
11. Integrating problems across disciplines	Interpersonal skills
41. Cooperating and working in teams	
39. Getting along with others	
25 Self confidence	

Table 5. Responses identifying the five main factors

Presence Mean	Importance Mean	Item (learning outcome)
3.78	4.03	37. Leading and mentoring
3.95	4.13	33. Allocating resources (eg, people)
4.09	4.2	13. Communicating in writing
4.48	4.52	14. Communicating verbally
4.21	4.05	11. Integrating problems across disciplines
4	4.08	26. Gaining enthusiasm and motivation for learning
4.48	4.55	41. Cooperating and working in teams
4.42	4.55	39. Getting along with others
4.3	4.3	38. Listening; being open minded; empathising
4.31	4.47	23. Taking the initiative
4.33	4.36	2. Seeking and gathering information
4.23	4.47	10. Making decisions, having a view
4	4.08	26. Gaining enthusiasm and motivation for learning
4.06	4.22	6. Analysing costs and benefits
4.02	4.23	25. Gaining self-confidence
3.81	3.59	8. Applying theory
3.54	3.73	54. Gaining theoretical knowledge about your profession

Table 6. Questions for which there was congruence between perceived need and achievement.

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Table 7 indicates those items where graduates reported a significant difference ($p < 0.10$) between the importance of skills currently used in their workplace and the presence of this learning in the MDIP.

Presence Mean	Importance Mean	Action priority	Item (learning outcome)
3.91	4.69		44. Working independently and without supervision
4.08	4.59		34. Managing time
3.51	4.56		17. Using computers
3.94	4.52		35. Establishing priorities
4	4.5		18. Committing to quality and efficiency
3.94	4.44	#	1. Defining problems and goals
3.3	4.44		28. Managing stress
3.84	4.41		45. Adding value for client
3.98	4.39		27. Exercising commonsense, practicality and intuition
3.52	4.22	#	16. Using communications media (eg, email)
3.56	4.08	#	3. Dealing with ambiguous, poor quality or missing data
4.28	4.55		32. Managing projects
4.32	4.54		22. Practicing critical thinking
4.02	4.23		25. Gaining self-confidence

Table 7. Items for which there were significant discrepancies between need and achievement.

Discussion

The high importance which graduates attach to most of the items and the strong congruence between importance and presence of those learning experiences in the MDIP, indicate that the program is largely meeting its objectives. The results in Table 7, however, flag a number of issues which could be better addressed in the Monash Industrial Engineering course. Those marked as 'action priority' (#) are important for the MDIP as most other issues are addressed in other subjects. Even though the items in Table 7 do show a significant difference between achievement and graduates needs, it should be observed that items including 'Managing Time', 'Managing Projects', 'Critical Thinking' and 'Gaining Confidence' all scored over 4 on a 5 point scale and the MDIP can be seen to deliver these learning outcomes at a high level.

It is interesting to note that while coordinators have followed Healey and Bankier's recommendation to minimise their intervention, this is not the perception of many graduates. Adding value for the client would seem to be met by most projects, otherwise those companies which participate every year would not continue their involvement. Discussions on time management, establishing priorities, and quality are all a focus of other subjects in the Industrial Engineering course which has developed a stronger management orientation in the last 3 years. A number of the issues not met such as managing stress and using common sense are not currently included in the objectives of the MDIP.

The issues which the MDIP should address better include those marked #; ie. 'defining problems and goals', 'dealing with poor or ambiguous data' and 'increasing communication by email'. To some extent, problem definition and email usage have already been addressed in 2003, but there is still scope for improvement; viz. there are plans to introduce a more extensive session in the Leadership Seminar in 2004 on problem definition and obtaining and interpreting data. Role plays to improve gathering useful information in interview situations are also envisaged.

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Conclusions

The aim of the MDIP is to address the broader skills raised in reviews of engineering education including leadership and management, communication, self knowledge and control, interpersonal skills and awareness of business ethics and procedures. Feedback from all sources has indicated that in most of these areas the project has been successful, but areas for specific improvement have been flagged and will be addressed in the coming year. The instigators of the MDIP concept feel that the positive endorsement of many aspects of the project by students, clients and graduates makes this a learning approach worthy of wider implementation.

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Accidental Teaching in Software Subjects

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***Abstract**: Teaching any subject may accidentally give messages that are entirely unintended, and very negative in terms of appropriate technical processes and professional attitudes. Software is a particular problem as the teaching of software languages can accidentally infuse poor software engineering principles in the minds of the student body. This "teaching by accident" can only be overcome by careful analysis of the intentional and unintentional messages that an education process delivers.*
This paper proposes a method that identifies these messages and generates a prioritized set of solutions. A modified form of FMEA (Failure Mode and Effects Analysis) is used to facilitate the process.
Potential problem messages in the teaching of a software language are considered and a case study is given for a problematic software language subject, drawn from a number of real world student experiences.

***Keywords**: Accidental Teaching, Intentional Teaching, Strategic Planning, Teaching Software Engineering.*

Introduction

There is no subject which merely teaches a programming language. Intentionally or unintentionally the lecturer and tutors give messages about how software should be developed and how professionals should conduct themselves. These messages can be accepted at a conscious or unconscious level as part of the student's attempt to join their desired professional group. This is a form of social norming that occurs whenever a group of people aim at cooperative behavior, or individuals attempt to join a group. This can apply to social issues such as binge drinking in colleges (Berkowitz 2002) and to most areas of human behavior including the use and abuse of technology. The unconscious acceptance of messages can be an insidious problem as there is no chance for logic or thought to reject inappropriate messages.
If the lecturer and tutor are conscious of the professional and Software Engineering messages they are giving, then the whole education process can be very positive. If little thought has been given to the messages delivered then students may be given, and accept, processes and professional attitudes that are totally unsuitable for industry and any non-trivial project.

Teaching by Accident

Consider a typical introductory software subject that teaches a language such as Java or C++ and in which students have a number of small exercises to complete. Each exercise is briefly checked by a tutor. The negative messages that students may accept are numerous (and the Machiavellian students thrive)-

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- Software only needs to stand up to one brief inspection (“If we can fool the tutor then that's fine.”).
- Failures are OK (“I can get a mark of 70% if 70% of the software works.”).
- Maintainability of the design and code is not an issue as the software will not be used again (“Software is a throw away commodity.”).
- Only normal modes of operation matter (“The tutor will not have much time to stress the program, check handling of incorrect inputs, or other problems.”).
- Testing can be trivial (“The tutor will not have time to do much, so we will not bother.”).
- Software is about software technology and coding (“Clients don't really matter so let's ignore them when we can.”).

It is quite possible that such a course may do more harm than good by accidentally teaching exactly the wrong ideas about Software Engineering and professional behavior.
Some students try to bypass or ignore client analysis and consultation, scenario analysis, software structural design, and thorough testing. The situation becomes acutely embarrassing if industry feedback on graduates indicates that they are basically "code jockeys" at heart and have no interpersonal skills or system level thinking capabilities.

Professionalism is just as important to employers as technical skills (arguably even more important). The attitude of lecturers, tutors, and support staff can be unconsciously accepted by students as the way that people in power act.
Most of us have worked with professionals who are lazy, deliver late, or are rude. Do we have a previous generation of academics to thank for this because they failed to communicate and enforce professional behavior in their students? Will we contribute to this problem for future generations of professionals by failing in the same way?

Case study : consider you have the network administrator from hell who is rude to students. What attitudes are they learning about how to related to clients and subordinates?

Teaching by Intent

Teaching by intent is the process of carefully analysing the range of messages given to students in the lecture material, the lab and project work, the personal examples given by staff, and the university. Adaptations are made to the educational process to reverse or at least ameliorate the negative messages identified, and possibly to enhance the positive aspects identified.
The analysis can start with a list of the technical and professional attributes that we desire to cultivate in our graduates. This list should include big picture issues which may not be the main goal of the subject being analysed. Some good sources of attributes include-

- Desirable graduate attribute lists published by most universities. At first sight some of these lists look like motherhood statements but on closer inspection many of these attributes are evaluated at the student's first employment interview and so do really matter.
- Employers have many valuable ideas about what makes a good graduate.
- System level analysis and design issues often indicate values and techniques that are important.
- Detailed design and execution issues.

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The final result of the attribute analysis should be improved lecture material, improved processes, and possibly the creation or selection of different tools. The translation of attributes to solutions can be helped by using a modified version of FMEA (Failure Mode Effects Analysis). FMEA is widely used in engineering to develop robust systems (Ford, Chrysler and GM 1995).

A teaching FMEA table can be structured as follows-

Student Attribute	**Current Message (The problem)**	**Criticality /10**	**Possible solutions. (priority (/10) : action required)**
Professional attitude.	Disorganization & poor knowledge OK. (Tutor problems).	7	8: give tutors direct instruction on how to act and what to say. 8: ensure tutors do preparatory exercises.
	Rudeness and arrogance is the right of rank. (Network admin has bad attitude).	9	8: use network resources as little as possible. 10: redesign projects/labs so that they can be done at home. 10: use tutors as buffer. Reassign network admin work.

Table 1 : FMEA Table Structure

Message identification

The first step in using a teaching FMEA is to identify desirable student attributes : this has already been discussed. The next step is to identify the messages currently given to students related to each attribute. There is considerable linkage between a message and a problem but the message to students is the important part as this is what can create a negative legacy for the future. If the problem is thought of first then it needs to be rephrased as a message in order to place it in the teaching FMEA table.

The formulation of messages can be quite challenging as lecturers have an emotional investment in their subjects and may find criticism difficult. This can usually be defused by breaking the blame cycle with questions such as-

"what improvements can be made", or
"with the benefit of hindsight what would we do differently", or
"what are the three best and three worst things about the subject".

These questions can be posed :-

- in the lecturer's own mind ;
- to students in lectures or tutorials, or on a written survey ;
- to other staff involved in teaching the same area of technology ;
- to tutors ;
- to technical support staff.

With all groups it is essential to maintain a positive non-blaming atmosphere. Failure to achieve this goal will usually result in total silence (which can be very embarrassing) or an aggressive response (which can be disturbing).

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Feedback opinions that appear wrong should be analysed just as carefully as those that appear right. If someone holds an opinion that is apparently "wrong" then the reason for that opinion may contain very valuable information. In many cases this indicates a client perception that must be directly addressed or client expectations that must be better managed.

Case study : student feedback indicated a subject was too much work.
"Rubbish" thinks the lecturer!
OK, let's ask "why".
Student answer : mathematics and business subjects are much less work.

In the case study opposite a subject's high workload is questioned by students. Is this a simple case of feedback being motivated by something other than a desire to improve the system? (We want an easy life!) Perhaps there is indeed a disparity that needs addressing. Two solutions are-

- In the subject guide and the first lecture explain to students why the subject has a high work load and why it is justified. Reasons may include that it is a core subject or will directly affect their employment prospects.
- Negotiate changes with the other subject lecturers to get a more even workload between subjects and that in total is acceptable.

Criticality

Criticality is a value judgement as to how important it is to alter the message being given to students. The example table given (Table 1) uses a simple 0 to 10 scale with 10 being extremely urgent. The absolute value matters less than the relative value between different messages. As such, the values are often adjusted up or down as new messages are identified. Messages with higher criticality naturally get early attention.

Possible solutions

The final column is labeled "Possible solutions" rather than "Solutions" in order to encourage a little brainstorming. A column called simply "Solutions" may discourage speculative thoughts that can often be tamed into excellent practical solutions.
When a possible solution is tamed and accepted for action it is preceded with a number between 0 and 10 (for example as 8:) which gives a relative measure of the importance and urgency of the solution. This can act as a priority order by which solutions are implemented.

In general, solutions belong to one of the following categories-

- Better explanations to students and tutors that clarify issues or manage student expectations. These explanations must be given very early in the subject, and possibly be placed in subject guides that are visible before students enrol in the subject.
- Better processes that avoid problems and enhance the acquisition of desired attributes. There is often the opportunity to reduce workload at the same time as improving quality.
- Changes to lecture materials and/or methods.
- Better tools that help students practice the desired attributes.

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Software Subject Specifics

Software language subjects can be a particular problem in terms of the unintentional messages that they deliver. Most software subjects fall into one of the following categories-

- Language based subjects that teach a particular language such as Java or C++.
- Systems level subjects that teach technical and management aspects of Software Engineering.
- Tool based subjects that teach the specifics of how to use a particular tool (or tools) such as the Microsoft .NET framework.

Messages from a Language Subject

The main and quite legitimate goal of a subject called "Introduction to Java" is indeed to teach the Java language. A tight focus on this goal can cause the lecturer to miss the unintentional messages being given about system level issues and design tools. Observed issues from a range of language oriented subjects from a variety of institutions as reported by students include-

- Tool costs important : the tools used are freeware/GPL code that students can use for free at home. The free issue is quite important given student and university finances.
  Unintended message : tool cost is very important and labor cost are less important.
  Industry view : in industry the opposite is usually true, labor costs are usually much more significant than tool costs.
- Code ASAP : all the examples in the lectures quickly drop into coding.
  Unintended message : software is created by coding ASAP.
  Industry view : coding first tends to produce products that are not fit for purpose and much of the code gets thrown away in later revisions. Even in iterative lifecycles there is considerable analysis and design before coding is started.
  According to Boehm and Basili (2001) 40% to 50% of project work is avoidable rework.
- Control first : the first software concepts taught are the flow of control as this is easier to teach.
  Unintended message : design code from the perspective of control flow.
  Software engineering view : this is exactly the wrong way to design software bigger than one function. The object-oriented approach requires an object, or at least a data vision of the problem be the first thing developed. Control flow is the last thing defined. Software Engineering subjects may have to un-teach the control first message given in earlier years.
- Defects OK : most projects are small and are marked using a cursory inspection by a tutor. If 90% of the functionality works a mark of 90% is awarded.
  Unintentional message : software defects are acceptable and there is a linear relationship between defect levels and marks.
  Industry view : delivered defects incur high repair costs and reputation loss. A product that 90% works does not get 90% of the market; it probably has no market share at all.
- No clients : there is no apparent client for the project work and no client needs to be satisfied.
  Unintended message : software technology is more important than client or commercial considerations.
  Industry view : client consultation, client satisfaction, and commercial issues are usually much more important than the software technology.

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- Coding style unimportant : there are usually no marks for good coding style, if any marks are allocated they are usually quite small.
  Unintended message : coding style is not particularly important.
  Industry view : whenever code must be maintained beyond the first delivery then good coding style can reduce the cost of maintenance. In non-trivial projects even the development phase is cheaper if good coding style is used.
- Management not important : management of resources and time is not mentioned.
  Unintended message : forward planning is not necessary.
  Industry view : in all bar trivial projects forward planning of resources and staffing is essential to commercial success.
- Testing last : testing is only considered after coding is finished.
  Unintended message : don't think about testing until testing starts.
  Industry view : much of industry makes the same mistake and pays the cost of delivering to clients a partly-tested product with high defect levels (Boehm 1981). More competent industry has thorough test planning from an early stage of the project and this usually results in an efficient test program that eliminates more faults.
- Throw away code : once an exercise is completed the code is never used again.
  Unintended message : the design methods, coding styles, and testing needed to make code easier to repair and extend - don't matter.
  Industry view : the majority of software development is repair and extension, according to Corbi (1989) around 90% of labor costs. Unmaintainable code can be a commercial disaster.

Teaching FMEA for a Software Language Subject

The creation of a teaching FMEA is a very personal thing as it encapsulates problems and failures. In this paper an FMEA is drawn for a software language subject that represents an amalgam of the worst aspects of subjects from a variety of universities. It has been derived from conversations with a number of current students, graduates, and several lecturers.
It is interesting that most "Possible solutions" have little effect on the time allocated to technical activities. The majority of solutions relate to better processes and better instructions to students and tutors.

The FEMA approach has been used by the author to improve three subjects (in first, third, and fourth year subjects). The creation of the FMEA and necessary consultation took about one day. The consequential actions took between a half day to three days at a time well before teaching started. There was a consequential reduction in problems observed in the subjects during teaching time which resulted in less remedial effort from staff. This effort was not measured but from the author's impression the saved time was greater than the total time spent in all the preventative activities. In all cases student enthusiasm and professionalism appeared to improve.

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Student Attribute	**Current Message (Problem)**	**Critic-ality /10**	**Possible solutions. (priority (/10) : action required)**
Professional attitude.	Disorganization & poor knowledge OK. (Tutor problems).	7	8: give tutors direct instruction on how to act and what to say. 8: ensure tutors do preparatory exercises.
	Rudeness and arrogance is the right of rank. (Network admin has bad attitude).	9	8: use network resources as little as possible. 10: redesign projects/labs so can be done at home. 10: use tutors as buffer. Reassign network admin work.
	Disorganization is OK. (What students must do is unclear or defined late.)	5	6: have a firm timetable to cover the whole semester. 7: state and enforce deadlines. 7: have several intermediate deliveries to force work to be started early in semester. 8: warn tutors when heavy marking time is required, incentives for timely delivery.
	Deadlines don't matter. (Extensions are easy to get.)	7	7: better warning that deadlines are real. 7: explain that backup is vital and disk crashes will not be accepted as an excuse.
	Excuses always work. (Any medical certificate is acceptable.)	9	9: insist that all special considerations based on a medical certificate also come with an extra form on which the doctor indicates the degree of incapacity and over what period of time.
Business and commercial vision.	Planning doesn't matter. (All projects are small.)	10	8: more tales from industry. 6: spot appearance by industry people. 8: have a larger project that can't be done in a few frantic nights.
	Management and customer demands don't matter. (No client.)	8	8: ensure project work relates to at least a theoretical client and management needs. 8: make this aspect part of marking.
	Costing doesn't matter. (No costing done.)	8	8: mark costing and time plans. 8: give more industry examples.
Written and oral communications skills.	Communications skills don't matter. (Never marked.)	8	8: require a written report at some point. 8: put some marks on quality of the user interface including clarity and wording. 8: mark major project by oral presentation. 8: require a work book with meeting minutes and work notes.
Teamwork and leadership.	Individual success matters. (No teamwork rewards).	7	7: make some activities group projects. 7: require formal meeting minutes and action point cycle to be shown at oral presentation. 8: relate to teams in industry. 8: have some group marking and a well defined team divorce process (students then work as individuals).
Ethics.	Software is ethics-free. (Topic never raised.)	9	9: relate projects to portions of critical software (e.g. financial, medical) and show stakeholder conflicts.
Critical thought, analysis, problem solving.	All you need is native cunning. (All problems are small and require little thought.)	8	8: set problems such that there is some intellectual challenge in design or testing. 8: set problems that need formal methods.

Table 2 : FMEA for an Amalgam of Real Subjects.

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Conclusions

Any teaching subject delivers technical content and a whole raft of messages about technical processes and professional behavior. If these messages are not carefully evaluated then the subject may be doing considerable harm to the student body by accidentally delivering the wrong messages about technical and professional issues.
The first step in eliminating this problem is simply to realize that it happens and keep a careful watch for the unintended negative messages. The second and more difficult step is designing a system that will eliminate or ameliorate those negative messages and where possible replace them with positive messages.
A teaching FMEA is a useful tool which will help an academic work through the negative message problem in a structured and methodical manner and so minimize the number and severity of these negative messages.

Software language subjects have a particular potential to generate negative messages. Care must be taken to ensure that the goals of software engineering and professional practice subjects are not accidentally compromised. The teaching FMEA has proven to be quite effective in analysing the potential problems and helping to generate solutions.

The author has used the FMEA approach on several subjects and found it to be very effective. A relatively small effort of between one half and three days well before teaching started resulted in a significant reduction of negative messages, a significant reduction in effort during the teaching period and improved student professionalism and enthusiasm.

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Development and Implementation of a Postgraduate Technology Management Program

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***Abstract**: The Faculty of Engineering and Surveying at the University of Southern Queensland is developing a Master of Technology Management (MTM) program that combines postgraduate business courses with specialised courses in engineering and technology management. The first students enrolled under this program commenced in 2003 and delivery of the first courses commenced in the first semester of 2004. Students have been attracted to these courses from fields as diverse as business administration, project management and engineering technology as well as technology management. All are studying on a part time, distance education basis. Most courses developed for this program are new. This has presented a number of challenges for course developers, including enhancing their knowledge base, maintaining parity with current trends in the course topic area, and above all willingly devoting the time necessary to develop a good off-campus postgraduate distance education product. A project management approach has been used to ensure that appropriate resources have been available and that development meets likely student expectations as well as time, cost and quality requirements. Online student interaction systems are being used to enhance learning, promote discussion and maintain student contact. Three courses have so far been written for this program and several others are in progress. While it is too early yet to evaluate how well these courses have met student needs, early signs are encouraging. Development of all courses is expected to be completed by the end of 2006. By then, it is intended that a relevant, useful program of courses will be available to equip technological and engineering managers to manage the technology of tomorrow.*

***Keywords**: Management, technology, education*

Introduction

One of the initiatives of the Faculty of Engineering and Surveying at the University of Southern Queensland (USQ) is developing and delivering the Master of Technology Management (MTM) program, which combines postgraduate business administration courses with specialised technology management courses in a way designed to form an integrated whole and address current issues.

The first two specialised technology management courses were delivered in the first semester of 2004. A third course is being delivered this semester, and other courses are under development. Development of all courses will be complete by 2006.

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Nearly all of the specialised technology management courses are new. Combined with a development team that contains both experienced academics and staff who have joined the University from government or industry, this has presented a number of challenges which have been progressively overcome.

A previous paper (Thorpe, 2003) discussed the challenges that led to development of this program, and the early development of some of its courses. This paper takes this discussion a step further, by firstly discussing the MTM program and some of its courses, and then describing the development and implementation experience.

What is the Master of Technology Management?

The purpose of the Master of Technology Management is to produce graduates "that are equipped with essential management knowledge and an appreciation of the latest technologies much broader than the initial specialisation" (University of Southern Queensland, 2002, p.7), in order to equip them to manage complex technological or engineering businesses.

This program is completed by part-time external delivery mode, over a minimum of six semesters. It consists of twelve courses, four of which are core Master of Business Administration (MBA) courses and eight of which are specialised technology management courses (see Figure 1).



Figure 1: Master of Technology Management Structure

An MBA with Technology Management specialisation, which has four selected core MTM courses plus eight MBA courses, along with a Master of Professional Engineering (which has a higher level of engineering specialisation than the MTM) and complementary Postgraduate Certificate and Diploma programs, are also offered.

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The MTM program was developed out of the recognition that a large number of engineers and other qualified people aspire to managerial positions in a technology or engineering environment. It was also recognised that qualified managers of technology play a crucial role in technologically advanced as well as developing societies (University of Southern Queensland, 2002, p. 11).

Selection between alternative study paths enables learners to select an appropriate mix of business and technology management to suit their needs.

The Master of Technology Management is primarily aimed at attracting engineers and technologists who wish to develop management skills but want these to be in the field of technology management. They would come from both Australia and overseas, and would be likely to be ambitious and motivated, and see additional qualifications as a means of career enhancement.

Description of Core Courses in the Program

The four core Technology Management courses shown in Figure 1 are:

- Technological Impact and its Management
- Asset Management in an Engineering Environment
- Management of Technological Risk
- Towards Sustainable Development

Technological Impact and its Management and *Asset Management in an Engineering Environment* were delivered for the first time in the first semester of 2004. *Management of Technological Risk* is being delivered for the first time in the current semester. Work on *Towards Sustainable Development* is well advanced, and should be completed by the end of 2005. Development of all courses is expected to be completed by the end of 2006.

These four courses are summarised below.

Technological Impact and its Management

Technological Impact and its Management is founded on the premise that the world of today is one in which there is dynamic change in the creation and development of technology. Therefore, it is necessary for managers of technology to understand the impact of technological development and the ways in which it can affect the society in which we live and the controls necessary to achieve a positive impact on mankind.

The course reviews current technological development, evaluates its impact on the world in which we live, examines the relationship between modern society and technological development, and discusses the role of technological development on wealth creation and business. It also assesses the overall social need to manage such development as well as technology creation, transfer and exploitation.

Asset Management in an Engineering Environment

The rationale for *Asset Management in an Engineering Environment* is that in the modern world, one of the highest expenditure for any government is the cost of developing and maintaining infrastructure.

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This course is designed to enhance the ability of technology managers in making better economical and financial decisions for the construction and maintenance of infrastructure assets. Taking a strategic view of asset management, it reviews the overall asset management process, discusses the strategic asset management framework, reviews asset management economics, and then deals with asset management operations, integrated asset management and asset management systems. The course concludes with a discussion of emerging issues in asset management.

Management of Technological Risk

Management of Technological Risk appreciates that the complexity of modern engineering products and systems is such that some risk of failure is inevitable. There is a financial incentive to reduce this risk and to improve reliability, and increasingly, there are statutory requirements to address reliability and safety issues explicitly. In addition, there may be opportunities to manage risks to the benefit of the organisation. Consequently, people in technology management need to be aware of the tools and techniques used for the identification, assessment and treatment of technological risks.

In its first part, this course overviews risk management in a technological context, then discusses the application of risk management standards and processes. Both qualitative and quantitative techniques used for the analysis of risk are discussed. In the second part of the course, learners apply risk management principles to technological and engineering projects and processes.

Towards Sustainable Development

Towards Sustainable Development appreciates that world of the 21st century is one in which there are increasing pressures on natural systems because of the desire of mankind to promote technological development. Therefore, it is necessary for managers of technology to understand the impact of technological development, the ways in which it can occur within the concept of a sustainable world system, and the controls necessary to achieve sustainability.

This course outlines the need for sustainable development and evaluates how this may be achieved in the world of the 21st century. It examines the relationship between sustainability, economics and technological development, and then discusses legislative controls on development. It also addresses the future of world energy sources, and the future of development.

The Program Development Experience

Development of the Master of Technology Management has, as would be expected with a new program, both a challenging and rewarding experience. The following discussion addresses three aspects of this development:

- focus of the program
- differing requirements and expectations of learners
- requirement to produce, in a short time frame, completely new courses

The first two points are closely related. All are considered in more depth below.

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Focus of the Master of Technology Management

There is a range of postgraduate management programs offered to engineers in Australia and elsewhere (see, for example, the programs offered by Australian universities in the *Career Development Handbook of University Courses for Engineering, Science and Technology Professionals 2004* (Engineering Education Australia 2004). For this reason, it has been important to clearly set the direction of the program so that it is differentiated from courses offered elsewhere.

This has been achieved through firstly defining what the program aims to achieve, and secondly defining who might want to undertake this program.

As an illustration of defining what the program might want to achieve, key terms such as "technology" and "technology management" have been defined. A particular challenge has been to ensure that "technology" was wider than the popular view of its being mainly concerned with information management systems.

Following investigation of a number of definitions, it was decided that technology was the scientific knowledge base whose outputs are the systems, processes and know-how that are integrated into engineered systems and processes for the betterment of the world.

The definition of "technology management" was based on that for the management of technology developed by the American National Research Council (1987). The definition adopted describes technology management as linking engineering, science and management disciplines to plan, develop, and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organisation and enhance its competency in innovation.

Therefore, the management of technology encompasses not only the management of existing technology but also the development of organisations so that they are effective and efficient innovators and can implement new technologies in a world increasingly concerned with complex issues, such as sustainability (the balancing of technical, economic, environmental and social objectives) and globalisation.

A further matter to consider was the way in which the courses in the MTM might deal with current issues. This has given a more specific direction to the program and its courses.

Sustainability and globalisation are two examples of such issues. The importance of these issues has been highlighted by Johnston (2003), who observes "sustainability needs to become a major driver for change in engineering education and practice" and "the increasing complexity of engineering tasks has been one significant effect of globalisation on engineering practice."

Both are clearly important considerations for the MTM courses. Sustainability is likely to continue to be of increasing importance both nationally and internationally. Similarly, globalisation is likely to increasingly important as advances in communication continue to shrink the world.

A combination of a technological management thrust and focus on key issues like sustainability and globalisation has given the MTM courses a clear direction.

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Expectations of Learners

In addition to having a clear direction, the courses in the MTM have also needed to meet the expectations of potential learners and industry. The learners will already be practising professionals, located in both Australia and overseas, many of whom will be working in organisations that are dynamically changing and will have different levels of technological maturity. While it is desirable that the learners be engineers, technologists, or scientists, this will not always be the case, as several of the courses in the MTM are also offered in other programs.

The differing levels of technological maturity of organisations, and the dynamic nature of technological development, have been discussed by Tschirky (2001). He argues that the discipline of technology management is changing over time. Thus, technology management initially aimed to close the link between the technological disciplines and general management. Technology was then brought into management through a paradigm shift. There is now a move into an enterprise science view that fully integrates technology-awareness into general management. This particularly applies to organisations with a strong research focus.

Accordingly, in developing the courses in the MTM, it has been necessary to appreciate that learners will come from a range of organisations in various stages of technological development. They will also have differing geographic and cultural backgrounds.

For example, the practice of asset management is likely to be quite different for a person in a developed country whose main concern is to ensure that an expected standard of service from a particular asset (such as a four lane asphalt surfaced road) is met, and a person in a less developed country, whose main concern might be justifying the construction of a road to a reasonable standard for its expected traffic and community needs. Course material should have examples of both types of situation. Assessment (such as assignments) may need to allow good hand-written assignments as well as the normal typed assignment expected of a person who has ready access to computers.

Similarly, requirements and expectations may differ across geographical and political regions. Therefore, course development has needed to consider both Australian and overseas practice. For example, *Management of Technological Risk* is primarily based on the Australian/New Zealand Standard for Risk Management. However, the course developer has had to appreciate that there are also other equally valid risk management methodologies (for example, see Chapman and Ward, 2003, pp 55-76) which need to be also considered.

Need to Meet Deadlines

In delivering the MTM courses, it was decided to use distance education, in part-time mode course delivery. One of the reasons for a decision to do so was based on the observation that there was seen to be evidence of the demise of traditional on-campus Masters degrees within Australia and possibly overseas (University of Southern Queensland, 2002, p. 10).

One of the constraints of developing courses for a distance education market is the necessity of meeting tight deadlines so that there is time to develop the new courses into a set of external study packages suitable for use by learners located in a range of geographical locations.

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This has been met through adopting a project management approach, with particular attention to the key knowledge areas and processes of project management such as:

- definition of the scope of the MTM program and its development
- assessment of time, cost and quality constraints
- identification of resources
- assessment of risks
- establishing communications
- developing an integrated suite of courses within the required delivery schedule.

(for a description of a project management methodology see, for example, PMI Standards Committee, 2000)

A team responsible for developing the courses in the MTM was formed. All members, except for the author, are part-time. There is support from a number of other experienced academics, who provide input into the development process and give feedback, as well as interaction with other related areas of the university.

The Course Development and Implementation Experience

The above discussion has focused on experiences with development of the overall Master of Technology Management program. This section concentrates on the experiences with development of the individual courses in the program. It is covered under three headings:

- structuring courses for learning
- course development
- implementation

Structuring Courses for Learning

The previous section included a discussion on the differing expectations of learners, who would come from both Australia and overseas, and would have different perspectives and understanding of the management of engineering and technology.

In addition, learners also come from a variety of academic backgrounds. The courses in the MTM are now being offered for a wider range of programs than was originally envisaged. In particular, as well as being offered for the Master of Business Administration, the courses are being offered for new postgraduate programs in project management.

This diversity of interests and backgrounds has required the balancing the challenge and interest for those learners with strong science, engineering, or technological backgrounds with the needs of people who do not have such backgrounds.

Similarly, some students will want to understand the basics of the courses, while others will want to explore particular topics in depth.

Because of this range of student interests and backgrounds, the courses have been developed so that they provide sufficient material in the course material to give basic information, while providing optional tasks for those people who want to be challenged more.

The need to meet the requirements of people with minimum technological background has required keeping mathematics in the courses in this program to a necessary minimum. However, this cannot be avoided in some cases.

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For example, quantitative methods for risk analysis discussed in *Management of Technological Risk* require at least a basic level of mathematical skill, as well as at least a basic understanding of probability and statistics. In order to make the course relevant to people without a statistical background, sections of the course have been written to guide learners through the necessary basic processes. At the same time, the needs of advanced learners have to be considered. Therefore, the course has covered the necessary background material at outline level only, and then moved fairly quickly to applications. Those learners who need to know the theory in more detail have been directed to appropriate books and websites.

Development of Courses

The development of courses to meet diverse learner needs is best illustrated by the example of developing *Asset Management in an Engineering Environment*.

Early tasks in designing and developing this course were to define those assets that should be managed by an engineer or technologist (the "technological assets"), assess what should be included in the course, and identify the likely profile of potential learners.

A further challenge was to decide on the way in which the course should be organised and presented to meet course objectives and to challenge learners. Thus, while the basic thrust of the course is strategic, operational aspects of asset management are also addressed. A modular design was adopted, both for ease of study and to permit selected modules to be offered as future short courses suitable for possible industry training purposes. Early modules deal with theoretical issues and later modules with application. Current and emerging issues like sustainability are addressed in the course.

A textbook was selected, and has been supplemented by other study resources designed to enhance learning and challenge advanced learners, while at the same time meeting the needs of people new to the study topic. The course uses guided research – reflection, research into key issues (supplemented by a series of questions to prompt the research process), development of opinions and problem solving. Extensive use is made of on-line research to supplement written material.

The availability of considerable information on this topic has presented particular challenges in balancing the needs of learners and maintaining their interest. Material had to be carefully selected to meet these requirements.

To assist learners with mastering the amount of available material, the course has a number of activities that are classified into the groups of "essential", "important", "background" or "other". The material studied in essential tasks provides basic knowledge of the course material. Important tasks include reading and understanding explanatory course or text material, or undertaking a reading or exercise that aids understanding of the principles being explained. Examples of background tasks may be directed or undirected research that enhances understanding of course material. Other tasks provide additional learning for learners who want to understand a particular topic in more depth. They would typically be undirected research using suggested resources.

Material in essential and important tasks is examinable and is accordingly structured to enable learners with minimal mathematical background to succeed in the course. Material in background and other tasks is not examinable.

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Implementation

As previously stated, two courses - *Technological Impact and its Management* and *Asset Management in an Engineering Environment* - were delivered for the first time in the first semester of 2004. *Management of Technological Risk* is being delivered in the current semester.

The students enrolling for these courses are, as expected, from diverse academic backgrounds, including business administration, project management, technology management and engineering technology. While it is too early to fully evaluate the success of these courses, early signs are encouraging.

The written learning material has been enhanced with on-line discussion using the WebCT package. This allows online discussion, notices, and posting of supplementary course material on the web. Hybrid delivery modes might be considered for the future.

A future step might be online learning. There have been many studies of this in the literature. For example, Macdonald (2001), reported on the use of online interactivity in assignment development and feedback in Britain's Open University; Deeks (1999) discussed the use of web-based assignments for structural analysis; and Ferris (2003), used web-based teaching for management engineering management.

Ferris reports that a difficulty in the web-based teaching method he used was the amount of development work required. Given that there is likely to be considerable development effort in developing a web-based delivery approach, it is likely that delivery for the moment will concentrate on the current method. However, online learning may well be the way of the future.

Summary and Conclusions

The Master of Technology Management combines business and engineering skills into an integrated package aimed at the innovative management of today's and tomorrow's technology based organisations, and is being developed in response to a changing world and changing demands. It is a distance education program aimed at attracting dynamic engineering and technology professionals worldwide.

Because of its need to be a dynamic program delivered by distance education to motivated professionals, the MTM has needed a tight focus, be suitable for learners with a range of backgrounds and experience, and be developed within a tight timeframe.

Learners in the courses offered so far come from a range of academic programs, including business administration, project management, technology management and engineering technology. They also come from a range of backgrounds.

Meeting the needs of this wide range of learners has meant that the courses in this program have had to be structured to meet a range of learning needs and interests.

While current delivery is through paper based materials supplemented by on-line contact with students, future delivery is likely to be more web-based.

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Development and delivery of the courses in this program has therefore provided a number of challenges. These have been overcome through using a project management approach and keeping abreast with current engineering and technological management needs.

As the courses in this program continue to be developed and refined, and as feedback is received about implementation of the courses in it, the task of developing and teaching a targeted, challenging and interesting master level qualification for tomorrow's engineering and technology managers is expected to be increasingly rewarding.

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Educating Engineers for the 21st Century

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***Abstract**: Engineering education today does not appear to be keeping pace with the broader challenges facing practising engineers, in terms of the need to address not only technological change, but also the social, economic, environmental and sustainability aspects of engineering endeavours. This paper argues that engineering education is approached in terms of engineering science with an overemphasis on theoretical, scientific and technical aspects of engineering, at the expense of the development of capability in dealing with engineering problems in an increasingly complex world, and answering to an increasingly diverse range of stakeholders. The paper further argues that the emphasis on research in universities, and on promotion by research at the expense of teaching, is further exacerbating this inability of engineering academia to adapt to new methods of teaching that will result in the consideration of these wider perspectives of engineering in context. The paper suggests some ways forward, including a focus on industry placements for staff, and overseas experience for students in real engineering projects of benefit to the third world.*

***Keywords**: social context of engineering; globalisation; reform of engineering education*

Factors affecting engineering education today

There are significant large-scale challenges facing the profession of engineering, including: the impact of globalisation; the rise of the biotechnologies; the constant innovation in information technology; and a growing societal awareness of issues of environmental sustainability. Whereas the basic science research and engineering innovation which informed 20th century breakthroughs were developed primarily through discrete disciplines and were often applied independently (Jackson, 2003), innovation and technological breakthroughs in the 21st century are likely to be characterised by much more fluidity across the disciplines. The rapid developments in biotechnologies and nanotechnologies have arisen as a result of interactions between, and a merging of, the disciplines.

The marketplace is also quite a different entity to the predictable engineering jobs market of the 20th century. The rapid expansion of globalisation and the consequent domination of engineering projects by market forces raise important issues for the practice of engineering. William Wulf, (2003), President of the National Academy of Engineering in the US, is concerned at the increasing invisibility of engineers in society and the loss of the engineering

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perspective. Engineering projects are increasingly being led by business analysts and decision making is becoming fuelled by questions of the bottom line rather than those of technical or social benefit. Critics of globalisation (Brown and Goricanec, 2003; Oxfam, 2002) also point to the enormous destructive powers of globalisation and market-driven decision making in terms of cultural decimation, social disintegration, environmental degradation and the increasing marginalisation of poor countries and the pillage of their natural resources, particularly in relation to much of Africa and South America.

Johnson (2003) argues that globalisation of the world economy has led to the globalisation of engineering activity. Engineers of the 21st century need more than ever to be able to work in multidisciplinary fields; they need to be able to communicate in culturally sensitive ways with a wide variety of specialists and non-specialists, and, most of all, they need to be able to be highly adaptive to constant change. This means that our graduates have to be not only technically competent, but they need to have highly developed ethical approaches to their work, to have communication skills that enable them to have their voices heard in the decision making process, and to be highly adaptable to a constantly changing marketplace.

Engineering by definition has always consisted of using theory from a variety of disciplines (mathematics, physics, material engineering etc…) to achieve practical, technical solutions to the challenges of life. Over time the emphasis on purely technical solutions has given way to a need for ethical and sustainable solutions, which are not purely technical. Unless engineering wishes to become a purely technical support service, these ethical and sustainability challenges will need to be addressed.

The technical ability of the developed world has increased to the level where the dominant questions are no longer so much technical: “how? and “can it be done?” but rather: “should it be done?” and “what are the ethical, political and sustainability impacts?” And yes, the word ‘political’ is part of this equation. Not addressing the political or social aspect of engineering activity would be to surrender it to purely economic and financial interests. It is the engineering profession that has the ‘know how’ and the ability to move between the technical and the wider implications. If the profession does not tackle the political and ethical impacts of engineering then others will do so and engineering will remain little more than a service commodity subservient to other more powerful interests.

Wulf (1998:2) believes that the engineering curriculum has not risen to this challenge and that it is in urgent need of reform. He asserts that, in the US, the curriculum hasn’t changed much over the past 40 years:

> “I think it is only a slight exaggeration to say that our students are being prepared to practise engineering in a world that existed when we were trained a generation or two ago.”

and that it still primarily focuses on ‘teaching the body of knowledge’. This approach, he argues, is disconnected from practising engineering and that many engineering faculty have never practised engineering. Engineering is not just ‘applied science’ and it is as much about process as it is about technical knowledge.

While a firm foundation of theory and fundamental knowledge is still paramount, it is no longer sufficient to just focus on technical content, particularly where the rapid rate of knowledge expansion can outstrip the four year study of a degree. As engineers begin to

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function in a wider arena than they have traditionally, there is an increasing need for them to be able to forecast and evaluate the social contexts, ethical implications and environmental consequences of their work. In doing this they need the requisite skills for communication, collaboration and creativity.

Curriculum change required

In recognition of this changing role of engineering in Australia, the professional accreditation body, 'Engineers Australia' (formerly 'Institute of Engineers, Australia') requires that engineering graduates develop not only their technical expertise in their chosen field, but also many specified personal, social, and business attributes, and requires that engineering programs provide evidence of this focus and development in their program structures and curriculum documentation.

A national review of engineering education in 1996 (Institute of Engineers, Australia) pointed to the urgent need for a focus, not just on the development of discipline-specific technical knowledge, but on new ways of conceptualising and delivering the curriculum so as to focus on the development of skills and abilities in students that would equip them to adapt to this new environment. The review argued strongly for a shift in focus from a content-driven curriculum, to a capability-driven curriculum. However, the ability of engineering education in Australia to adapt to these challenges has been sporadic. Research by Bons and McLay (2003) found that there were significant gaps in the engineering curriculum with relation to graduate attribute development and that some key attributes such as ethical understanding, interpersonal advocacy and communication skills had little focus in the engineering curriculum yet were valued by industry employers and graduates as the key to effective practice in industry.

Upon commencing work, graduates generally report a sizeable gap between the knowledge taught at University and the practical requirements of their employers. Management is usually the way ahead for the majority of engineers. Most engineers in Australia do not perform original design work, but use building blocks and software packages to simulate and design larger systems from an existing range of options. This further raises the question of what should be taught in an engineering course. Much employer feedback is focused on the gap in time and learning that graduates take to become productive.

Given this state of affairs, the curriculum as it stands now needs to be re-examined, not only in terms of content, but also in terms of the structure of learning experiences that will enable these capabilities to be practised and developed. It is not a matter of updating the various 'theory slots' of an engineering course. The current curriculum sometimes resembles a potpourri compiled from the available research interests of the teaching staff and does not always serve employers or graduates as well as it might.

Factors impeding change

Technological advances have put more and more pressure on the curriculum. Engineering academics are trying to cover more and more ground to keep pace with new knowledge. This has resulted in individual courses that are overstuffed with content and programs that are largely fragmented with increasing choice of specialised courses in the later years of study to cover the new emerging areas.

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Additionally, the most widespread response to extra skill requirements such as an understanding of business practice for engineers, has tended to be treated in a similar way, with additional individual courses from other faculties tacked onto the engineering curriculum, more as a stand alone add-on, rather than in any integrated way. These courses are also presented with their own discipline's theoretical perspective:

> "characteristically defined by codified knowledge and single paradigms...(which) do little to develop the intellectual and critical skills needed in the engineering profession. "
> (Royter, 2002:329).

Presentation of more and more technical content does not contribute to attribute development when the teaching methods favoured are those that rely on delivery of this content to a largely passive audience of students, and then a testing of segments of knowledge through formal examination. Laboratory work does not fare much better where students are presented with a series of exercises divorced from a realistic problem, and Airey and Hull (2002) argue that this amounts to little more than understanding the method but not the concepts. Williams (2002) further argues that bench-scale experiments do not replicate industry scale systems and that we are producing graduates who are only 'turnkeys' and 'button pushers'.

The emphasis in Australian universities on building research activity is also having an effect on further fragmenting curriculum development in engineering. The need to build research activity in universities is resulting in an increased emphasis on a PhD as the major criteria for selection at the expense of industry experience. Many new appointments to engineering faculties have little or no industry experience and tend to exacerbate the teaching with their own tradition of focus on discipline specific scientific investigation quite removed from the many process and negotiation skills required of a practising engineer. Engineering is taught in the context of research at universities. Research, by its very nature, is highly focused on clearly defined areas and addressed to specific and often discrete challenges.

The fragmentation of engineering education is largely derived from this structure. The subjects offered in an engineering course are usually the general offerings of the specializations of those who pursue research interests. Research is required to advance the technical body of engineering knowledge but engineering education for undergraduates is a different issue. As research is often cited as being essential for good teaching, then research would best be rewarded once those benefits have been shown to have an impact on improved teaching outcomes. In undergraduate courses, the level of specialization required is not the calibre required for successful publications in a research context. Therefore while a particular academic may be very knowledgeable in their field, this skill does not necessarily translate into relevant and up to date undergraduate courses. Undergraduate courses require a practical level of application that is relevant and reflects the state of commercial engineering activities. Employers are increasingly asking for graduates who are familiar with the practical aspects of engineering as practised in industry rather than only a purely theoretical foundation.

Furthermore promotion, remuneration and prestige are intimately tied up with research and publications, not with teaching students in lectures, or with curriculum development or laboratory programs. No lasting or fundamental change in engineering will be successful as long as the most lucrative career path bypasses teaching in favour of the number of publications and research grants an academic is able to achieve. While teaching has its own rewards for the vast majority of academic staff, career advancement takes them into research

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publications and grants. Teaching is often seen as a necessary distraction to be left behind as research publications and grants provide the next steps forward on the career ladder.

Wulf (1998) points to a similar situation in describing engineering faculty staff as engineering scientists who have little experience of the practice of engineering. He also points to the difficulty of bringing practising engineers who have spent a large part of their careers in industry, onto the faculty, as "their resumes simply don't fit what the reward system values." Conversely it is difficult for faculty staff to get appropriate recognition for a sabbatical in industry. While this topic may not be the most palatable, efforts to change engineering education will be sabotaged unless the personal career structure for teaching engineering is remodelled such that equivalent benefits in terms of remuneration and promotion can be achieved in the teaching path.

Demographics of engineering faculty also show an increasingly aged faculty staff profile, many of whom have not been in industry for many years. In data collection for a recent round of reaccreditation of programs, it was found that, at one of the largest engineering schools in RMIT, 40% were 50 years old and over; 49% had industry experience more than 5 years ago; and 36% had some current industry involvement such as standards, committees or supervision of industry related projects. Many older staff also tend to be change-adverse and prefer to remain with what they feel comfortable with in terms of content, delivery style and assessment practices. In addition, not only does engineering have a very low number of female academic staff (less than 1% on average), but also very few engineering academics have had any formal training in pedagogy. Membership of professional engineering education bodies was also found in this round of data collection to be not widespread, compared to membership of discipline specific professional bodies: 34% belonged to AaeE, whereas 66% belonged to IEEE.

This lack of connection with and enthusiasm for pedagogy means that many engineering academics do not understand the critical relationship between active, contextualized learning and the development of those graduate attributes required for practice in the 21st century. Many engineering academics have not been able to make the shift from delivery of a body of content, to the design of learning activities, problems and projects that will provide opportunities for students to become actively engaged in grappling with real world engineering challenges and with negotiating risks and solutions with a variety of stakeholders.

In addition, the Engineers Australia accreditation procedures, while requiring detailed reporting of all aspects of curriculum design and course focus, and despite their commendable focus on the development of graduate attributes, do not unfortunately lead to either a change in understanding or a change in practice on the part of the engineering academic. Ethical understanding and issues of sustainability, two of the attributes most crucial for successful practice in the 21st century, were the least reported of all graduate attributes developed across programs in the recent accreditation round at RMIT. The development of the remaining attributes were largely relegated to the design stream of courses and not dealt with in any significant way in the majority of the remaining technical courses. A perusal of course guides also reveals a lack of understanding of framing course objectives in terms of student capability development. Many course objectives are little more than a list of content to be covered than skills to be developed. Jolly and Humphries (2003:29) found that

> "The requirement to impart technical skills and knowledge is seen as far more important than paying attention to many of the 'soft' attributes and certainly

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> more important than mapping where they might be expected to be addressed in any particular courses."

The way forward

It would seem that engineering could be very well placed to provide the bridge between the ethical/political dimension of human activities and the practical physical applications and outworking in environmental and societal terms.

Current engineering education may be seen as an engineering challenge in itself and is perhaps one of the more urgent tasks that face the profession now. The following are a number of suggestions regarding teaching engineering. However a greater overarching consideration is the structural and 'political' environment in which engineering education finds itself.

- *The development of a national engineering educator's training program with appropriate accreditation which feeds into a career structure that is a viable alternative to the research path.* Such a program could be devised to address the specific needs of engineering educators as opposed to a generalist certificate in pedagogy.

- *Practicing engineers to have a significant input in the actual teaching of undergraduate engineering.* This would ensure a more up to date and relevant curriculum and the use of current industry practice input. To ensure the full benefits of such a scheme, financial inducements would have to be on par with the median industry rate to ensure the best representative sample of practicing engineers is tapped.

- *Actual case studies as the primary teaching methodology throughout the entire engineering course.* Currently many first and second year students as well as the community at large, lack an accurate understanding of engineering and what an engineer actually does. Real case studies would convey a better picture of the nature of engineering in Australia to these students.

- *Industry placements and workplace learning.* This would enable students to participate at first hand in the work of practicing engineers and is an excellent teaching tool to communicate the practicalities of the profession. There are obvious benefits for both sides in terms of closer liaison and direct input into the education of future engineers. Large administrative and structural changes would be required to implement such a scheme effectively.

- *Additional projects such as overseas placements in Europe, the USA or the Asia Pacific region as electives.* The Australian Agency for International Development (AusAID) has a range of projects in which student participation could play a useful role. A formal agreement between AusAID and various Universities would lay the foundations for exposing engineering students to a broader social and political reality in which Australia as nation needs to play a role. Many of the development contractors working in the Asia Pacific region contracted through AusAID are engineering companies (SAGRIC, Hassals, OPCV) and play an important role in the wider social contexts in which they operate.

The thrust of all these suggestions is to expand the curriculum from a heavily theoretical and segmented one to one much more aligned with professional knowledge and professional ways

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of working. Such a curriculum incorporates a continual feedback loop which includes practicing engineers and industry representatives or other stakeholders, giving effective input into the education of engineering graduates.

Initial contact with industry and practicing engineers would best be achieved by establishing an alumni network that is an integral part of a University's School of Engineering. Current contact with alumni is generally very low and sporadic. This could in part be due to the divergent emphasis of theory and research in the Universities versus applied engineering in industry.

It must be stressed again that the above suggestions will be undermined and hampered unless the teaching of engineering is accorded equivalent status and remuneration as the research path. How this may be achieved and the nature of the changes required is a topic for further discussion and presents a socio-political engineering challenge – a challenge that could be seen as being outside the traditional engineering domain, if we take the traditional technocrat's viewpoint, or a task that reflects precisely the kind of challenges that engineers of the future need to tackle.

Unless engineering as a profession does address this challenge, there is a very real danger that engineers of the future will more and more become purely technical tools in the hands of other interests. This is a safe, but perhaps less than inspiring role to aim for. For a discipline that prides itself on finding practical solutions in complex environments, such a state of affairs would indeed be regrettable. The challenges of the future are both technical as well as social, structural and even political. Ethics and sustainability are not topics that always ensure a smooth road, though with good reasoning, sound technical and factual knowledge, as well as a dedication to the common good, engineers are uniquely qualified to take the reigns in shaping our societies.

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Untutored minds and learning in engineering

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***Abstract**: Harnessing the "strengths of the untutored mind" is advocated by many well known teachers around the world, in order to achieve very high standards of learning in different disciplines.*

This paper presents a hypothesis, which advocates minimum dependence on lecturing and tutoring efforts, to encourage life long learning capabilities. Project based concepts and assessment methods are recommended in creating and maintaining a highly motivated, student centred learning environment. This paper proposes a model, based on this hypothesis, to assist courseware design, development and implementation.

This approach has been used to facilitate the learning of civil engineering design subjects outside the confines of the classroom, over three-years. Started in 2002 with 2nd year civil engineering graduates at RMIT, the author had the rare opportunity to work with the same group of about 80-90 engineering graduates over three consecutive years using this approach. These graduates are now in their final year of study. The outcomes of this endeavour, measured in the way of student experience responses, volume and quality of learning, acquired engineering attributes and the accumulated experiences through this process have thus far been refreshing and encouraging.

Details of the course development, implementation and experiences are presented elsewhere in a companion paper titled: 'Defining boundaries of PBL in the context of engineering education' by the author.

***Keywords**: untutored mindset, engineering education, PBL*

Background

The 'Untutored mind', here refers to a mind set, which is both inquisitive and open. 'Learning' refers to an inner activity in that mind setting, which is fuelled by self-drive rather than imposed by design. The main intention of this paper is to discuss engineering education in this light.

The tutor rushed to my room early in the second semester of 2002. Stressed, she complained, "All they [the students] are interested in, is what I want them to do, when I want it done by and how many marks they are going to get for each section." All the fuss was about a major project worth 60% of the overall mark. The students were in their second year at the time. The tutor's frustration stemmed from being uncomfortable with or unprepared to confront the numerous questions generated by 90 students, dealing with structural design and

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documentation of thirty different building configurations (4-storeyed). She also proposed that the easiest way to manage the project was to give specimen calculations for each section.

The tutor's and the students' dilemma stemmed from the same source, which is the over tutored mindset. This is exactly the mindset I was trying to change. Although I felt that I had given both the tutor and the students enough information to launch their journey, they were confused and apprehensive.

During the next meeting with my students, after listening to their concerns, I asked a simple question. If I were to provide each one of them with a very tight budget to visit Paris for the first time, would they be complaining or launching a fact-finding mission with all the excitement they could muster? All of a sudden the class went absolutely silent. We then discussed the ways to get around things, without getting overwhelmed. We would revisit this incident later to seek some answers.

Challenge

Stimulating 'inward thinking', within both the teacher and the student in professional education is essential, but difficult. Two aspects constitute this difficulty. Firstly, the institutionalised modern education system, which is a shabbily assembled mass production line, is designed not to provoke this. Secondly, the traditional accreditation guidelines imposed by the professional bodies, by which the programs are normally guided, influenced that design. The recent Institution of Engineers Australia (1999) guidelines for professional engineering programs, which call for programs focusing on graduate attributes, are a clear departure from the traditional mindset.

Understandably, performance measures of such a mechanism are the efficiency of delivery of programs and administrative ease. In pragmatic terms both the teacher and the student appear to have been embedded in a system of constraints and rewards, which is neither motivating nor fulfilling. This system provides an illusion of learning and establishes a value system, which over a period of time becomes a life long habit of responding to outward pressure rather than to inward drive. It is not designed to nurture or reward the teachers' or students' potential and freedom to learn. In other words, the existing structure has already 'tutored' the teachers mindset as 'how to teach' through imposed constraints such as pre-requisites, assessment components, core subjects, electives etc. As a consequence, the teacher has to make sure that the learner is 'tutored' enough to achieve perceived high standards. Donald Schon (1987), in his address on educating the reflective practitioner in 1987, stated that, "the introduction of a reflective practicum into a professional school is an uphill business." I feel his observation, some 17 years ago, has become even more relevant and truthful today.

Many great motivators of learning have demonstrated the wisdom of harnessing the strengths of the untutored mind. History is filled with evidence of such teachers, leaders and events, which either harnessed the strengths of the untutored mind or exploited the 'weaknesses' of the untutored mind. This phenomenon is apparent and documented in both forms – in teaching and learning. Events, through mass movements such as freedom struggles, religious and spiritual teachings or through individual brilliances in sciences, engineering, art and architecture, which created the world we live in today, provide testimonies for harnessing the strengths of the untutored mind from within. Reading into and analysing the 'inner learning', which took place in shaping these events provides a great insight in to how humans choose to learn.

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Mahathma Gandhi (1869–1948), is one of the greatest inward thinkers of our time. He had the ability to provoke and command millions of his fellow countrymen and women to independence through the passive resistance movement, from his *ashram*. On his death, Albert Einstein wrote: "Gandhi had demonstrated that a powerful human following can be assembled not only through the cunning game of the usual political manoeuvres and trickeries but through the cogent example of a morally superior conduct of life" (Fischer, L., 1982). I wonder how many academics would agree with me on the relevance of this statement to education practices today.

Selfless commitment and leadership is essential in exiting from the vicious cycle of an 'over-tutored' mindset in order to harness the strengths of the untutored mind; firstly of the teacher and secondly of the student. The challenge then, for an innovative academic is, to refuse to be 'over-tutored' by the system and allow his/her own initiative and imagination to defy the existing paradox.

Hypothesis: 'Inner Learning of Untutored Minds'

As mentioned before, harnessing the strengths of the untutored mind is advocated by many well-known teachers around the world in order to achieve very high standards of learning in different disciplines. Zuzuki (2000) noted that toddlers learn to speak their native language by themselves without formal coaching prior to reading and writing. He has utilised this observation to revolutionise the way music is taught and learned. There is a fascinating story about how he devised a method, utilising his inner thinking as a teacher, to help a blind girl play the violin at the highest level within four years. Anthony Robins (1991), motivational writer and leader in the science of peak performance, has introduced strategies for self-awareness and self-mastery.

Most spiritual and religious teachings fall into this same category, which encourages inner learning. For example, Buddhist teachings and meditation techniques are designed to promote absolute control of the mind's limitless power. The mind is seen in Buddhist philosophy as an activity rather than an entity, which refers to *citta*, *mano* and *vinnana*. *Citta* refers to the emotional part of activity, which is directly associated with the chemistry of the body. *Mano* refers to the intellectual and conceptual part of activity, which is associated with the brain. *Vinnana* refers to the perceptual and cognitive part of activity, which is associated with the five senses. *Mano-vinnana* is a combined term used to describe one's imagination, the processing of information gathered through the five senses to construct intellectual and conceptual meaning, in one's mind (Wimala, B.Y., 1997). It teaches us that the enigmatic, elusive, yet powerful force of the mind knows no limits, and that it is the constant companion and master of oneself. Therefore, if we are training our students to be 'life long learners', it is this constant companion and master, mind, that we must condition.

I can't go pass this point without telling you the fascinating story of the blind girl who excelled in playing the violin, which I mentioned before, or analysing the genius teacher's unorthodox approach, which made it possible. Zuzuki, knew well enough that, to excel in playing the violin at the highest level, one has to master absolute control of the bow. Although the blindness was not a major handicap when training her left hand, which uses fingers, Zuzuki felt that blindness would impact her right hand training, which holds the bow. His conscience could not refuse the hopeful child or the pleading parents. He requested more time to think about his ability to train her before taking the responsibility. It is worth noting that

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music teaching and learning uses three out of five human senses *(vinnana)* interactively; that is, sight, hearing and touch. Dr Suzuki started manoeuvring the bow by him-self with his eyes closed to experience blindness. Even with years of training behind him he found it extremely difficult. Finally he came up with a simple drill, which could condition the mind, to *feel* the position of the bow without *seeing* it. When practiced for several hours he was able to touch the tip of the bow in one attempt, eyes closed, with his left hand while his right hand wrist moving the position of the tip of the bow. He then accepted to train the little blind girl.

Great motivators of learning are capable of devising ways and means to stimulate *citta* (emotions), *mano* (intellect) and *vinnana* (senses) in a complementing manner to facilitate inner learning. If and when the correct combination is found, learning will take care of the knowledge, and the need for tutoring will fade in to the background. Quite often, within a short period of time, students' knowledge may even challenge and surpass the boundaries of the tutor's expertise. Obviously, coaching an athlete requires one to stimulate, combine and compliment *citta-mano-vinnana* in a different way to that of coaching an engineer. In Buddhist teachings there are seven faculties, which can be trained and conditioned, in order to have total control of mind in different ways. The scientific explanation to some of the Buddhist teachings discussed above can be found in the science of neuro-associative conditioning (Robins, A., 1991).

To put this into context in engineering education, teachers should be conscientious to strike the appropriate balance of these three activities within the mind when designing courseware, developing new study programs, assessments and feedback strategies, etc. Obviously, different engineering disciplines and subjects demand different combinations. The teachers who possess the greatest capacity to influence students are those who chose appropriate combinations either instinctively, or by design, which are responsive and flexible.

It is important to re-visit the incident described at the beginning to seek some answers in light of the above.

- Why has the 'first journey experiencing civil engineering design' triggered a different reaction within students compared to the 'first visit to Paris'?
- Why were students seeking a recipe more to my liking than theirs and seeking a reward for doing that?
- Why did the tutor believe that the easiest way to manage the project was to give specimen calculations for each section?

Obviously, we all chase perceived pleasures and attempt to stay away from perceived pains. This neuro-conditioning appears to be the underpinning theory to all of the three questions above. Neuro-conditioning, through life experiences, becomes likes and dislikes which over the years become habits. I am not, at any stretch of the imagination, suggesting that it is the responsibility of engineering academics' to change such mindsets. My hypothesis however, is that our technical knowledge, industry experience and professional attributes need another dimension for us to become better engineering educators. That is the understanding of the secrets of inner learning and our ability to practice it in order to command the respect and motivation of our students. It is my view that engineering educationists are well equipped to understand and incorporate new strategies based on principles of mindfulness, self-mastery and motivational psychology in their teaching.

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Calm within the storm

It is unfortunate that arguably the noblest of professions – teaching – has lost its vigour and heart. Social standing of the 'teacher' has plummeted, purged by numerous alternative ways and means available to learn. Our places of work, tertiary institutions, are financially unviable to provide the comfort or support we require. Our take home salary does not necessarily provide our family needs and support the living standard we deserve. Academics are engaged in one of the most stressful jobs in the country with the least hourly rate. Academics nowadays have no time to think before they act. Students are demanding and not sympathetic. Basically, our value system is falling apart.

It is no good pretending that all aspects of academic life are in order, because they are not. These conditions affect our psyche and can sap our enthusiasm and energy. In effect, it impacts on our quality and motivation to teach. No matter how hard you try, it is inevitable that frustration filters into your innovative mind. It is also important to recognise that the conditions listed above are, to a great extent, not within our control, and as such cannot change. What we can change though, are the things within our influence to counteract those negative thoughts. That is the only option available to us to supplement and nourish our declining value system. This is mandatory if you want to enjoy your teaching.

When these thoughts bother me, I turn to my inner self to seek refuge or to seek pleasure by sharing my knowledge with young people. Kevin Sheedy, the legendary AFL coach replying to a question from a journalist as to where he finds his energy to keep him going said, he draws it from his young players. I think teachers do the same without realising it. This is an aspect, which we must give prominence to, in order to sustain our daily supply of energy and enthusiasm.

You may wonder what relevance this has on the concepts discussed in this paper. Without devising methods to counteract such negative thoughts, any hypothesis, similar to the one we discussed above, can become merely an ideology. In inner learning, the best remedy for grievance is to acknowledge it. In other words, rather than pretending to ignore our frustration, we must confront it. Traditional classroom based teaching does not provide this personal reward as much as project based teaching does. Associating young minds in an interactive manner is one great way to bring your-self closer to this fulfilment. In the current academic environment, this may be, apart from peer recognition, the only remaining reward one can muster.

I was a long-serving civil and structural engineer, prior to becoming an engineering academic at RMIT University in 1999. I was given the privilege to teach in statics, structural mechanics, structural analysis and structural and civil engineering design subjects to civil engineering undergraduates. I have been using PBL methods in my teaching practice since 2000, more by intuition rather than design. I have launched a journey of self-discovery in my teaching, encouraged and equipped with my experience and self-learning. The hypothesis discussed above is an outcome of this journey, which I now practice by design.

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Four dimensions of course design

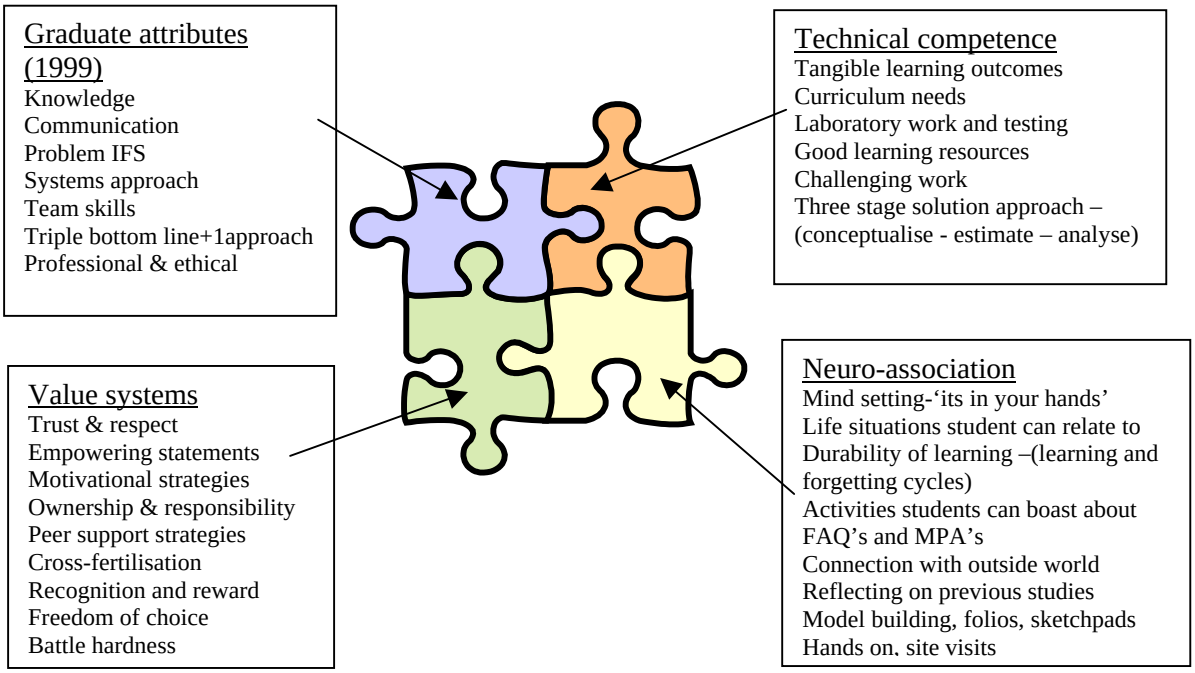


Figure 1: Four dimensions of course design

Figure 1 illustrates the four dimensions of the course design model, which sums up the proposed hypothesis. In my experience, this model would enable the capturing and fostering of learning in an untutored mindset. The underpinning concept of the model is simple enough to understand and interpret. It is designed to capture, conscientiously, the three activities of the mind. Namely: emotions, intellect and the senses (*chitta, mano* and *vinnana*) in learning. The most significant difference in the proposed approach compared to other methods is the prominence it gives to 'neuro-association' and 'value system' components. The model can be used to guide you in designing a new course or adding value to an existing one. The same model is applicable to the vertical integration of a subject stream over the full duration of the program (say engineering design from 2nd year through to 4th year) or lateral integration of all subjects at a year level. Each major learning activity, such as lectures, tutorials, assessments etc., must capture a minimum of two out of four components of the proposed model, in the design of these activities. For example, lectures should not only capture activities from 'technical competence' but activities from at least one other dimension such as 'neuro-association' or a 'value system' as well. It must be noted that assessments are regarded here as a major learning activities and must follow the same rule. When carefully designed and fine-tuned through practice (minimum of three year period), one should have a fully interwoven system with an amazingly rich knowledgebase at teachers command. The interesting fact is that it is the students who mainly create the knowledgebase. Rigid boundaries of traditional curriculum shy away; leaving rich intellect with pleasant memories.

I have revitalised and practiced structural and civil engineering design courses at the School of Civil and Chemical Engineering to incorporate and test the above hypothesis in response to program design and renewal project (RMIT, 2002). It was a progressive improvement, which commenced in 2002 with my 2nd year undergraduate students. It is a successful story. Details

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of this course development and experiences are presented in a companion paper titled: ***'Defining boundaries of PBL in the context of engineering education'*** by the author.

I wish to end this paper sighting two quotes, in conclusion:

"I know of no more encouraging fact than the unquestionable ability of man to elevate his life by a conscious endeavour"

- Henry David Thoreau

"The beginning of a habit is like an invisible thread, but every time we repeat the act we strengthen the strand, add to it another filament, until it becomes a great cable and binds us irrevocably, thought and act."

- Orison Sweet Marden

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The role of Humanities and Social Sciences in Engineering practice and Engineering education

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Abstract: *The relatively poor social standing of the engineering profession in Australia relative to other major professions, and its general inability to attract both a higher proportion of women as well as a high caliber of more intellectually able young people, has been of concern to both the profession and engineering educators. This paper argues that this is due to the unclear perceptions of the engineering profession as being "hard hat" and highly technical in nature; a perception which is at odds with the realities of the world of engineering practice, where the application of broad knowledge and an understanding of the human dimension of engineering enterprise is required. These realities are not generally reflected by the engineering curricula at Australia universities. In many schools there is an excessive emphasis on highly technical matters in engineering curricula, which excludes not only greater technical diversity but also the skills and knowledge of human affairs necessary in engineering practice. An analysis shows that despite many recommendations in Australia for a greater emphasis on social sciences and humanities in engineering curricula, the expansion in these non-technical areas has been slow to take anchor within the schools, departments and faculties of engineering in Australia. It is argued that this is essentially a problem of the academic culture operating within engineering schools and faculties in Australia, which is based on scientific norms derived from science. Finally the idea of cultural change is explored.*

Keywords: *Curriculum design, Women in engineering, Engineering education for sustainability*

Introduction

The strategic role that the engineering profession occupies in the national well-being has ensured the public and private scrutiny of it in its professional practice and its education. Statistical data from DEST (2000) and DEETYA (1998) have shown a relative decrease over a number of years in engineering enrolment at Australian universities. International comparisons for engineering enrolment, however, are of concern. Data gathered by the European Commission (2000) shows that in the European Union approximately 16 percent of all higher education students are enrolled in engineering/architecture courses. In comparison such enrolment for Australia is approximately 7.7 percent. The cut off scores for students entering engineering courses in Australia have also been an issue over many years. Yates (2000) has pointed to a long tail of students with relatively poor academic achievement in the final year at school entering engineering education. This reflects adversely on the engineering profession when compared with the type of academic talent attracted to professional courses such as medicine, law and business.

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The relatively low attractiveness of engineering cannot be attributed to an anti-science stance among the young but rather to their perception of the engineering profession. The ratio of engineering to natural sciences student enrolment is relatively low: 1:2 for Australia, and compares poorly with the European Union where data gathered by The European Commission (2000) shows this ratio comparison to be 3:2, three times greater. In addition to the poor marketing of the engineering profession in Australia there is ample evidence that the engineering profession and education have not connected well to the worlds of employment and the community. Johnson (1996), in his report, points to a survey, conducted in Australia, which shows that 97 percent of employers felt that engineering graduates did not display an adequate diversity of knowledge and skills to meet the future needs of the professional engineering workforce.

The gender imbalance in Australia in the engineering profession and education is an issue of great concern. It compares badly with other major professions such as law and medicine where the enrolment of girls reached and exceeded the parity with boys. This is not to say that there has not been greater proportion of girls in engineering courses. The data published by DEETYA (2000) shows an increased participation, over the past 25 years, in the proportion of girls in enrolled in engineering courses, from 8 percent to 14 percent. However this is largely due to the demographic shift of greater female participation in university education rather than to inspiring girls to choose engineering. The proportion of girls entering universities and who enroll in engineering courses at Australian universities has remained fairly constant at around 2 percent over the past twenty-five years. It does not reflect the reality of a potential market for engineering education and the profession. Some disparity between the number of girls and boys enrolling in engineering courses can be attributed to the streaming process in senior years in secondary schools where the ratio of boys to girls undertaking the pre-requisite subjects for engineering course is 1.5:1. However this only partially justifies the ratio in engineering courses, which is greater than 7:1. The composition of female students varies considerably across engineering disciplines. DEETYA (2000) data shows that the more socially oriented engineering disciplines such as chemical, environmental and civil engineering have the highest proportion of girls in their courses. Johnston (1994) reported that the highest proportion of girls were found in combined arts/engineering degrees where, as in the case of Monash University, in terms of numbers, the girls reached parity with boys].

However the argument for expanding humanities content in the engineering curriculum should not rely simply on improving the attractiveness of engineering education, but must reflect the enhancement of professional engineering practice.

The Role of Humanities in Engineering Practice

Over many years professional discourses have been a fertile ground of inquiry by many social theorists such as Barber (19630, Illich (1977), Larson (1979) and Schon (1991) who tried to define the epistemology of professional discourses. In the professional engineering workplace, discourses based on scientific theory and development play a significant, but not the only, part in the techno-scientific aspect of engineering work. Davis (1998) suggests that the techno-scientific component of professional engineering work derives much of its style of work from awareness of craft knowledge and techniques. Procedural methods, styles of working, historical precedents, rules of thumb, instinct and aesthetics all constitute the engineering method that takes into cognition other experiences as an essential ingredient in reaching technical outcomes.

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Drawing on the ideas of Dewey (1933) on professions' work I will extend these to the engineering profession whose workplace discourses could be defined as an activity of productive pragmatism, and show a consensus of this view. To Dewey (1933), professional work centred around technoscience which epistemically embodied more than a body of knowledge defined by theories and paradigms: technology is not viewed as merely applied science but is inclusive of other knowledge, human experience and aesthetics. A professional discourse was one of a productive pragmatist who used technoscience, in a rational way, as a general intelligence with a tool for critical inquiry and application.

The recognition that professional engineering work discourses encompass humanities has been mentioned as early as 1853. Finniston (1980), in Britain, recognized engineering practice to be one of productive pragmatism and called for the inclusion of greater humanities content into engineering curricula to transform the engineering profession (in Britain) from a technical profession into a social profession that reflects the realities of engineering workplaces. Wragge (1987) and Williams (1988), in major reviews into engineering education in Australia, also emphasized that awareness of human affairs plays an essential role in effective professional engineering workplace discourses. The lack of social literacy and knowledge concerned with human affairs amongst engineering graduates was clearly identified by Beswick, Julian and Macmillan (1988), in a survey of Australian employers, as an impediment to best professional practice. The employers suggested that a greater allocation in engineering curriculum be given to humanities and social science subjects even if it meant that this could be achieved at the expense of some scientific and technical subjects. This is not surprising given, as Solomon (1996) shows, that the destination of graduate engineers is directed into areas that concern themselves with human affairs. Engineering graduates needed skills and knowledge that was required in the workplace but not acquired in education. Johnson (1996), Solomon (1996) and Florman (1996) noted that engineering graduates lacked the cultural awareness and diversity needed for an effective engineering practice and the enhancement of the profession

The relevance of humanities and social sciences to engineering practice cannot be viewed just as an acquisition of knowledge capital but also as the acquisition of engineering skills. It provides professional engineers with the means of a new way of critical thinking and inquiry. Hudson (1975) in a study of humanities and engineering graduates found that humanities students had highly developed divergent thinking skills whereas engineering graduates were more convergent thinkers. Divergent thinkers were more effective in conceptualizing an issue into a problem which itself could be further conceptualized. Convergent thinkers, on the other hand, were less conceptual but more effective in setting the parameters of the problem and, in a mechanistic way, solving it. In fact a combination of convergent and divergent thinking is a good representation of technoscience and what Schon (1991) would see as a basis for a reflective practitioner**].**

Humanities and Social Sciences in Engineering Curriculum

The role of humanities in engineering curriculum can be observed in two ways, and these are:

- The nature of humanities and social science subjects that belong in an engineering curriculum; and
- The proportion of an engineering curriculum which needs to be allocated to humanities and social sciences.

The nature of humanities and social sciences, which are to be incorporated into engineering courses, must be relevant to workplace discourses embedded in the engineering profession.

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If engineering is to be considered as a social profession and its practice has social consequences then subjects dealing with broad human experience would be relevant in the engineering curriculum. Ashby (1966) recognized this and recommended that subjects concerned with ethics, jurisprudence, languages, social and industrial history, and the history of technology were relevant to engineering education. However such inclusion would either reduce substantially the technical and scientific content of the curriculum or would be treated superficially. In the second case it would mean that humanities and social sciences in as few subjects as possible to ensure academic rigour.

Monash University Faculties of Arts and Engineering (1991) conducted a survey of government, private and multinational companies in Australia, which revealed that knowledge of languages as a desirable attribute of engineering graduates was placed highly by the respondents. The desire for broadening cultural awareness and communication skills in the survey reflected the awareness of commencing globalization processes. There was a concern that Australian engineering graduates would have difficulty competing with their multi-lingual European and Asian counterparts on the international stage.

Olsson (1995) notes that a report into engineering education in Sweden recommended the inclusion of History in the core engineering curriculum. As a subject, history expands cultural references and enhances the understanding of the human condition in the context of the development of ideas. In interpreting the human condition, history draws on theories from political science, economics and sociology and, as such, the subject is multi-disciplinary. History can also be highly contextual to the technical and scientific part of engineering curricula. History of ideas and technology may insure that engineering graduates will not go through a process of “re-inventing the wheel”. Philosophy should also be an essential contextual subject in the core engineering curriculum. Application of ethics in professional practice must concern itself with human and social consequences and this requires the study of value systems through which ethical frameworks are constructed for effective professional engineering judgments.

There is a general agreement for some allocation of the engineering curriculum to social sciences and humanities. Grinter (1995), in the United States, suggested that 30 percent of engineering curricula be allocated to core humanities and social science disciplines. Heitmann (1995) in his overview of European engineering education felt that 20 percent allocation to humanities and social sciences was adequate. ABET (The Accreditation Board for Engineering and Technology) (2000, 2002), a body responsible for accrediting professional engineering courses in the United States, set aside a minimum of 12.5 percent of the engineering curriculum that had to be allocated to humanities and social sciences if these course were to be accredited. This figure was exclusive of management and communication studies subjects. Lloyd (2001), in an analysis of engineering curricula at Australian universities, includes information from the accreditation course manual of the Institution of Engineers Australia, which recommends that 9 percent of the curriculum be set aside for subjects concerned with management and ethics and a further 15 percent be set aside for other areas which could incorporate humanities and social science. Theoretically the humanities and social content of engineering curricula could exceed the minimum requirement in the United States. However the recommendations, prescriptive as they are, set by the Institution of Engineers Australia for course accreditation, are not mandatory and there is no great pressure placed on universities to conform with these recommendations. Engineering schools and faculties in Australia often allocate to management, humanities and social science subjects

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less than the prescribed minimum. The response by the universities for a greater inclusion of social sciences and humanities to reports by Williams (1988) and Johnson (1996) has been less than dramatic (see table 1), though with some notable exceptions.

Name of the Institution	**Engineering Course**	**Percentage Allocation to Humanities, Social Sciences and Management subjects in engineering curriculum**			
		1987	**1992**	**1997**	**2000**
University of Melbourne	Chemical	0.0	3.1	1.1	3.1/9.4* [0/6.3*]
	Civil	8.5	2.7	3.8	10.7/19.9*[0/15.6*]
	Electrical	5.5	5.0	3.5	12.5/15.6*[0]
	Industrial/Manufacturing	5.0	6.0	13.8	12.5/17.9*[0/1.8*]
	Mechanical	5.0	6.0	13.8	4.9/10.3*[3.1/4.9*]
University of Sydney	Chemical	0.0	2.0	2.3	6.3/18.8*[0/12.5*]
	Civil	2.0	0.0	4.7	5.2/11.5* [0/6.3*]
	Electrical	2.0	1.5	1.8	2.1/13.5* [0/11.5*]
	Mechanical	3.0	3.8	7.1	7.8/10.9*[2.1/5.2*]
Monash University (Clayton)	Chemical	2.0	4.5	3.1	4.1/7.3* [0/3.1*]
	Civil	3.5	1.6	1.6	11.4/17.7*[0/9.4*]
	Electrical	3.5	3.0	4.7	6.3 [0]
	Materials	1.5	2.5	1.6	9.4/12.5* [0/6.3*]
	Mechanical	4.5	7.2	6.3	8.3 [2.1]
University of New South Wales (UNSW)	Civil	9.0	9.0	10.2	14.1 [6.3]
	Electrical	3.5	6.5	11.9	10.8 [5.8]
	Industrial/Manufacturing	10.0	12.6	17.6	19.8 [7.8]
	Mechanical	11.0	12.6	14.4	12.8 [7.8]
RMIT University (RMIT)	Aeronautical/Aerospace	9.9	9.6	7.2	5.2/10.4*[2.1/5.2*]
	Chemical	6.0	7.0	8.9	7.3/13.5*[0/6.2*]
	Civil	6.8	11.6	9.4	9.3/18.8*[2.1/3.6*]
	Electrical	8.0	10.4	1.8	6.3 [2.1]
	Manufacturing	11.8	13.4	9.0	15.6 [3.1]
	Mechanical	9.7	10.0	6.9	13.5 [2.1]
Victoria University of Technology (VUT)	Civil	8.3	6.4	5.1	11.0[1.0]
	Electrical	11.4	7.4	5.1	9.0 [1.0]
	Mechanical	8.5	15.1	8.3	9.0[1.0]

Figures in brackets for year 2000 refer to humanities and social sciences, the highest number represents the maximum percentage content allocated to humanities and social sciences. (Economics is classified here as a social science subject). * In these cases the social science and the humanities subjects are selected as electives from a range of subjects that include areas such as science, engineering science and management. The figures therefore shown represent the maximum proportion that is allocated to humanities and social sciences.

Table 1: Proportion (%) of engineering curriculum, at selected Australian Universities, allocated to humanities, social science and management subjects.

The manufacturing engineering course (Table 1) had the highest allocation, in Australia, of an engineering curriculum to management, humanities and social sciences: 19.8 percent well below the recommended 24 percent of which only 7.8 percent consisted of humanities and social sciences. The courses in civil engineering at University of Melbourne and chemical engineering at University of Sydney could meet the minimum requirement in the United

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States for the allocation of engineering curricula to humanities and social sciences, and this was optional through choice of appropriate electives by students. In terms of humanities and social sciences the Australian universities were well short of best practice in engineering education as found in the United States and the European Community. Also the courses did not satisfy accreditation recommendations set by the Institution of Engineers Australia.

Institutional Impediments

The general failure in engineering education to incorporate greater non-technical content into engineering curriculum can be attributed to the organizational culture of engineering education at many Australian universities.

Lyotard (1984) declared that the hegemony of science as the grand knowledge narrative was over. Science operated in its own domain and could subjugate other bodies of knowledge, human experiences and aesthetics. In some way Lyotard reflected the ideas of technoscience put forward by Dewey, half a century earlier, whose ideas can be extended into an aesthetic concept by which the work discourse of the engineering profession can be viewed through the prism of productive pragmatism]. Technology cannot be seen as just as an applied science but a technoscience which connects to humanities, social sciences, art and human experiences.

Unlike the professional engineering workplace discourses, the notions of science as the grand narrative are, by and large, deeply embedded in the culture of engineering education in Australia. Knowledge is treated, in general, in a highly objectified and value-free form. It is thus not surprising, as shown in table 1, that engineering education is reluctant to incorporate into its curricula humanities and social sciences because these knowledge bases engage a conversation within a value-laden framework. The problem of paradigm change in engineering curricula in Australia is a problem of culture change in engineering education and its (wrongful) assumption that scientific education ensures the standing of the engineering profession in Australia.

This assumption had a lot to do with the university culture. Engineering, as an academic discipline, at universities, was viewed with suspicion and even alarm by academic disciplines as not a proper area for academic study. To overcome this and to gain acceptance by the university community, engineering at universities in Australia adopted scientific norms of highly codified knowledge. All inquiry followed linear processes. The alternative path to professional recognition through practical and highly vocational education at technical institutes or colleges was killed off by the Institution of Engineers Australia, in the 1970's, to accredit four years post secondary education courses which had defied academic standards. Engineering faculties and departments at colleges used their university counterparts as benchmarks for the introduction of new engineering curricula. There was a shift in academic staff recruitment from professional practitioners in engineering to those graduating with higher degrees in engineering from Australian universities. By 1988 when the bifurcation of higher education ended, engineering courses at the "old technical colleges" resembled those of traditional universities with deeply ingrained norms of science. The hegemony of science in engineering education became further entrenched when as a result of poor intakes into science in many universities the faculties of science and engineering merged. The view of engineering as applied science was given further credence by research funding government bodies because staff recruitment could be gained through research funding and therefore, through new staff, engineering schools and faculties became further scientifically oriented. The culture of engineering schools was largely shaped by their academic profile and therefore by the recruitment of academics. This recruitment into engineering schools was, by and large,

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through research doctoral degrees, which often could have been carried out in science faculties. The academic profile of engineering schools therefore resembles that of science faculties (Table 2), rather than other professional education schools such as law, medicine and architecture, where the academic recruitment placed value on professional practitioners**.**

DISCIPLINE	PROPORTION (%) OF ACADEMIC STAFF HOLDING DOCTORATES
Humanities	59.2 (70.3)
Architecture	16.6 (31.6)
Education	38.2 (60.9)
Science	82.1 (92.2)
Law	21.0 (24.4)
Medicine/ Dentistry	52.7 (54.7)
Engineering	68.0 (84.2)
Economics/ Business/ Administration	34.9 (51.9)
Overall[8]	54.2

Figures in brackets indicate the proportion at old (pre 1990) universities. [Department of Education, Training and Youth Affairs, 1997, Table 4.1].
* This data is provided by DEST (2004), table 25

Table 2: Proportion of the academic staff, in various academic disciplines at Australian Universities, who hold doctoral degrees

The education for the engineering profession has been overly "academicized" given that the profile of its academic staff closely resembles the academic profile of such highly academic disciplines as English, history, political science and philosophy.

Conclusion

Professional engineering discourses occupy different locations in the workplace and in the community from educational engineering discourses. I will define a professional engineering discourse as an activity concerned with design, implementation, control, maintenance, innovation and management of systems and processes with the objective to ameliorate the human condition. The knowledge of physical, biological, environmental, mathematical and computer sciences as well as management, law, humanities and social sciences, and the skills of the craft underpin this activity. To include more diverse bodies of knowledge into the engineering curriculum would necessitate a paradigm shift in the culture of engineering education. This culture of change therefore must be imposed externally. It is not likely to come from the Institution of Engineers Australia, the accrediting body for engineering education, because in recent times its musings have been relegated to a mere advisory role.

The culture change in engineering education is likely to be effected by two forces, which are:

- Globalization. Both supply and demand forces can drive this change. The Australian employers recruit overseas engineering graduates in preference to local engineering graduates because of their particular skills. An international demand for engineering graduates with different skills and knowledge would also provide an impetus for change.
- The second process for change in engineering education is more structural and economically driven, to reduce the cost of engineering education. It is likely to a more

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vocational orientation and be located in Technical and Further Education Colleges (TAFE's)

Both forces for change are going to present challenges to engineering departments and schools at many Australian universities. It would force them to revise their curricula and become more eclectic in areas of social education, and this must necessitate cultural change from an academic orientation to one that views engineering from the perspective of workplace and social discourses.

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Student treatment of 'consequential effects' of project work

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Abstract: *A requirement of the final year Research Project in the USQ Bachelor of Engineering is that students assess the sustainability and ethical issues arising from their work. Student responses to this requirement over the last two years have been analysed to assess how different factors impact on the quality of their thinking in these non-technical areas. Because USQ offers its degrees both internally and externally, and both within Australia and beyond, there are opportunities to assess how factors such as age, national culture and mode of study influence their appreciation of these non-technical issues. While students were able to nominate a wide range of possible ethical and sustainability consequences of their work, few addressed the issues with any great depth, suggesting, as expected, the on-going need for cultural change in engineering and in engineering education.*

Keywords: *Sustainability, ethics, project*

Introduction

In common with most other degree programmes worldwide, engineering students completing the four-year Bachelor of Engineering (BEng) programme at USQ must complete a major open-ended individual project in their final-year. A small but compulsory part of this undertaking at USQ is the requirement that students think about the non-technical and non-managerial aspects of their proposed work. These span social, sustainability and ethical matters, and together are conveniently referred to as 'consequential effects'.

'Consequential Effects' and the BEng Degree

In the construction of the current BEng degree program (FOES 2001) it was decided that the requirement on the student to address these issues should be implemented via projectwork, and specifically via the student's individual final-year project (as recommended by UNEP et al. (1997) and many others) because this is a major undertaking for which the student would, or should, feel a major sense of ownership. This was felt to be preferable to a formal, and inevitably somewhat artificial, classwork exercise. Accordingly the course 'Research Project Part 1', has the specific educational objective (ENG4111, 2003):

- *Identify sustainability, safety and ethical issues associated with a major technical task.*

This decision has two immediate implications. Firstly it is unavoidable – and perhaps no bad thing – that students will have very different scenarios for which to ponder the consequential effects. The learning experience may then be very different. Secondly, unavoidably, there

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will be differences in the extent to which an individual supervisor considers these matters significant for the particular project topic; and therefore, perhaps, the effort they expect the student to put in to addressing these aspects. Overall, however, this is no different to any other aspect of the education imparted via the traditional one-on-one supervisor/mentor model of project supervision.

Implementation within Project work

'Research Project' in the BEng Degree

The final-year subject 'Research Project' at USQ spans the whole academic year and comprises a quarter of the student's final year workload. The activity is labeled 'research' as indication that every topic will have a dimension of 'non-standardness' such that routine solutions cannot be directly employed. A small minority constitute 'original research' and produce publishable outcomes.

Students derive their topic by one of two routes. They may express preferences from the annual list of topics offered by USQ faculty staff. Alternatively they may undertake the negotiation and development of an 'own topic' with the aid of guidelines provided. In both cases the project topic eventually allocated to each student is determined by the Examiner (currently the co-author of this paper, Nigel Hancock).

The 'Project Appreciation' Assignment

In addition to the final report (a full academic dissertation), a major assignment to be completed early in the execution of the project is the 'Project Appreciation' (Hancock, 2003, sec.7). As the name indicates, the educational objective of this assignment is not just to be assured that the student has made a satisfactory start. Specifically it requires the student:

- to set out broad aims and specific objectives;
- to set out background information (i.e. the 'literature review' in the broadest sense);
- to recognise the 'consequential effects' of the project activities and outcomes;
- to provide an analysis of the safety issues involved;
- to identify and quantify the resource requirements; and
- to determine appropriate timelines for the project activities.

Formal guidance is provided to assist the student to address each of these issues: each is separately assessed by the supervisor/s on a four-point scale of:

Good – Satisfactory – Marginally satisfactory – Unsatisfactory

and a judgment of *unsatisfactory* requires a reworking and resubmission of that aspect. For each of the six items, a dismissive response of "not applicable" is not acceptable: the lesson here is that ALL engineering enterprises will require, *a priori*, consideration of ALL of these aspects. As a last resort, any student unable to master this dimension of professional engineering work is not permitted to take their project to conclusion until this work is repeated successfully via a re-enrolment in course ENG4111 *Research Project Part 1*.

The Cultural Context

Engineers and engineering students have traditionally been reluctant to engage with the intellectual requirements of environmental and social issues. During most of the lifetimes of current mid- and late-career engineers, the attitude has most commonly been that (i) the best design is the best *technical* design and (ii) that as long as we comply with current relevant legislation, that is all that is required of us as engineers (Hood, 1998).

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Even now when sustainability issues are clearly on the public agenda, such engineers typically remain reluctant to engage with the more subtle or challenging aspects of sustainability or with the more complex social and ethical issues (Johnston 1997). There is no reason to suppose that this is any less true of engineering academics as it is of engineers at large: indeed with the ageing cohort, engineering academics may tend to be more conservative in this regard.

Student Support and Guidance

In view of the 'change in mindset' potentially required, substantial guidance is provided to aid students to address the issues within 'consequential effects' (Hancock, 2003, sec.10.5). The guidance draws heavily on the materials provided by the profession, specifically the Institution of Engineers, Australia (IEAust,1997; IEAust, 2000) and also the Board of Surveyors (ISA, 2004). For some more details about these materials see figures 1 and 2.

An Analysis of Student Responses

Student responses for the years 2002 and 2003, 115 students in total, have been analysed to assess how students and staff have responded. Analysis has been by a subjective assessment of the written responses by one of the authors (David Parsons) in four categories: Which aspects of sustainability they identified; Which aspects of ethics they identified; How deeply they appear to have thought about the two issues; and The extent to which thinking went beyond the simple application of the guidelines given to them – thinking creatively.

Examples

To illustrate the subjective judgments made, some examples of responses for two quite dissimilar topic areas are given together with comments by the assessor.

Example (i): An Inspection Robot

Sustainability Issues. The student argued that the machine did not handle any environmentally damaging materials and produced no pollution other than that from the generation of the electric power it consumes.

Ethical Issues. The student argued briefly that, since the robot was designed to improve the quality of the engineering work being inspected, there was no ethical reason not to continue with its construction and use.

Depth of Thinking and Thinking Creatively. The student carefully worked through all ten of the aspects of sustainability raised by the IEAust. (1997), and briefly attempted to address each. However in every case, he was unable to nominate anything relevant to sustainability. Thus his response was judged to be a reasonable attempt but one lacking in informed thought and certainly not one showing much thinking outside the conventional engineering box of "everything we do which improves human lifestyle is good".

Example (ii): Asset Management of Infrastructure

Sustainability Issues. The student worked through the ten points individually and responded to each with some small level of thoughtfulness. He considered short and long term issues, impact on the environment immediately surrounding the asset, and the people using and paying for the asset. This response was judged to be acceptable in the context, even though not very detailed.

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Ethical Issues. The student worked through the nine points specified in the IEAust code of ethics and very briefly dismissed each one with the assumption that since this was a documented plan to be implemented by a Shire Council, then everyone concerned would be treated fairly and no ethical principles would be breached. This response was judged to be an acceptable approach since the student had at least focused on some ethics ideas.

Depth of Thinking. Overall the student applied the level of thinking likely to be engaged in about these issues by many practicing engineers, who typically have little training in sustainability issues (UNEP et al. 1997), and who are primarily concerned with the engineering job in hand. This level of response was therefore judged to be acceptable, but only of course in the context of this exercise.

Thinking Creatively. The student did not show any deep thinking about the more subtle aspects of sustainability or ethics and so this aspect was judged to be poor.

For guidance about assessing sustainability consequences, students are referred to the following list of aspects of sustainability taken from IEAust (1997):

1. Development today should not undermine the development and environmental needs of future generations.
2. Environmental protection shall constitute an integral part the development process.
3. Engineering (and surveying) people should take into consideration the global environmental impacts of local actions and policies.
4. The precautionary approach should be taken – scientific uncertainty should not be used to postpone measures to prevent environmental degradation.
5. Environmental issues should be handled with the participation of all concerned citizens.
6. The community has a right of access to, and an understanding of, environmental information.
7. The polluter should bear the cost of pollution and so environmental costs should be internalized by adding them to the cost of production.
8. The eradication of poverty, the reduction in differences in living standards and the full participation of women, youth and indigenous people, are essential to achieve sustainability.
9. People in developed countries bear a special responsibility to assist in the achievement of sustainability.
10. Warfare is inherently destructive of sustainability, and, in contrast, peace, development and environmental protection, are interdependent and indivisible.

Figure 1: Sustainability issues as given to students

For guidance about assessing ethical consequences, students are referred to either the Engineering or the Surveying codes of ethics, and are provided with the following thought-provoking questions which refer implicitly to the major theories of ethical thought (Hancock 2003, Sec. 10.5):

1. It appears that the consequences of your project will result in considerable benefit to a lot of people, but some harm to a few others. Is this ethically acceptable because the 'good' greatly outweighs the 'harm'?
2. Your project activities and anticipated outcomes are determined to be not violating anyone's rights. Does this automatically make the activities and anticipated outcomes ethically acceptable?
3. At the conclusion of your project activities you have done what others regard as a 'good job'. Does this automatically make the activities and outcomes ethically acceptable?
4. It is concluded by others that a 'good person' would have performed the project work in the same way that you did. Again does this automatically make your activities ethically acceptable?

Figure 2: Ethical issues as given to students

Sustainability Issues

The responses from students covered a wide variety of aspects of sustainability. Brief descriptions of the aspects mentioned together with the number of students who mentioned each aspect are given in table 1. Simple mentioning was deemed to be evidence of at least some relevant thought.

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Aspect of sustainability	Number of student mentions
More efficient use of resources	55
Making the engineering better	25
Minimising pollution	30
Specific environmental benefit	18
Social sustainability – making things better for people	1
Preservation of heritage	1
Improving positive community perceptions	1
Specific argument that sustainability was not relevant (e.g. software products)	10
Statement or implication that sustainability was not relevant	21

Table 1: Number of students mentioning certain aspects of sustainability

Ethical Issues

Similarly, the range of ethical consequences mentioned was quite wide. Table 2 gives the aspects of ethical consequence and the number of students mentioning this aspect.

Ethical Consequence	Number of student mentions
Impact on employment	8
Redistribution of benefits among industries	6
Distribution of benefits among nations, individuals, disadvantaged, elderly, landholders, rich and poor	7
Intellectual property, plagiarism	7
Safety	7
Quality of products and fair product information	5
Health and welfare in community	14
Accountability, honesty, professionalism	4
Confidentiality, privacy, security	6
Change in society, short and long term	4
Simple application of IEAust code of ethics points such as confidentiality	11
Arguments that there were no relevant ethical issues	0
Idea of ethics not understood	47

Table 2: Number of students mentioning certain ethical aspects

Depth of Thinking

This measure was an attempt to judge the extent to which the student treated sustainability and ethical considerations as serious professional issues. It was judged on a simple scale as shown in table 3, which also shows the number of student responses in each category.

Thinking Creatively

This measure was an attempt to judge the extent to which students thought about the meaning of the relevant sustainability or ethics points, many of which are quite sophisticated. It was judged in the categories given in table 4, which also shows the number of student responses in each category. Some responses fell into more than one category.

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Level of treatment	Number of students
Thorough/Serious (detailed treatment in several categories, evidence of some thinking through of most issues)	14
Acceptable (covered several categories in some detail, evidence of appreciation of simpler issues)	14
Mediocre (little evidence of appreciation of most issues, lack of detail)	28
Token (very brief, little or no detail, little evidence of appreciation of issues)	57

Table 3: Number of students responding with certain levels of depth

Category of thoughtfulness	Number of students
Creative/thoughtful (awareness of possible consequential effects, evidence of careful consideration of many points)	9
Point-by-point (special category for those who systematically dealt with each point but who did not generally show appreciation of the consequential effects)	30
Mediocre (consideration of some issues in some small detail)	11
Poor/No serious thought (showed little understanding of issues, very brief, generally dismissive coverage)	74

Table 4: Number of student responses in certain categories of thoughtfulness

Comparison of performance with final grades

Figure 3 shows the distribution of final grades for Research Project and the distribution of depth of thinking about the sustainability and ethical issues. These data suggests that many students who performed well in the project overall did not perform in a corresponding fashion when addressing the consequential effects of the project work. This result was to be expected given the cultural context described above.

Variation of student performance with country of origin

Using both the depth of thinking and thinking creatively scores, each on a 4-point scale, a broad analysis of performance was conducted against country of origin. There were 96 students from Australia plus Great Britain and New Zealand and 19 from other mainly South East Asian nations. The results of this analysis are given in table 5.

Level of Response	Comment
Thorough/Thoughtful	Most Australian, 1 from Great Britain
Acceptable/Careful	Nearly all Australian, 1 international
Mediocre/Mediocre	Nearly all Australian, 1 international
Tokenistic/Poor	Mostly international, a few Australians

Table 5: Variation of level of response with country of origin

These results suggest that while levels of response were not high overall for any group, those who did understand and address the issues tended to be Australian students. There was a significant problem with South East Asian students failing to come to grips with the issues. From anecdotal evidence, this may be due to the fact that these students are often first-generation university-educated. They come from societies where standards of living are climbing rapidly and material progress appears to be placed ahead of sustainability and relevant ethical issues. These students commonly thought entirely from a commercial point of

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view which emphasized the success of the engineering organization they worked for. However, the authors are aware that the above analysis may be flawed because it simply blames the students whereas it may be our teaching which is deficient (Biggs 1999, Parsons and Dowling 2004).

This result may also reflect the fact that most of these international students enter the USQ programmes with advanced standing and so miss some of the earlier education where sustainability and ethics feature at least briefly.

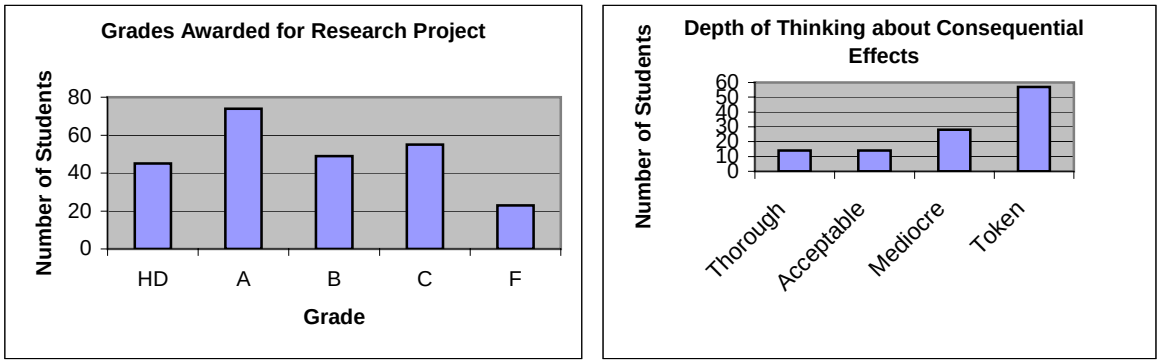


Figure 3: Comparison of grades awarded for Research Project and depth of thinking about the consequential effects. No correlation between grade and depth is implied.

*Variation of student performance with m*ode of study

The educational experiences of external students are undoubtedly quite different to those of on-campus students. A comparison of the responses of the two groups is presented in figures 4 and 5.

This data suggests that, somewhat unexpectedly, on campus students have responded more thoughtfully than external students. Possible explanations for this result are:

- On campus students may be more likely to have recently completed formal secondary schooling and thus been exposed to some relevant ideas. External students, being generally older, may have achieved entry to university through tertiary preparatory courses with limited breadth of content.
- Most non-Australian students are studying externally, and, as shown above, the responses from these students was not as thoughtful as might have been hoped.

Variation of student performance with age

Because USQ has many external students, there is a range of age groups represented in student groups. The data was analysed against age to see the extent to which life experience has enabled students to better appreciate and handle questions of sustainability and ethics. The data is given in figures 6 and 7. This data does not indicate significant differences across the age groups. This suggests that life experience without specific education in an area is not enough to allow useful assessment of the sustainability or ethical dimensions of engineering work. It also reinforces the educational principle that students need to be taught what they need to know (see, for example, Kelly 2004).

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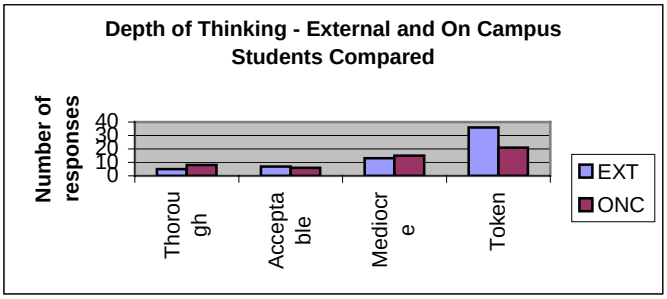


Figure 4: Depth of Thinking - External and On Campus Students Compared

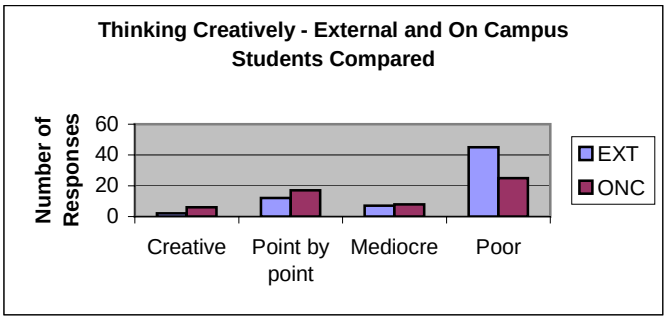


Figure 5: Thinking Creatively - External and On Campus Students Compared

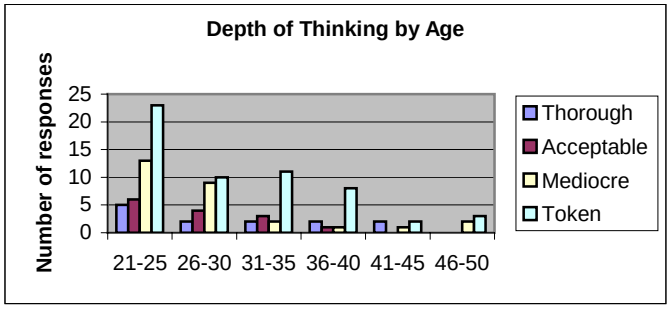


Figure 6: Depth of Thinking - Variation by Age

Discussion

The issues surrounding consequential effects are becoming progressively more important in engineering practice and they go beyond the assessment of environment impact. Hood (1998 p.673), for example, suggests that we even need to question the lifestyles, desires, industries, transport and energy systems we as engineers should encourage or discourage. Similarly Johnston (1997) suggests that engineers should be framing the problems, not just solving them. In other words, the ethics of engineering which includes responsibility for both social and environmental sustainability, must progressively move to a consideration of macro-ethics. In this context then, the quality of the student responses was disappointing. Many students showed, for example, that they did not fully appreciate the meaning of several of the sustainability points given and certainly showed little evidence of being aware of some of the more fundamental questions suggested in the paragraph above. For example, work on a software product, from many students' points of view, raises few consequential issues because it is confined to the inner workings of a computer.

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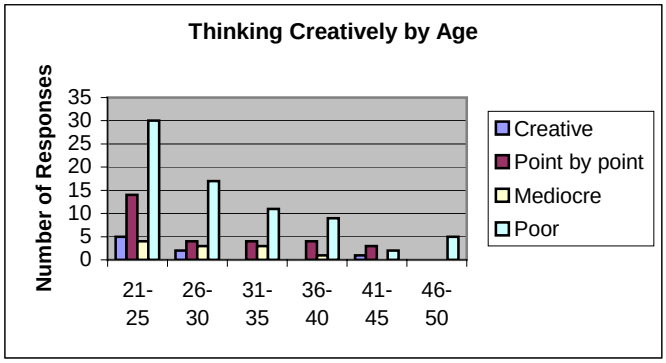


Figure 7: Thinking Creatively - Variation by Age

There may be several reasons for this low quality. Firstly it is a self-evident fact to most students that most small engineering works such as those addressed by Research Project topics, are intended to improve something which is good by definition, and that their consequential effects, by their scale, are small and therefore negligible. Student are also aware that many consequential effects arise from the complex interaction between the engineering work under consideration, the economics involved and the society in which they are used. They then simply place the responsibility with others.

Another reason for the lower than desired quality of responses is that, generally, students lacked specific knowledge, ideas and tools by which to judge the consequential effects of their work. The data above suggests that experience has not been sufficient to help typical mature age engineering students achieve these skills. Those students studying an Environmental Engineering major generally did a better job of assessing the sustainability issues, presumably because they were already equipped with some relevant skills. Most of the students in the present sample have not done a recently-introduced USQ course called Technology and Society which attempts to communicate some aspects of these consequential issues more explicitly than in the past. There is therefore some hope that future student cohorts who will have done that course, will improve in their assessment of these issues. Going further still, it may be better to integrate more sustainability and ethics content throughout programmes as recommended by UPEP et al. (1997).

It may also be true that some staff also lacked either the skills referred to above or the inclination to expect thoughtful responses from their students in these ‘soft engineering’ areas. This may be a reflection of the relatively conservative approach taken by engineering academics as discussed above. There is also hope that this situation may improve over time. We could also question whether simply presenting the students with written material about consequential effects and expecting them to absorb its implications is sufficient. Current understanding of the diversity of student learning styles suggests that this method of presentation may suit only a portion of the student population (Biggs 1996).

On a more positive note, it was pleasing that the very shallow treatment of environmental issues as those simply related to flora and fauna, which is often evident in first and second year students, was not evident in this group, and this can be counted as evidence of maturity and some development in awareness of consequential issues.

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Conclusions

The requirement that students assess consequential issues arising from their work in Research Project remains a useful one. Because each project topic is unique and real, the students are more likely to feel ownership and thus to develop good appreciation of the importance of thinking about the consequences of the work. This is true in spite of the fact that many students' work about consequential effects was not of the same quality as their overall Research Project work.

The somewhat disappointing results indicate an on-going need for cultural change as recommended in the "Changing the Culture" report (IEAust. 1996). To achieve this goal it is suggested that students and staff also need to be equipped with more thinking 'tools' which might help them to bridge the gap between the technical aspects of engineering and the environmental and social consequences of that engineering.

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Encouraging Engineering Students to Publish

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***Abstract**: Students interested in engineering and technologies usually show modest interest in linguistic subjects and communication skills and therefore often have a weakness in this area. Undergraduate engineering studies at university do not encourage the development of these skills although 'writing' reports and other documentation does feature in contemporary curriculum. As a result of this, students may leave the university ill prepared for many of the oral, written communication and negotiation roles they will encounter in today's industrial environment.*

The paper "Industrial Computing", taught at Auckland University of Technology (AUT), Auckland, New Zealand is an innovative strategy to address these issues by incorporating literature reviews, writing professional articles on selected topics and moderation reports into the curriculum.

***Keywords**: Innovative teaching, writing skills, curriculum development*

Introduction

One of industry's most common complaints about engineers is their lack of communication skills, in particular writing skills (Davies and Cousin, 2002; Kramberg-Walker, 2003; Oakley et al., 1999; Tharp, 1998; Zhihong and Yuejin, 2001). The ability to use written words is very important for today's engineers as this enables them to produce accurate and professional documents and reports, to negotiate with clients and suppliers, and to write proposals, journal articles and the like. For companies investing in research and development, the success of a company can be dependent on the project engineer's ability to apply for grants and research funding. Therefore, employers usually place the ability to communicate near the top of lists of skills they consider important in graduates (Davies and Cousin, 2002; Scott and Yates, 2002). Yet, some students still choose an engineering career to avoid writing (Kramberg-Walker, 2003).

Feedback from employers in industry and studies of successful graduates (Scott and Yates, 2002) indicate that an ability to write coherently is crucial for engineers. While research into this aspect of engineering education is being undertaken it is still an area that appears to suffer from a certain amount of neglect. Students submit written documentation in assessment, but little time is spent on 'how to write and review'. Time constraints and the perception that written and oral communication skills are not "proper" engineering topics are still the

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dominant arguments. Therefore, it comes as no surprise that lecturers, and in particular external examiners, are concerned about the writing skills of engineering graduates.

Scott and Yates (2002) surveyed twenty engineering graduates from seven different companies with three to five years of work experience. These students, identified as high performers by their supervisors, were felt to possess the attributes of a successful graduate. Scott and Yates divided the professional capabilities of a successful engineer into four main desirable attributes of engineering graduates. These characteristics are illustrated in Figure 1. Interestingly, high emotional intelligence (personal and interpersonal) was ranked as the most desirable attribute by the young engineers as well as by their supervisors.



Figure 1: Attributes of the Engineering Graduate

Emotional intelligence and generic skills & knowledge can be developed in the context of innovative teaching methods such as group work, role play, presentations and exercises involving interaction within the group. This paper presents an approach to include these teaching methods into the curriculum to further the students writing and communication skills while they develop an understanding of contemporary computer integrated manufacturing systems and their associated software applications.

Case Study: "Industrial Computing"

Objectives

The objectives of the paper "Industrial Computing" are to research and evaluate the complex interactions and elements of industrial computer systems and their applications in an engineering context. The topics covered in this paper identify and acknowledge the complexity involved in industrial computer applications and equipment, in particular in the fast changing field of computer integrated design and manufacturing (CIM). Various system elements are discussed, investigated, evaluated and documented. Selected problems are solved and systems are analysed.

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Learning Elements

By the end of this paper the student will be able to:

1. Identify the complexity of commercial computer applications in industry.
2. Analyse and compute processes as applied to elements of an integrated system.
3. Evaluate, critique and reflect upon a publication (namely, the Literature Review).
4. Research about a selected specific topic and produce professional documentation with reference to literature (namely, the Special Topic).
5. Reflect constructively upon work produced by other students (namely, the Moderation Process).
6. Work in a team towards a complex goal (namely, the Class Publication).

Curriculum Development

Davies and Cousin (2002) postulate that there are three different approaches for including writing development into engineering courses as part of communication skills development. They can be identified as *embedded*, *integrated* or *bolted-on*:

- Embedded, where skill development is implicit in the general content.
- Integrated, where skill development is explicit in the aims, yet integrated in the technical and academic content.
- Bolted-on, where skill development is treated in separate modules.

Learning Elements 3 to 6 emphasise the integration of written and verbal communication skills to aid the development of the student into a reflective and independent learner. The 'complex goal' in Learning Element 6 represents the collaborative class publication of the book "Industrial Computing". The cover page is shown in Figure 2.

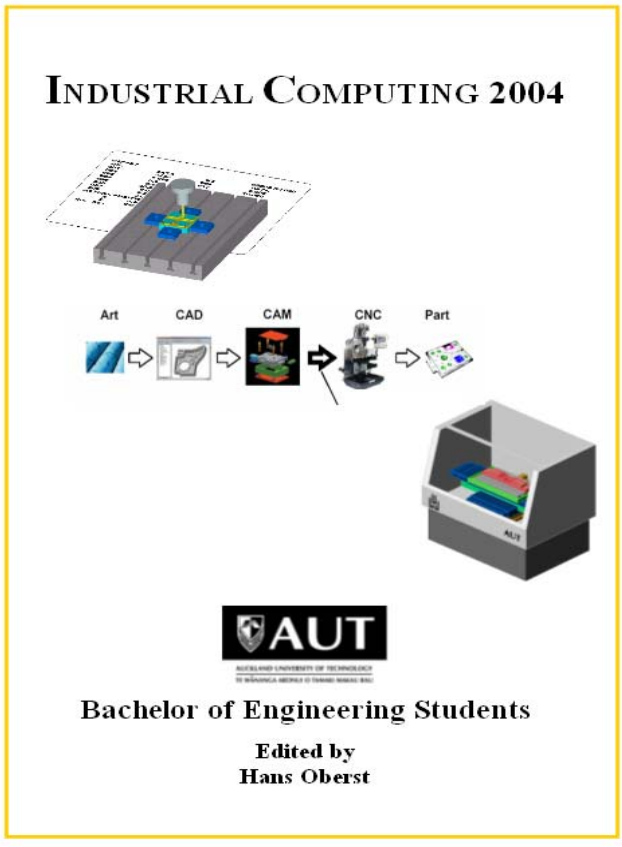


Figure 2: Cover page of "Industrial Computing"

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While Learning Element 1 focuses on profession-specific skills and knowledge, Element 2 helps to develop the intellectual capabilities of the future graduate.

The following activities are considered to foster the student's ability to become a reflective writer:

- Summarising and critiquing a publication.
- Researching and writing about a specific topic.
- Moderating other students work.
- Responding to the moderation in order to improve the initial document about the specific topic.
- Presenting the work to the class.

Course Assessment

The distribution of the course work mark is itemised in Table 1:

• Summarise, discuss and critique a publication (Literature Review)	10 %
• Special Topic for collective class publication	25 %
• 2 x Moderation Report (5 % each)	10 %
• Power Point Presentation about the Special Topic	5 %
• 4 x Lab reports using specific software applications (2.5% each)	10 %
• Mid Semester Test	10 %
• Exam	30 %

Table 1: Course Assessment

The students are also provided with a timeline in form of a Gantt chart, shown in Figure 3, to help them keep track of their deadlines.

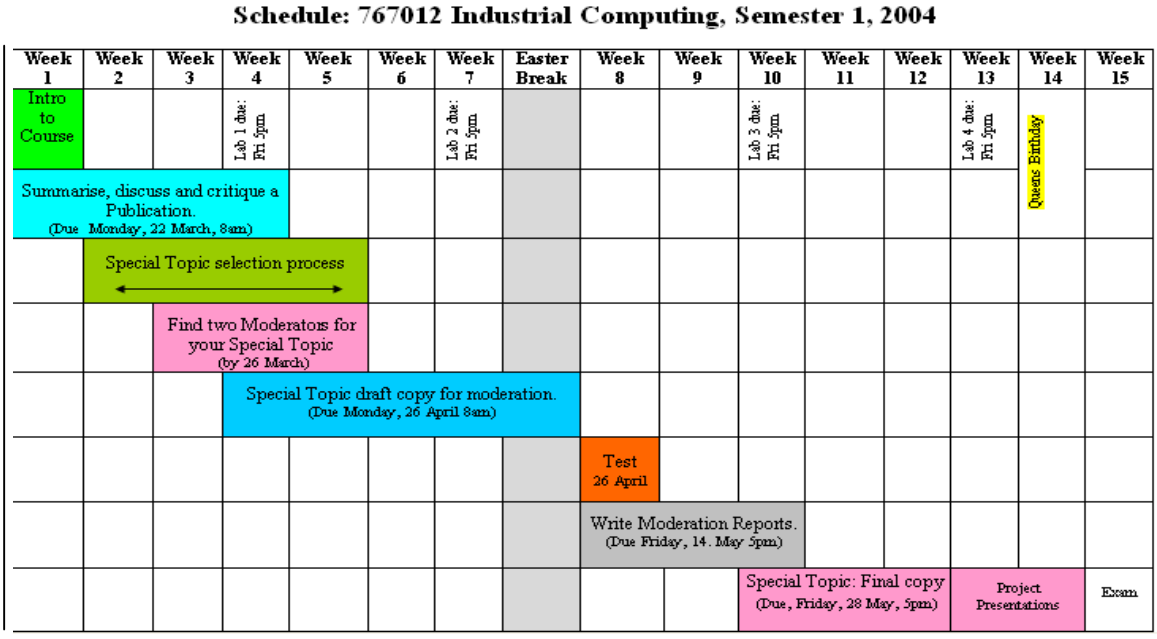


Figure 3: Gantt chart of Timeline

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Assessment Details

Summarise, Discuss and Critique a Publication

The aim of this assignment is to provide students with an opportunity to evaluate, critique and reflect upon a publication. The publication given to the students is of high academic standard (usually a refereed journal article) and discusses a topic relevant to the paper. Students are required to critique and discuss the article in 500 – 800 words. Student criticisms should be supported by relevant literature and these citations should be properly referenced using EndNote.

Special Topic for Publication

This assignment contributes towards a collective class publication and gives the students the opportunity to research a topic of their own choice (approved by the lecturer). The special topic must be the student's own work; any citations taken from literature must be appropriately referenced using EndNote. The special topic should include figures, tables, diagrams and equations and must be between 4000 and 6000 words long. All figures, diagrams, equations and tables must be captured properly in Word and cross references must be made to these items in the document. Each special topic will become a chapter in the class publication. Having 'published' generates a sense of achievement in the students. It also demonstrates to them that it is not an easy task to write professional documentation. Students from previous years have proudly added their chapter to their portfolio to show to prospective employers:

> *"Now that I write so many applications for a job I always mention the CNC chapter I have written for your book. That makes my CV look very good, I am sure it will help me to get the job at Airbus (in Hamburg, Germany).*"
> Roland Larek, (2002)

The compilation and editing of the final version of the book is handled by a group of editors from the cohort under the lecturer's supervision. This ensures that students engage with their cohort in driving the process to completion, not simply the lecturer. Issuing a book written by previous year's students (Figure 2) appears to motivate the students to take part in the project. Students are aware of the standards and expectations of the 'publication' as the previous year's book is used as a class resource by each cohort.

Moderation Process

Writing moderation reports of theses special topics gives the students an opportunity to review someone else's work and requires them to further investigate other topics related to the syllabus of this paper. Reading each others work enables students to better analyse problems and present solutions (Oakley et al., 1999). The moderation reports are marked based on the value of the student's suggestions for improvement and constructiveness of critique of the author's special topic.

As shown in Figure 4, every author of a special topic receives two moderation reports and feedback from the lecturer. On completion of the moderation process the draft copy is returned to the author who will review the article in accordance to the feedback received from the moderators and lecturer.

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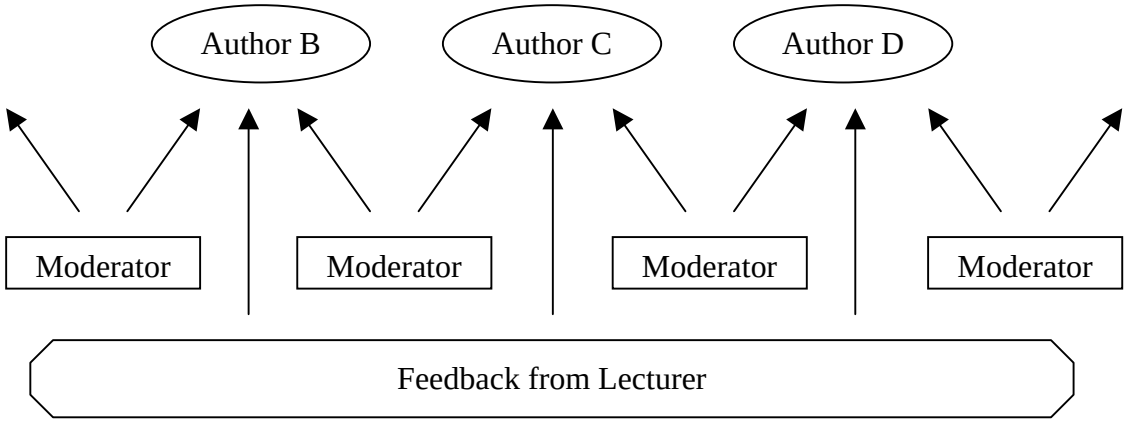


Figure 4: Moderation Process

Special Topic Presentation

A Power Point presentation and a 10 minute speech is required of each student at the end of the semester when presenting his or her special topic. Peer assessment contributes to the weighted assessment grade. Developing good presentation skills using technology is also essential in today's engineering environment. Students are encouraged to use Power Point in a constructive, non distracting manner.

Discussion

How can we best provide students with the skills they will need as professionals who write? The best way to resolve the chronic writing problems experienced by engineers might be to provide engineering students with more writing instruction (Kramberg-Walker, 2003). Almost every university today has student learning and writing support centres to address the writing problems of engineering students. A very simple solution is to point them in the direction of the numerous writing textbooks and guides which fill the market. But the most effective solution is to provide writing instruction in the academic genre at the appropriate level. Using genre theory as a framework for writing in the disciplines is gaining wider acceptance. Such theory supports the discourse and theoretical analysis necessary for concrete instructions in writing (Walker, 1999).

Because students lack confidence initially there is a high degree of procrastination and resistance amongst the students towards the assignment relating to the publication (Special Topic). It appears that the key to developing engineering students' writing skills is context and confidence (Davies and Cousin, 2002). The context is created by embedding writing skill development throughout the curriculum and confidence is encouraged by the activities discussed in this paper. Through repeated exposure and practice, the students' writing ability will improve, and this exposure will enhance the student's confidence when they are asked to write while on the job (Tharp, 1998).

Conclusions

Even if good feedback is given by the lecturer, most marked assignments are usually stored away by the students never to be looked at again. Having the opportunity to improve an existing document (the Special Topic) after moderation creates a sense of ownership in the work and raises an awareness of problems encountered in the writing process. Also, the opportunity to review someone else's work (Moderation Process) is a new experience for most students and tends to initiate critical thinking, resulting in a higher standard of their own

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work. Student feedback indicates that the process of becoming a "professional writer" is a very rewarding experience for most dedicated engineering students. The timing of the paper is fortunate as it precedes the final year project. After their experience on this paper writing a report for the final year industrial project suddenly seems a more manageable task. Robbie Peris (AUT Student, 2004) writes in an email: "I*'ve got more work to do with my writing in order to get a better result for my industrial project"*. An anonymous student concludes in the student evaluation (2002): *"Reviewing publications, moderating and being moderated for our chapters will prepare us well for our academic life"*.

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Automatic Testing of Software in University Courses.

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***Abstract**: The appropriate testing of software is an important issue for industry, and one where many enterprises fail. This can in part be blamed on inadequate teaching in the undergraduate curriculum.*
This paper examines the causes of inadequate teaching of software testing in Universities and then goes on to propose solutions. A tool created by the author called E-AutoTest is introduced that can run, mark, Email feedback to students, and provide collated reports. Hundreds of student programs per hour can be processed using E-AutoTest. This removes the labour and time barrier that is a significant issue in the evaluation of student programs.

***Keywords**: Automatic Software Testing,. Testing Costs, Software Testing Levels, Testing Student Programs*.

Introduction

The last 30 years have seen an amazing rise in the productivity of the software development process. Major applications that were once written in assembler are now written in high level languages. According to Caper-Jones (1995) this has raised productivity by a factor of around 50. Visual components and visual development environments such as Microsoft's .NET have made it possible for an individual to develop applications that would have required an entire company only twenty years ago.
One area of software development has not advanced at such as rapid rate - that of software testing. This is evidenced by the increasing proportion of a project's resources spent on testing - as other parts of the software development lifecycle become more efficient the proportion spent on testing increases. For example Putnam (1980) estimates the cost of testing and debugging at 30%-45% of budget. Atif Memon (2002) quotes the cost of testing at usually between 50%- 60% of budget. The quality of Australian software implementations is certainly in question (Woodhead 2003) and this in part is due to poor testing.

If industry needs to improve testing then the university system should be placing a heavy emphasis on testing, and this should be evidenced with the word "testing" being in some subject names and testing being seen as a significant part of subject descriptions. At the detail level within software subjects the students should see that a significant proportion of marks are allocated to testing. A web search of subject content from Victorian Universities shows that while some subjects achieve these goals, some do not and so do not serve the needs of industry as well as they could. For example the Department of Computer Science & Software Engineering at Melbourne University (2004) lists the generic skills developed by 53 software subjects. Testing is mentioned in only one subject. At Monash (2004) the Bachelor of Software Engineering lists the details of 18 software subjects and six of these mention testing.

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At RMIT (2004) the Bachelor of Applied Science (Software Engineering) lists 12 software subjects in the first 2 years of the course, five of which mention testing in the subject guide.

This paper examines some basic concepts related to software testing and examines the reasons why testing is different to other software development activities. Methods and tools that can be used within teaching subjects are then discussed. Finally a tool called E-AutoTest is described which satisfies the needs of automatic software testing within a typical university software subject. This tool will be tested on real classes in semester 2 of 2004.

The Educational Environment

Test Level Problems

One reason that testing is not well taught is confusion over the level at which testing can occur. Some levels are well served by existing tools but other levels have little in the way of off-the-shelf tools. In both the educational and industry environments it is important to decide which levels are required.

Machine level testing is the lowest level of testing where functionality is checked at the register level either in assembly code or binary code. In general this has little use except in the teaching of machine architectures or the optimization of time critical sections of code.

Source level testing is the most familiar level of testing. Source level testing can start with a careful review of the source code by the developer and reviewers. This is commonly called a code walk-through.
Source level testing of executing code is implemented in most IDEs (Integrated Development Environments) and in stand alone debuggers such as the GNU gdb under UNIX. The behaviour of functions and fragments of code can be checked on a line by line basis, and by using of breakpoints. This approach is very good for checking that code segments work correctly but is very inefficient at checking the higher levels of system behaviour.

System level testing requires a description of how sub-systems must interact with each other and the external world in order to achieve some goal (which is normally defined in the specification). The definition of the system interactions can be in text form or any behavioural description including interaction diagrams, state diagrams, and data flow diagrams.
Like source code testing it is possible to perform a walk-through to test the system. Unlike source level testing there are no generic tools available off the shelf to test executing code at system level. In industry, purpose specific tools are commonly built ; for example a power train tester developed by Ford (Toeppe, Ranville, and Butts 1998).

Specification level testing allows the software to be directly tested against the specification. Several specifications languages such as VDM enable this goal to be achieved but such approaches have not met with general industry acceptance (Hall 1996). Reasons for this include the difficulty and effort required to write and test the specification in the specification language, the difficulty of modeling non-trivial problems, difficulties in modeling some aspects of the problem, and difficulties communicating to non-technical people.

In an educational environment machine level testing is seldom appropriate, specification level testing is not feasible, and source level testing is well covered. System level testing,

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which is critical to larger systems, is generally ignored and this represents a gaping hole in the education process (Melbourne (2004), Monash (2004), RMIT (2004)).

Other Confounding Issues

There are a whole range of other reasons why software testing is not well taught in universities-

- Cost : In most subjects a student need only test their own program at source level and system level. The needs of the lecturer or tutor are quite different - they must evaluate large numbers of usually identical programs.
  Consider a large class of 150 students where there are 6 programming assignments that must be evaluated by a tutor who costs $35 / hour including on-costs. Assume that each program takes 10 minutes to evaluate including the administrative costs of getting marks into spreadsheets and giving feedback to students. The total cost of marking the assignments is-
  6 assignments * 150 students * 1/6 hour * $35/hr = $5,250
  Most Australian universities are being forced to reduce costs and the tutor budget is an early target. The project and laboratory program of our hypothetical subject has to be cut as a result and so the testing of student code can be less thorough and students have less motivation to become better at testing.

- Standardization problems : the tools for analysis, design, coding and unit test can be standardized and so allow tool developers to create a product that has a wide market, and so offer a high potential profit. For example the C++ GUI development tool Qt Designer can be used to solve a vast variety of problems on Windows, Macintosh, and Linux platforms.
  Testing tools at the level of unit test (source code level testing) can be standardized but testing at the level of system test requires highly customized tools as already discussed. These tools are expensive and very specific and so not suitable for the teaching programs in most university subjects. Similarly such specialized tools with a small market are not attractive to tool developers.

- Body of knowledge weak : many areas of software technology have a standardized and formal set of tools and techniques -- for example the UML modelling language used to model Object Oriented systems (Booch, Rumbaugh, & Jacobson 1998).
  Testing theory and methods is less organised and less and so appeals less to university academics.

Basic Testing for All Subjects

Every software subject can contribute to the teaching of testing without compromising the goals of that subject. In general each subject should-

- Clearly articulate to the students the importance and industry relevance of testing.
- Introduce the conceptual levels of testing and demonstrate testing methods appropriate to the subject.
- Introduce lists of things which can be tested including not only normal operation but a whole variety of mistakes, errors, breakdowns, and fraud possibilities.
- Provide and explain suitable testing tools and methods.
- Arrange assignments to require thorough testing.
- Allocate a significant proportion of marks to testing. This may be as simple as marking against an extensive set of inputs and expected outputs.

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The degree to which a subject implements these requirements depends on what other subjects the students have taken, and the year level to which the subject belongs.

Automated Software Testing in Education

One solution to the cost problem is to have an automated tool that can test the students' code and so significantly reduce labour costs. The testing tool used depends on the nature of the code written. Most student projects falls into one of the following categories : command line programs, GUI programs, network programs, and resident or daemon programs. Command line programs are probably the most useful target for testing because command line is used in most first year programming courses and can be used in later year courses to teach topics such as software patterns and Linux IPC (Inter-Process Communication).
This paper will focus on the testing of command line programs.
Automatic testing of student command line programs looks simple. A simple script program can be written to give the student program an input and then check the output is as expected.

The author tried this approach with a class of 90 students in the year 2000. The student project was to simulate the reception of asynchronous serial data using state machines written in C++ code. The basic tasks for the tutor were-

- Collect all student programs.
- Check for coding style and plagiarism.
- Compile each program.
- Run each test automatically using a script file. There were 10 tests applied.
- Record and collate marks for each test.
- Write down feedback and send this to students.
- Manually enter marks into a results spreadsheet.
- Collated marks into a class performance graph to facilitate class discussion about what had been done both right and wrong.

No detailed labour records were kept but this author's impression was that the automated testing using script files saved only about 20% of the total tutor labour that would otherwise have been spent. From the author's experience this result is not uncommon – the administrative and organisational activities take more time than the core activity, in this case full testing of student programs.

The collation of student programs is usually not difficult. Given a computer network, students can write to a directory which has write-only privileges for the class group. Alternatively, most universities have some form of electronic submission system that can be used. The other points in the list above tend to be far more difficult and time-consuming to solve and need some form of automation.

There are a huge variety of test tools on the market, for example see the long list at Aptest (2004). None of these tools directly address all the needs as detailed in the list above. Some tools such as those from Edwards (2003) provide more complex testing features but do not support all the administrative tasks identified.

E-AutoTest

The experiences outlined above led the author to design the E-AutoTest program to automate the testing process for command line programs and more importantly to automate the administrative tasks identified.

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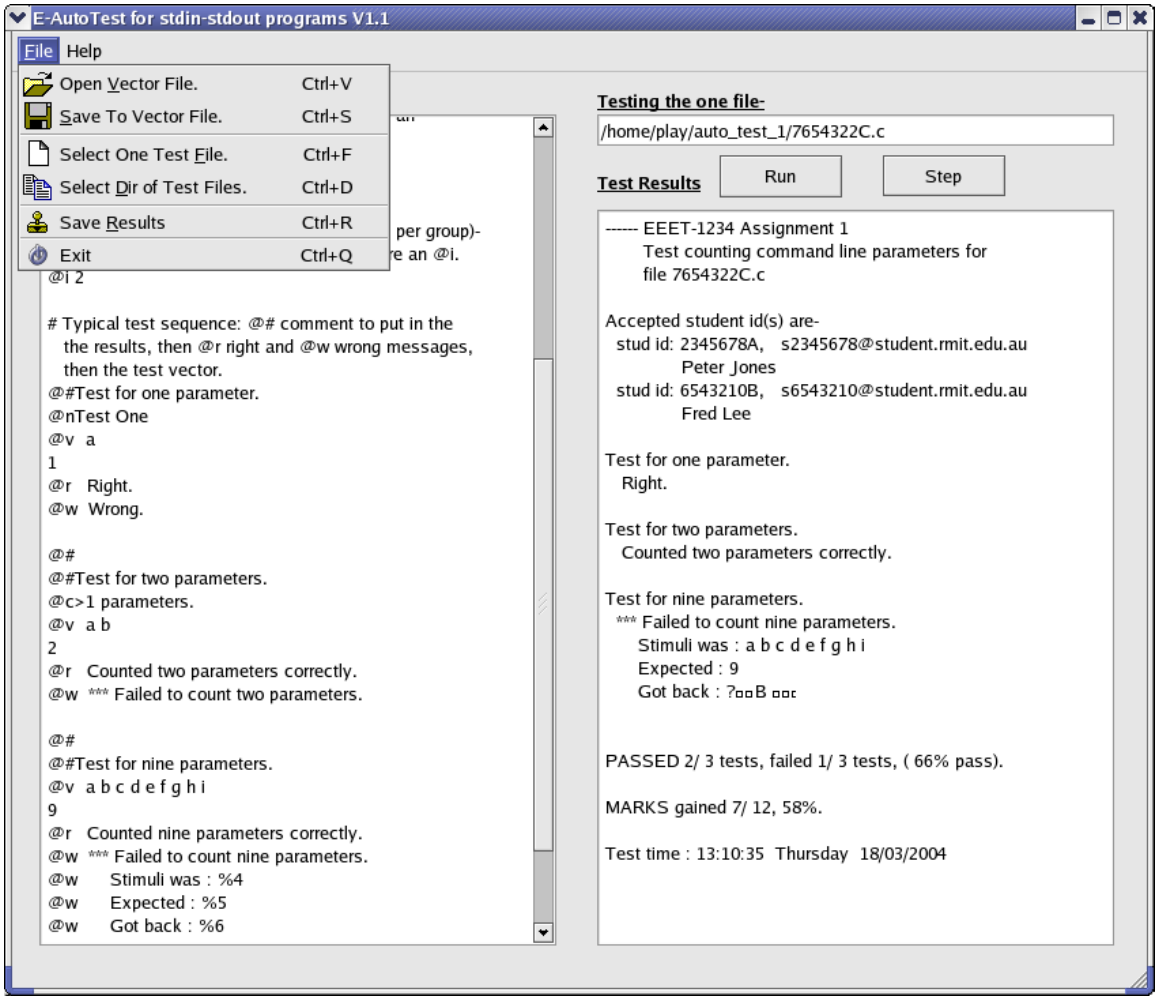


Illustration 1 : E-AutoTest Main Screen

Key features of E-AutoTest include-

- Test vectors file : tests can be defined using a very simple macro language as shown in the Test Vector box on the left of the E-AutoTest screen dump. A single test vector defines an input applied to the program to be tested, the expected output from the program, messages to show if the result is correct or incorrect, and marking. The test vector file may contain many vectors.
- Student feedback : if the test vector file has been properly set up then the test results, as seen in the right hand box of the screen dump, should contain valuable feedback as to where the student went right and wrong.
- Email to students : a directory of email messages is created with one email per student. The email contains the text seen in the results box on the right hand side of E-AutoTest. Email files can be sent to students automatically via sendmail from a UNIX host.
- One or all student files can be tested. If all student files are tested then marks are collated into CSV files that can be loaded into any spreadsheet thus saving administrative effort and reducing the chance of transcription errors.
- Marks collation is done in three different ways - on a student number basis, on a test by test basis for the whole class, and on a category by category basis for the whole class. Categories join several tests that have a common theme, for example several tests may check the program's ability to cope with parameter errors such as missing or corrupted

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input parameters.
The test by test and category statistics are extremely useful in generating class discussion about the thoroughness of the test and their own programming. The CSV files can be loaded into a spreadsheet to create graphs or other visual representations. Class discussions driven by such graphs will raise the profile and expectations of testing in the student's mind.

- Better result, lower cost : the use of E-AutoTest will result in a much better educational outcome with far less labour. The main labour requirement is to define the test vectors; the rest is largely automatic.
- Flexible : the test vector file can call any command line program. This makes it possible to use external programs to operate on and evaluate the student program and files created by the student program. Examples include plagiarism detectors, code coverage analysers, and code readability auditors.
- Robust : students may accidentally or intentionally submit a program that acts maliciously. For example a program may hang up, a program may attempt to delete files, or a program may attempt to take control of the computer. E-AutoTest can protect against these attacks providing the operating system provides some degree of access control.
- Multi-platform : E-AutoTest was developed using Qt Designer from Trolltech which allows the same code to be compiled for multiple platforms. The current version of E-AutoTest runs under Linux but a version that runs under Microsoft Windows should be available soon.

Key process and activities when using E-AutoTest include-

- Proforma to students : students should be given a proforma program that handles the basic student identification and shows how to handle input and output. This program may also contain the full instructions for the assignment thus negating the need for a separate assignment guide.
  Note : the instructions to students must be very well thought out with an eye to how students could misinterpret the instructions or make mistakes.
- Provide test vectors : some test vectors should be provided to give the student body some idea of what to think about. . From an educational and fairness perspective it must be made clear to students the nature of the testing tool and the type of things that will be tested.
- Competition versus copying : consider explaining to the students that the assignment has a competitive element. If a student develops a good test vector (that others student do not develop), and the lecturer uses it, then that student's own mark will be relatively higher. To this end explain to students they should keep their own test vectors secret from other students but Email them to the lecturer.
  This innovation will decrease copying, reduce the lecturer's labour effort, and improve the quality of the test vector used on the entire class!
- Lab test or assignment : E-AutoTest can be used on take home assignments or on laboratory tests.

Projects suited to E-AutoTest

At first glance a program such as E-AutoTest appears very limited in the type of projects it can examine. Simple things such as first year programming tasks leap to mind, for example reversing the letters in a word or correctly implementing shift operators. The automatic testing of these simple programs is actually very valuable, especially since these introductory subjects may have large numbers of students.

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Conceptually quite complex problems can be turned into command line programs that can be extensively tested using E-AutoTest. Examples include-

- Decision-making : some problems take input data and must evaluate that information using complex decision making.
  For example consider the triangle test : given 3 points in unsigned 16 bit, 2 dimensional integer space, determine whether the points define an equilateral triangle, and isosceles triangle, a scalene triangle, or no triangle at all. The are many errors that can be set for the students to detect. General categories include parameter errors including under and overflow, points at identical coordinates, and points in a straight line.
  The triangle test is not that difficult and a good warm up exercise. The test can be made more difficult by using 3 dimensional space, and even higher dimensions.
- Formula based : formula based problems can be tested. Examples include the design of microwave components, statistical problems, and electronic circuits. Different outputs can be requested given a mode parameter.
  ```
  test_1  A 1.5 2.3 4.4 7.8        # A means return standard deviation.
  test_1  B 1.5 2.3 4.4 7.8        # B means return average.
  ```
- Input stream : many engineering applications must process a stream of input data, often using a state machine. Examples include parsing lines of text, reading the head output from magnetic swipe cards, decoding RS232 style serial data, and the detection of telephony tones.
  Consider tone detection : the sampling of 1s and 0s from the tone detector hardware can be simulated with the student's program reading a string of dots and exclamation marks-
  ```
  detect_ring ...!!!...!!!.....................!!!...!!!...
  ```
- Simulation : the problem set is to simulate some real system and to produce the correct response to a given stimuli. Example problems include control theory, fuzzy and neural logic systems, and mechanical systems.

E-AutoTest Status

As of June 2004 the E-AutoTest program has been tested on a variety of student projects but not on a whole class. In semester 2 of 2004 it will be tested on a class group of 70 final year students with a variety of Linux programming tasks. If this proves successful E-AutoTest will be considered for use in earlier years.

In the longer term E-AutoTest may become a commercial product that will be only sold to lecture staff who work in an educational institution. It will come with a variety of problems complete with a comprehensive test vector file and skeleton code for the project that can be given to students. There may also be a free student version of E-AutoTest which has no class marking ability and can only handle a small number of test vectors.

Conclusions

Testing of software is lagging behind other areas of software technology such as code development. Part of the problem lies in the way software is taught and the resources that can be allocated to testing issues. The problem is compounded by an increasingly stringent financial environment that forces practical and project work to be sacrificed in order to keep within budgetary constraints.
The teaching of software testing skills can be enhanced by the thorough and complete testing of students' programs. Evaluation of student programs using human labour is too expensive. Evaluation using simple test scripts provides only a small reduction in effort because much of

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the labour costs are in the administrative and organisational activities associated with the testing of many students' code.
A solution proposed and implemented by this author is a program called E-AutoTest that specifically addresses the administrative and organisational issues. It will radically reduce labor costs and will be used on a live class group in semester 2 2004. Assuming the results are positive the product will be used in other subjects and may become commercial in 2005.

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Experiences in adapting and implementing NURAPID - a Student-centred skills development tool

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***Abstract**: At the AAEE conference in 2002, Williams and Sher (2002) described the adaptation of a web-based personal development tool, RAPID (an acronym for "**R**ecording **A**cademic, **P**rofessional and **I**ndividual **D**evelopment") at the University of Newcastle, NSW. This paper briefly revisits the rationale underpinning the initial development of the tool in the UK and describes developments both abroad and at the University of Newcastle. RAPID offers students a means of auditing and recording their skills. It also enables students to engage in a process of planning the development of skill competence and acquisition and to reflect upon the strategies adopted and the outcomes achieved. The paper reports on the development of new versions of RAPID and describes collaborative work which has resulted in an Australian variant, NURAPID (the original system adapted and implemented at the University of Newcastle). The paper also reports on the evaluation strategies and outcomes of the UK and Australian versions of the system. In addition, the authors address the role of Professional Institutions in the UK in moving these processes forward and in ensuring the sustainability of the benefits derived.*

***Keywords**: Skills, Competencies, Professional Institutions*

Introduction

Over the past six years, the Department of Civil and BuildingEngineering at Loughborough University, UK, has obtained government funding to encourage a lifelong perspective on personal and professional development. The first two-year project, funded by the *Department for Education and Employment*, was a partnership between the University and the Chartered Institute of Building (CIOB). This project sought to promote a culture to enable and support students and graduates to monitor, build and reflect upon their own personal development within the construction discipline. It also aimed to introduce students to the professional development process at an early stage by encouraging them to build, maintain and develop a 'record of achievement' compatible with the CIOB's Professional Development Programme (PDP) (Maddocks, Sher and Wilson, 2000). The second three-year project, funded by the *Fund for the Development for Teaching and Learning*, extended the processes and precedents set in the initial project to other Professional Institutions. This has resulted in eight different versions of the web-based RAPID Progress File (http://rapid.lboro.ac.uk/) which service the disciplines of: Architectural Technology, Construction Management Engineering, Civil Engineering, Construction Management (the original version), Quantity / Construction

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Management Surveying, and Town Planning. The remaining two versions have been developed for students in the discipline of Transport Management, and for graduates engaged in Loughborough's Graduate Professional Development Award. In addition, work is currently in progress at the University of Newcastle, Australia, to adapt and develop versions of RAPID suitable to several disciplines, in the Australian context, and these developments are reported later in this paper.

The web-based RAPID Progress File is used both as a learning tool (inducting students in the processes of self-assessment, action planning, reflection, and evidence gathering), and as a support mechanism (recording achievement, construction management an electronic curriculum vitae, identifying individual strengths and weaknesses, and directing students to appropriate support services). By using RAPID the authors offer students engaging and accessible opportunities to continue their professional development, reflection and life-long learning.

Since 2001 over 2000 students have been inducted in the use of RAPID in twelve UK Higher Education Institutions. The Institutions involved and the versions employed are shown in Table 1.

HE Institution	Number	Versions used
Loughborough University	5	CE, CM, GPDA, Q/BS,TM
Anglia Polytechnic University	4	AT, CE, CM, Q/BS
Bolton Institute	5	AT, BE, CE, CM, Q/BS
Coventry University	4	AT, CE, CM, Q/BS
Kingston University	2	CE, CM
Liverpool John Moores Uni'	5	AT, CE, CM, Q/BS, TP
UMIST	3	CE, CM, Q/BS
Uni' of Central England	3	AT, Q/BS, TP
University of Greenwich	1	CE
University of Manchester	1	TP
University of Sheffield	1	CE
Uni' of the West of England	5	AT, CE, CM, Q/BS, TP

Note:

Version: Code	Version: Title
AT	Architectural Technology
BE	Construction Management Engineering
CE	Civil Engineering
CM	Construction Management
GPDA	Graduate Professional Development Award
Q/BS	Quantity / Construction Management Surveying
TM	Transport Management
TP	Town Planning

Table 1: Versions of RAPID used in UK Higher Education Institutions

The RAPID Progress File

This system enables registered users to record their achievements, and to audit and develop skills appropriate to their professional development. It has two main components: PACE and SPEED.

PACE acts as a 'record of achievement'. In this area students store personal details, records of their achievements (including both qualifications and extra-curricular achievements), a

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summary of relevant work experiences and a 'personal statement'. These data may be downloaded and used within Curriculum Vitae (CV).

The SPEED contains up to sixty separate skills compatible with the professional competence requirements of the respective Professional Institution. These skills are divided into:

- Key skills (based on Qualifications and Curriculum Authority [QCA] Key skills),
- Personal and Professional skills (based on generic graduate and management competencies), and
- Technical skills (based on discipline specific competence requirements).

Each skill is presented in the same format. This template offers students four statements of competence in that skill. These statements range from a fairly low level of competence in the skill to a fairly high level of competence. In addition to the four statements each student is required to record evidence to support the claim of competence that he/she makes.

Students are encouraged to audit a broad range of their skills to help them assess their strengths and weaknesses prior to engaging in the SPEED skill development process. This audit (represented in Table 2) involves action planning, reviewing and reflecting upon activity undertaken and documenting evidence of competence gained. Exemplars, guidance, defined skills levels and their descriptors are provided to help support students with these activities. In particular, advice is provided on skills auditing, action planning, reviewing, evaluating, and reflecting upon actions taken and processes engaged in. The importance of documenting valid, current, authentic and sufficient evidence is highlighted.

STAGES	ACTIVITIES INVOLVED
Survey	a) Skills Audit b) Identify skill development needs c) Search for skill development opportunities
Plan	a) Set skill development goals b) Identify appropriate tasks c) Produce action plan
Execute	a) Carry out development activities b) Monitor progress c) Revise activities, as required
Evaluate	a) Review outcomes of skills development process b) Evaluate effectiveness of the process c) Reflect upon learning experience
Document	a) Record development of skill competence b) Store evidence of skill competence

Table 2: The SPEED skill audit / development cycle

Implementation of RAPID

RAPID has been employed by over 2000 students in 12 Higher Education Institutions (see Table 1) in the UK over the last three academic years. The nature of this implementation, and the contexts within which RAPID has been implemented, has varied from institution to institution. In general, four separate approaches have been adopted. These approaches have been adopted with varying degrees of success. An example of each approach is summarised in Table 3.

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Example	Implementation method	Evaluations
Embedding within existing practice	The use of RAPID is incorporated within existing module to help create a CV. In addition RAPID is used on selected pieces of coursework to encourage students to reflect upon the development of certain skills. Students use RAPID to help plan, record and report upon their work-placements	Students, in general, appreciate the option of creating and maintaining a CV / Record of Achievement through the electronic medium. Most students recognise the benefits of auditing and developing their skills
Used as discrete activity within module / unit	Students use RAPID to help create a 'learning journal'. In addition, they report on their skill development / future plans on the basis of their RAPID record, which becomes a requirement for progression	Students happy to use the system. Staff support / satisfaction higher than expected. Students recognise the need to evidence their skill competence
Supporting project-based learning	Students are set paper-based exercises based on RAPID to help articulate skills developed through project-based activities. Use of RAPID is voluntary	Voluntary nature has led to a patchy uptake by students. It has worked well with those who are sufficiently motivated and/or fully recognise the benefits
Portfolio for Work-based learning	Used with full and part-time students to record and assess work-based learning. Assessment framework established on the basis of skill development recorded	Has provided students with a means to have work-based learning accredited. Positive feedback from both students and staff

Table 3: Examples of different approaches/contexts in implementing RAPID

Extending RAPID to the Australian Context

The University of Newcastle, NSW (NU) has now extensively adapted and developed RAPID under licence. Internal University funding (obtained through competitive grant) facilitated trial implementations of the system within the disciplines of Construction Management, Education and Nursing for a year. This period ended in January 2003, and the system has now moved from trial status to one that is adopted and supported by the University. To date, mainstream users remain the disciplines of Construction Management, Education and Nursing but other disciplines within the Faculty of Engineering are progressing toward implementation during 2004.

The initial implementations used the University's "Core Skills" as a framework for the descriptors. Stakeholder interest in the attainment of these skills is recognised as critical and thirteen 'core skills' (shown in RAPID format in Table 4) have been defined as those which all NU students need to attain during their time at university. These skills aligned closely with the professional skills of the participating disciplines, this was evidenced in the Institution of Engineers accreditation process in 2003 where the University Core Skills were mapped against the Institution's defined "Graduate Attributes". Consequently, NURAPID (Newcastle University RAPID) uses two skills categories, (*core* and *discipline*) rather that the two used with RAPID (*key* and *personal and professional*).

In a similar manner to UK implementations, NURAPID allows students to track their progress in developing these and other discipline specific skills during their undergraduate university career.

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1	**Operate effectively with comprehensive and well-founded knowledge, skills and ethical standards appropriate to their fields of study.**
1.1	Managing and applying knowledge
1.2	Knowledge of Discipline and current affairs
1.3	Reading and responding to written material
1.4	Skills of the Discipline
1.5	Ethical Standards of the Discipline
2	**Acquire, organise and present information.**
2.1	Acquiring information
2.2	Organising information
2.3	Producing written material
2.4	Making presentations
3	**Reflect on and continue to develop their knowledge, skills & attitudes.**
3.1	Reflecting
3.2	Working towards identified targets
3.3	Managing personal development
4	**Think logically, laterally, critically and creatively; analyse and synthesise.**
4.1	Critical reasoning
4.2	Conceptualising ideas
4.3	Applying creativity
5	**Act effectively in decision-making and problem solving.**
5.1	Investigating problems
5.2	Solving problems
6	**Carry out research activities.**
6.1	Utilising appropriate investigative and research methods
7	**Communicate effectively as members of their communities.**
7.1	Methods of documenting and reporting on my work and knowledge
7.2	Methods of communicating ideas and concepts
7.3	Taking part in discussions meetings
8	**Work autonomously and collaboratively.**
8.1	Managing time effectively
8.2	Planning activities with others
8.3	Team-construction managment
9	**Utilise information technology appropriately and competently.**
9.1	Using Information Technology
10	**Seek improvement in organisational, social and cultural contexts, in an ethical manner.**
10.1	Negotiating
10.2	Persuading/motivating others
10.3	Ethical responsibilities
11	**Recognise social, cultural, physical and intellectual diversity, including the history and diversity of Australian indigenous peoples.**
11.1	Recognition of social, cultural, physical and intellectual diversity, including Australian indigenous peoples.
12	**Recognise and respond appropriately to globalisation and other changes of context.**
12.1	Responding to globalisation and other changes of context
13	**Recognise human impact on the environment, and its implications for environmental sustainability.**
13.1	Managing environmental issues and considerations

Table 4: The 'core skills' of students at the University of Newcastle

Implementation in disciplines

In 2002, the discipline of Construction management introduced NURAPID to first year students on the Bachelor of Construction Management (Construction management) program. The students used the system to support the development of their skills. NURAPID was used to underpin students' *self-assessments* and *reflective journals,* practices which form integral elements of their formative and summative assessment. During 2003, more widespread use was made of NURAPID. Second and final year students used the system as a framework for recording the development of their skills and their reflections. They submitted their *reflective self-assessments* electronically, using the system.

In the discipline of Education, the School of Education sees considerable merit in using the tools and framework provided by NURAPID to assist pre-service teachers in the development and recording of skills. Full implementation will not be considered until the teacher

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competency profile currently being developed by the New South Wales Board of Education, is published. This framework will then be incorporated into NURAPID.

In the discipline of Nursing, NURAPID was introduced to first year students in the Bachelor of Nursing program at the Gosford Hospital campus in Semester Two, 2002 and to first year students at Callaghan campus in Semester One 2003. Progressively NURAPID will be used to enable students to maintain a 'Clinical Portfolio' throughout the three years of their program. The Australian Nursing Council Inc. (ANCI) *Competency Standards for the Registered Nurse* have been included in NURAPID as a separate set 'discipline specific' skills.

Evaluation of NURAPID (in Australia)

A baseline questionnaire was developed in conjunction with Newcastle University Survey and Evaluation Services and has been delivered to the first and final year cohorts of the Construction Management program. This provides baseline data on which future comparisons may be made. The questionnaire elicits undergraduate student views on core skills, skills development, mechanisms for promoting skills development and recording of accomplishments. A complementary survey has also been administered to teaching staff (Sharkey, Williams and Sher, 2003).

The data obtained will provide a baseline of student and staff perceptions before they engage with NURAPID, and will also provide an eventual comparison between different cohorts of students (e.g. current final years with no experience of NURAPID compared to students who graduate having had opportunities to use the system throughout their academic careers). In addition they will underpin further development of the system, and will provide University management at NU with evidence of the efficacy of the system.

The surveys provided a great deal of information concerning the students understanding of the professional skills and the importance of their development whilst studying at University. Both groups of students when responding to the survey question relating to the importance of The University's Core Skills rated them as very high, with 90% of those surveyed stating that they were important or extremely important. Of interest was the high percentage of students in their first year that had heard of the skill profile and knew what the skills were, 80%. The student's acknowledged the importance of relating their learning to professional attributes.

The NURAPID system's value to the students was also evaluated in the survey. The survey included three questions concerning the value of the system, these questions were:
What value do you see in a system that allows you to:

a) Compare your skills to those required by professionals in your discipline?
b) Record your progress and achievements?
c) Plan to improve your skills?

The results of the survey were very supportive of the system which supported their professional development. The results are documented in the following diagrams.

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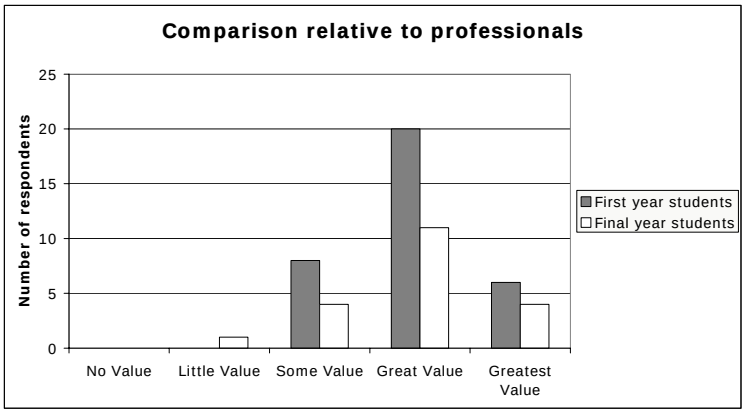


Figure 1: Importance of comparing performance to professional standards

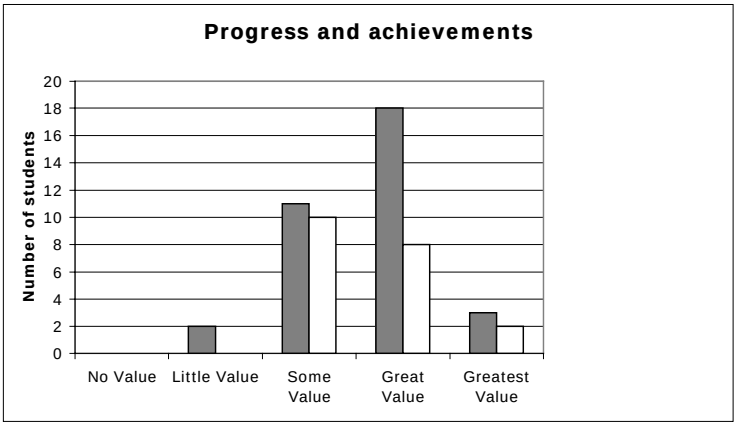


Figure 2: The importance of recording their achievements

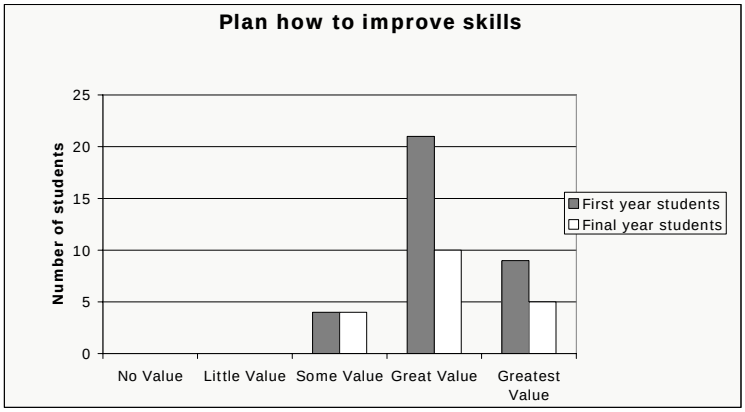


Figure 3: Did the system help planning learning

As indicated in the results of the survey, the students appreciated the role the system would provide in the students appreciation of and documentation of their professional attributes. Since the survey the system has been utilised, in the Construction Management Program, in the support of students in reflective practice. The students are able to reflect on their practice in terms of professional attribute definitions.

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The role of the professional institutions

Each version of NURAPID has been developed with the assistance of the Professional Institutions and their role in defining the attributes of the profession. The process of taking these attributes and expressing them in terms the students relate to and the development of the hierarchy of descriptors in each level provides the framework student need to effectively relate their learning to their future profession.

At the University of Newcastle review of Engineering Programs Engineers Australia acknowledged the potential value of the NURAPID system to students. The Faculty is now progressing the development of the system to align with the Graduate Attributes of Engineers Australia and the Australian Computer Society to the respective programs.

At the conclusion of the next phase of development the system will be able to provide direct support to students involved in Engineering and Computer Science in relating their learning to professional attributes.

Within the Nursing component of the project the system is now being applied to the Graduate Nursing Program at the John Hunter Hospital. Nurses in their first year of practice following graduation are required to demonstrate the acquisition of or demonstration of a range of skills. The NURAPID system is being trialled as a means of supporting the documentation and reporting of the attainment of these proficiencies. There has been a research project running parallel to this initiative to evaluate the effectiveness of the system and to identify potential improvements. This research will in turn support the development of the Engineering and Computing versions of the system.

Conclusion

Based on evaluations received from students and tutors engaged in the implementation of the RAPID Progress File, the authors are confident that it has the potential to meet the needs of both students and the Higher Education community. RAPID offers students a tool that will let them engage in a process of skill development and evidence gathering that will facilitate their future professional development.

For the Higher Education community, RAPID offers a means of meeting requirements to provide students with ways to engage in PDP. RAPID has shown itself to be adaptable and flexible. It is robust in that it meets the needs of a range of stakeholders. It is adaptable in that it can be used to support both learning and teaching in a variety of contexts. Furthermore, it is flexible in that it can be transferred both across disciplines and academic cultures. The evidence is that RAPID provides solutions to many of the challenges that the authors as educators in Higher Education face.

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Transition to Engineering mathematics: issues and solutions

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Abstract: *First year at university is universally accepted to be problematic for all students but is especially the case for students commencing studies of engineering mathematics, a subject which is strongly hierarchical in nature. Today, more than ever before, students enter engineering studies with a vast diversity in mathematical backgrounds, beliefs and study experiences. A single course must address the needs of students immersed in diverse disciplines of varying levels, from different educational backgrounds and with a diversity of beliefs and attitudes towards mathematics. It is also required to assist students to develop effective time management and study skills suited to the university culture of learning. These challenges are even more extreme when such courses are offered in multi-mode format (on-campus and by distance education). This paper describes the curriculum design of a foundation mathematics course, which currently integrates self-paced skill-based materials, authentic problem solving activities and generic study skills into a unified flexible curriculum. The course is characterized by its ability to manage groups of students with different levels of mathematical preparation, the introduction of authentic group problem solving (for on-campus and distance education students) and the development of mathematical communication skills in first year students.*

Keywords*: transition, engineering mathematics, first year*

Introduction

Today it is generally accepted that the first year at university is problematic (McInnis 2001). Students often have an uncertain start with many of them indicating that they were not well prepared, were unmotivated to study and did not get satisfaction from their participation in study (McInnis, James, and Hartley 2000). Others face personal adjustment issues. Kantanis (2000) in a survey of on-campus students found that by the end of first year only 50% had established a friendship group. Many others appear unable to negotiate the new culture that is presented to them at university. Lawrence (2002) in a discussion of the critical competencies necessary for success stated that pivotal to a student's success is the use of specific socio-

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cultural competencies, such as seeking help, participating in a team, making social contact, seeking and giving feedback, expressing disagreement and refusing a request.

Compounding this situation is the predicament of service courses, particularly the mathematics service course for engineering. In these cases a single course is expected to address the needs of students immersed in diverse disciplines at varying levels, from different educational backgrounds and with a diversity of beliefs and attitudes towards mathematics. The occurrence of this type of uneven preparedness is reported widely within commencing engineering students (Croft and Ward, 2001; Coutis, Cuthbert and MacGillivray, 2002; Taylor and Mander, 2002). However, increasing evidence indicates that students are also having difficulties coming to terms with how to study in the university mathematics environment (Taylor and Mander 2003). Nunn, MacDonald and Lowen (1992) after interviewing adult students, held that it may take months for them to organise themselves and their work to get the most out of study. Cerrito and Levi (1999) found that students in a pre-calculus college course were not spending sufficient time studying, while Anthony, (2000) investigating the factors influencing first year students' success in mathematics, indicated they were unable to achieve their desired grades because of ineffective study skills.

Mathematics is the lynch pin of successful studies within engineering, yet the challenges facing those charged with teaching mathematics to first year engineering students are vast. A first year foundation mathematics course for engineering students should:

- develop mathematics skills that are transferable to diverse disciplines;
- cater for uneven preparedness in a subject in which knowledge is hierarchical;
- develop self management skills for success in university study;
- address generic skills, especially those associated with problem solving, and communication, that are transferable to diverse disciplines; and
- build group cohesiveness and a sense of community.

Numerous solutions have been presented to some of these problems, the most recently detailed by Croft and Ward (2001), Coutis et al. (2002), Borges, Goncalves and Cunha (2003) and Fuller (2002). This paper proposes a curriculum design solution, that addresses all of the above issues, and which has been developed and trialled in a self-paced mathematics service course for on-campus and distance education students in a large regional multi-mode Australian university.

Background

The University of Southern Queensland (USQ) is a large regional Australian university which offers courses across 5 faculties in on-campus, distance education and online modes. It currently enrols approximately 25 000 students, 75% of whom study off campus from every state in Australia and overseas. The Foundation Mathematics service course has a long history at USQ. Originally it was designed as a self-paced refresher course for students who were unable to cope with the traditional algebra and calculus course offered at the commencement of a Bachelor of Engineering degree. Today, with the changing student profile and the expansion of engineering offerings to include Associate Degrees of Engineering and Surveying and Bachelor of Engineering Technology studies, it is a core course for all first year Engineering and Surveying students, independent of their level of study, as well as for students enrolled in Science and Information Technology courses. The differing pre-requisite entry requirements for these levels of Engineering studies mean that students can now be

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enrolled in Foundation Mathematics after having studied either the most general forms of school mathematics (Maths A in Queensland) or the more specific and formal (Maths B and C in Queensland). Approximately 30% of students have studied (not necessarily successfully) the lowest level of mathematics or equivalent at senior school with 70% having studied levels of mathematics which contain some calculus. On average students have been away from study for 5 years (range = 1- 20 years) and have tertiary entrance scores of 70 (standard deviation of 20) on a scale of 0 to 100, where 100 is the highest level. Table 1 displays the distribution of students by program of study.

Program of origin	**2002 (711 students)**	**2003 (706 students)**
Engineering and Surveying	**55 %**	**52%**
• B. Engineering	17%	16%
• B. Engineering Technology	18%	17%
• Associate Degrees	20%	20%
Sciences	9%	14%
Information Technology	20%	20%
Other programs	16%	14%

Table 1: Percentage (rounded) of students by program of study in 2002 and 2003

To manage this diversity in mathematical background and experience the course was merged with a bridging course. The new course can be taken by students over one or two semesters depending on their mathematics experience on entry to the course. Each student is assigned to one of three alternative entry points on the basis of performance in an entry test. Entry Point 1 requires the student to complete all the preparatory material before continuing on to the pre-existing Foundation Mathematics content. Entry Point 2 requires the student to begin halfway through the preparatory material, while Entry Point 3 students begin at the start of the pre-existing Foundation Mathematics material. On the basis of school results very able students are allowed to enter directly into the next mathematics course selecting an elective course to replace Foundation Mathematics in their program structure. Since 2001 the course curriculum has been developed in stages so that in 2004 it now includes the following components:

1. A series of mastery based modules, accompanied by lectures for on-campus students, that focus on the basic mathematical skills and content.
2. An overlay of self management and study strategies to assist students make the transition to university studies and to manage the flexibility embedded within this course.
3. A series of problem based group sessions/discussions.
4. A series of assessment strategies which include
   - production and maintenance of an action plan for study;
   - mastery tests to assess basic mathematical skills;
   - written assignments to assess problem solving in authentic situations and mathematical communication skills; and
   - a final examination.

Curriculum Design

The theoretical framework behind the course design has been described in Taylor and Mander (2002) and Taylor and Mohr (2001). The self-paced structure and the flexibility of three alternative entry points and pathways through the course allows students to work at their own pace developing confidence with mathematics and general problem solving skills appropriate

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to this level of mathematics. Figure 1 displays the sequence of events. The course objectives are that on successful completion of this course the student should be able to:

- demonstrate an understanding of a number of mathematical topics essential for tertiary study;
- demonstrate the skills necessary to extend mathematical knowledge beyond this course;
- interpret and solve a range of authentic problems involving mathematical concepts relevant to this course; and
- effectively communicate mathematical concepts and arguments.

Course Content

The content of the course is structured around three sets of materials contained in Study Books A, B and C (Table 2) and reinforced in the lectures for on-campus students. All students have access to the lecture notes through the course web site. Students studying through Entry Point 1 commence at the beginning of Study Book A and complete at the end of Study Book C by the end of semester 2. Students on Entry Point 3 complete topics in Study Book C by the end of semester 1.

Study Book A	Study Book B	Study Book C
Arithmetic operations	Fractions and indices	The metric system and scientific notation
Introductory algebra	Further algebra	Algebra
Introductory graphing	Simple functions and their graphs	Graphing of diverse functions
	Introductory exponential and logarithmic equations and functions	Exponential and logarithmic functions
	Basic trigonometry	Advanced trigonometry
		Matrices
		Introductory differential calculus
		Introductory integral calculus

Table 2: Summary of mathematical topics contained within each entry point set of materials.

The problem solving workshops are offered to on-campus students in a 2 hour tutorial time and to off-campus students through asynchronous online discussion groups offered through a WebCT platform. The workshops aim to

- develop mathematics skills, including mathematical communication and problem solving skills, under quasi-authentic situations;
- promote the usefulness and value of mathematics;
- address the attitudes of students to mathematics;
- introduce the nature of mathematical enquiry
- build group cohesiveness and a sense of community within the course; and
- provide a personal face to the assistance that is available within the course.

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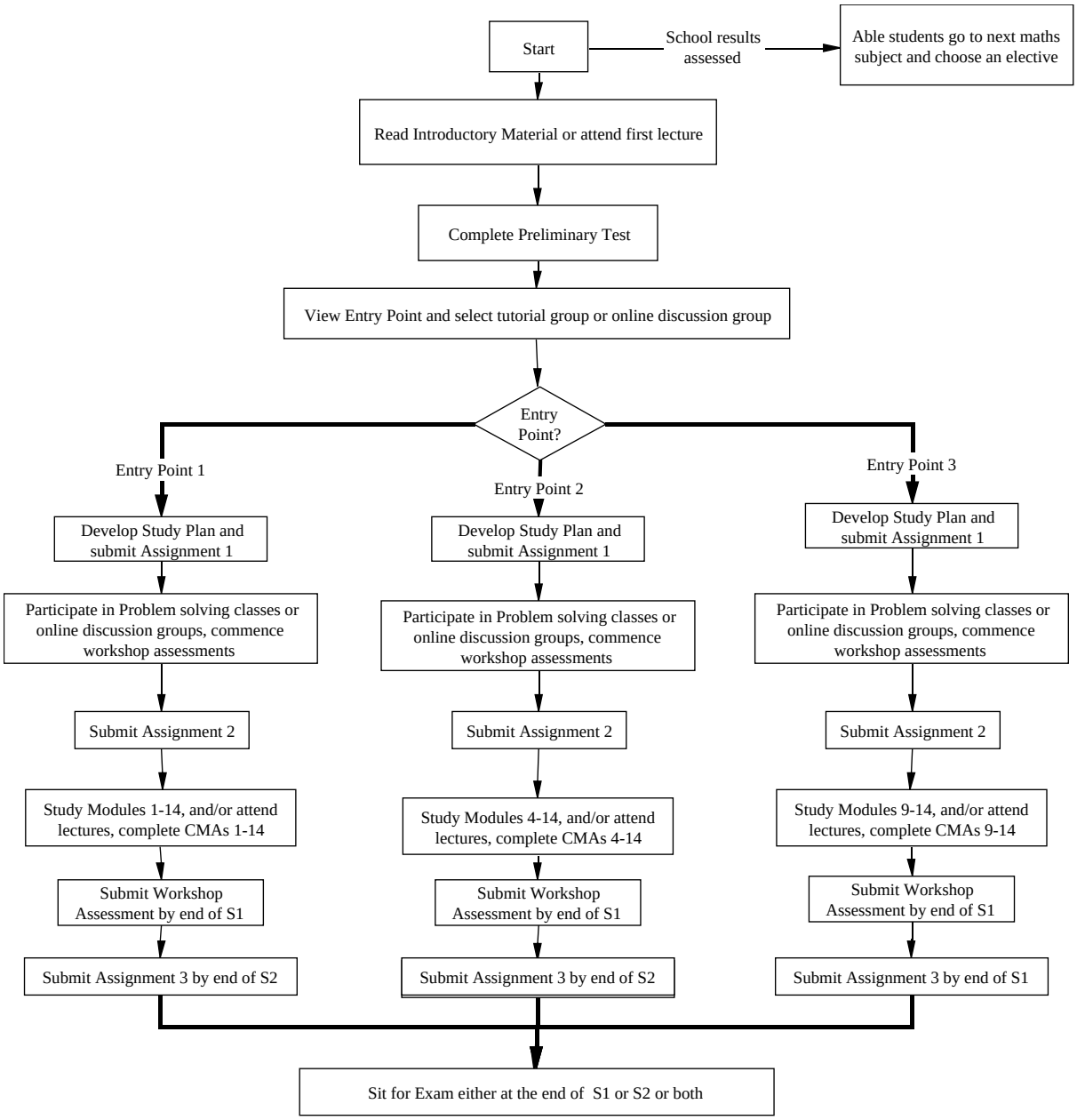


Figure 1: Summary of stages of the Foundation Mathematics course in 2004 (S1 refers to semester 1 and S2 to semester 2, CMA to Computer Managed Assessment)

Although on-campus students are given lectures these are not able to cover every detail of the topics of study. The text-based materials are the cornerstone of the course and are designed with novice students in mind. They are characterised by:

- the presence of informal language. All text materials are written in informal language with little mathematical jargon thus making them more accessible to novice students. Formal mathematical language is introduced at a slow pace.
- content that is presented in context and applied to events that many students may be expected to have encountered previously. Sections entitled "*A taste of ….*" are scattered throughout each module to include applications modified from their possible future university studies. At the end of each module is a section entitled "*Putting it all together…*" in which a number of sections within a module are linked in an authentic problem-based setting.

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- content and activities that are presented in manageable chunks grouped in small bursts to allow students to experience early success and to build confidence, knowledge and skills gradually. Most activities have fully worked solutions with problem solving prompts to guide students through the steps as appropriate.

The workshop sessions are designed to mimic authentic applied problem solving. Although students are allocated to workshop sessions on the basis of their entry points, the problems offered (one each week) are open ended and able to be solved using a range of methods by students with a variety of mathematical competencies, for example

> *A surveyor is part of an environmental impact team investigating the possible forestry development of two areas. Two regions are chosen, both running along existing creeks and roads. Do the regions have the same area?*

Students are provided with information on working in groups, the nature of problem solving using Polya's model (Polya, 1957) and how to communicate mathematics effectively. Students solve problems in groups and at the end of each session present a written report on the current problem.

Development of generic skills

Students' development of generic skills is addressed from the commencement of the course. Included in the introductory book is a module containing discussions of past students' experiences of mathematics and mathematics learning with suggestions about general study strategies and specific instructions on how to develop a study plan for this course. The introductory book also contains activities that force students to reflect on their current beliefs and attitudes towards mathematics and to develop a study plan for the semester, both of which are necessary activities for the first assignment due in week 2 of the course. These activities are resourced by sections of the materials called the 'Foundation Maths Toolbox' which contains readings on 'How to study maths successfully', 'Producing a study plan', 'Working through the study materials', 'Assignment Guidelines', 'Maths communication guidelines' and exemplar assignments.

The development of generic study skills is reinforced throughout the print materials, where small study skills tips called 'Hints for success' are included as needed. Students are asked again to reflect on their progress through the course in week 8 within the body of the second assignment. Specific details of this are reported elsewhere (Taylor and Mander, 2003)

Assessment

Assessments for the course are an important part of the curriculum design to ensure students' participation in all activities.

Assignment 1

This assignment is compulsory and is completed in week 2 and ensures students reflect on their past mathematical performance as well as produce a study plan for the future. This plan includes the dates for the assessment tasks for Foundation Mathematics as well as all other enrolled courses. This assignment is designed to ensure that students face and reflect upon their past mathematical experiences and prepare a plan for study for the next semester.

Assignment 2

This assignment is completed in week 6 by all students and includes a reflection on their current progress and a written report on a given mathematically-based problem. This assignment is designed to develop mathematical communication and problem solving skills and contributes 10% to their final grade. Students must communicate their solution to the

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problem using communication guidelines practised in on-campus workshops or online discussions.

Computer Managed Assessment (CMA)

Students' knowledge of the study material is self-assessed by students using a series of computer marked quizzes. Students have access to multiple alternative quizzes so that they can achieve mastery before progressing to the next module. Students are offered 5 quizzes for each module but need only to get 50% on one quiz to be deemed to have passed that module. Students may choose to attempt different versions of a quiz a second or third time, if they wish to improve their score and show mastery of the topic. All students must complete a series of quizzes relevant to their entry point (see Figure 1). Quizzes are completed online at times determined by each student and reported in their study plan in assignment 1. The onus is on the student to keep to this plan, although specific requirements are set for students wanting to be awarded a final grade or to continue into semester 2. Overall the quizzes contribute to 6% of the final grade.

Assignment 3

This assignment is another written report on a given mathematically-based problem and is attempted either at the end of semester 1 or at the end of semester 2 dependent upon the student's entry point. It is a complex assignment which usually requires students to be near completion of the study materials and to have an understanding of introductory calculus. This assignment is designed to further develop mathematical communication and problem solving skills and contributes to 20% of the final grade.

Workshop submission

Students are presented with 9 workshop problems throughout semester 1. On-campus students are required to participate from week 2 in group-based face-to-face problem solving sessions where they write up the problem according to a given template. Distance education students participate in asynchronous online discussions of the same problems. Proof of participation in the form of a printout of online postings is submitted at the end of semester 1. This component contributes to 4% of the final grade.

Examination

A 3 hour open book exam contributes to the remaining 60% of the grade for this course. Students are provided with written advice on how to succeed in an open book exam, and with on-campus workshops and online synchronous chat sessions on examination technique.

Student views

Although a formal evaluation of this course has not as yet been completed, the results and responses of students have been positive. Initially when the entrance to engineering was expanded by reducing the entry requirements into some programs, the pass rates for the on-campus students were 50%. In 2001, the year the planning assignment was first introduced, the pass rates for Entry Point 1 and 2 students doubled, raising the overall pass rate by 5 percentage points. In 2003 the pass rate for on-campus students studying the course was 70%. Comments from students in the university wide student evaluation of teaching indicate that students are well pleased with the structure of the course.

> *It is by far the best course I've come across because of its flexibility, concern for time management, help available and on-line quizzes and discussion groups. A great balanced package.*

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The setting out of material is excellent. Worked answers to activity questions are very good. I enjoyed the topic on Matrices. What about Vectors? The 'Hints for Success' and 'CMA Test' are very good.

Clear practical explanations, worked solutions, very few mistakes in Study Book. No prior knowledge assumed, exercises, examples explored most things adequately. I felt neither lost, nor bored with the complexity of the work. Good revision throughout.

As part of another study undertaken in 2002, 212 students responded to a survey (Table 3) in which they were asked specific questions about the structure of the course. 93% of students agreed that they believed that the structure of the course would assist them to be successful.

Survey Questions	**% of students not in disagreement**
The structure of the course, which allows for students to study one of 3 entry points will help me to succeed in the course.	93%
Information about the structure of the course was communicated clearly.	86%
The self-paced nature of the course is well suited to my way of studying and learning	72%
The study materials are clear and easy to understand	87%
The workshop/discussion group activities have helped me with the study of mathematics	62%
The computer testing helps me assess my skills in mathematics	76%
I am using my study plan developed in Assignment 1	69%

Table 3: Percentage of students who did not disagree with the statements given in the survey (212 were sampled which was 32% of the total cohort in 2002)

In that survey 69% of students indicated that they were using Assignment 1 to assist in their time management of the workload. Informal comments from students indicate that although orientation activities suggest they view course specifications and compile study plans, few actually do it unless they are required to complete a task as part of a formal assessment item. One student commented that;

It made me realize how much stuff's actually due, and when they're due, and how busy it's going to be.

The move away from traditional tutorials to problem solving tutorials is not usual in skills development courses, but 62% of students indicated that the workshops helped with their study of mathematics. Attendance at these tutorials is now high (approximately 80%) and above average when compared with other engineering tutorial based courses. Students have made the following comments.

I really liked the way I could come into a workshop understanding very little and leave understanding everything

Discussion groups and assignments have real-life applications, not just theory and equations.

The group discussion during tutorial. It allows me to understand better.

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Conclusion

The multiplicity of needs of first year students in engineering mathematics courses means that these courses must extend beyond the traditional requirement to develop transferable mathematical skills to a wider framework that ensures that other skills (communication, problem solving, team work, effective time management and study skills) are explicitly addressed and developed. Traditional instructional models used in Higher Education are not flexible enough to cope with these demands. This paper presents a flexible curriculum design alternative that has proven practical and successful in a very large first year course offered in a multi-mode situation.

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What do engineers want?

Examining engineering education through Bloom's taxonomy

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Abstract: *Using Bloom's taxonomy as the basis for an empirical investigation, this paper examines what engineering students and professionals want from engineering education. Fifty engineering students, from Computer Science and Information Technology courses, were asked to rank activity verbs in order of their impression about frequency of their occurrence in their assignments and examinations. Another group of sixteen students was asked to rank activity verbs as per their learning effectiveness. Thirteen professional Engineers were also asked to assign ranking to activity verbs in order of their perceived importance. A set of fifteen examination papers were then scrutinised for the usage of these activity verbs.*

Data analysis revealed that there is high correlation between students' impression and examination papers. It also demonstrated that there is high correlation between what engineering students and professionals want. However, a negative correlation was discovered between what students and professional engineers want and the activity verbs used in evaluative and non-evaluative tasks. Other established criterion for imparting good engineering education, such as the guidelines provided by ABET (Accreditation Board for Engineering and Technology) are discussed in light of the findings of this study. We conclude that, to foster creativity, critical thinking and innovative problem solving amongst engineering students we need to develop flexible curricula that aim to engage the students in higher-level cognitive activities. Changing the verb set used by engineering educators can be employed as a catalyst to facilitate this strategic transformation in engineering curriculum.

Keywords*: Active learning, Activity verbs, Bloom's taxonomy, Engineering education, Higher order learning.*

Introduction

Many economies worldwide are rapidly advancing from the traditional industrial base and embracing a shift to information and / or service base. This shift often entails solving open ended and multi-disciplinary problems. Such real-world problems typically involve an overlay of

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technological and social imperatives. This demands a significant shift towards higher-order learning in university education, in general, and Engineering education in particular. This shift has been predicated by education researchers including Fennimore and Tinzmann (1990), who suggest that, "Changes in society itself require higher-order learning". Traditional courses, even in applied disciplines like engineering, emphasise topics over process. Goel (2003) argues that curriculum is often interpreted as fixed course structure and course content. Educational goals are considered to be achieved by giving the answers, or, at best, the ability to find answers. Training students to seek right questions is not on the agenda of teacher centric (or even worse, text book centric) standard courses.

The role of experience in the creation of knowledge is grossly under estimated, and learning is interpreted as knowledge acquisition rather than knowledge construction. Schank (1995) states that conventional teaching methods involving only lectures, and problem set format, neither promote creativity nor do they develop the independent thought processes that are desired in the future endeavours of students in the real world. Other authors (e.g. Felder (1988), Suresh Kumar (2001) and Kolodner (1995)) have also expressed similar thoughts. There are comments in the literature (e.g. Bruner (1996) and Fennimore and Tinzmann (1990)) that these methods are based on impoverished conception that a course provides a learning experience in which an omniscient teacher explicitly tells or shows presumably unknowing learners something they presumably know nothing about.

Standard courses for engineering students generally aim to impart a predefined and fixed amount of established knowledge, concepts, and skills; and do not emphasise exploration, imagination, and creativity. Such a format is unsuitable for a self-directed and discovery oriented learner. Repeated learning experience in this format makes many creative and discovery oriented students disinterested in the course, forcing resigned conversion to dependant and passive learners.

Thus, there is an urgent need to transform engineering curricula to a more flexible format that engenders creative learning. Our aim is to involve current and past students in developing the agenda for this transformation. Goel (2004) reports the findings of an initial comparative study of engineering students and working professionals.

This paper reports the outcomes of the continued comparative study of the students' impression of their experience as a learner, with perceptions of professional engineers on what do they want from a course in an engineering discipline. This study uses Bloom's taxonomy of cognitive processes as the basis for investigating learning outcomes. Association of the various Bloom's levels with activity verbs was used as the instrument to get feedback from the participants of the study.

Bloom's Taxonomy

Benjamin Bloom (1956) classified the cognitive process into six major levels arranged in a hierarchical order. Beginning with the simplest level and increasing in complexity, the cognitive levels are: Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. Several authors (e.g. Krumme (2002) and TALS (1998)) have given a summary and commentary on his work.

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The simplest level 'Knowledge' exhibits previously learned material by recalling facts, terms, basic concepts and answers. The 'Comprehension' level demonstrates understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions and stating main ideas. 'Application' is about solving problems by applying acquired knowledge, facts, techniques and rules in a different way.

'Analysis' represents the act of examining and breaking information into parts by identifying motives or causes; making inferences and finding evidence to support generalizations. 'Synthesis' aims at compiling information in different ways by combining elements in new patterns or proposing alternative solutions. 'Evaluation' is about presenting and defending opinions by making judgments about information, validity of ideas or quality of work based on a set of criteria.

The last three levels are considered to represent higher-level cognitive activities that require and develop mental faculties of creativity, critical thinking and innovative problem solving. This paper reports a quantitative analysis of activities formally assigned to engineering students using this taxonomy as a metric.

What do engineers want?

The main aim of this study was to understand the degree to which the formal components of traditional teaching-learning-evaluation process in engineering education succeed in creating opportunities for enhancing higher-order thinking skills through practice.

Activity Verbs for Bloom's Cognitive Levels

Several authors (Bloom (1956), Krumme (2002) and TALS (1998), have reported mappings of activity verbs to different Bloom levels. Existing Bloom-level-to-activity-verb-lists mappings were extended to include the verbs that were not found in the current literature. Following mapping was used in this research.

Level 1 - Knowledge: acquire, cite, define (studied definitions), derive, fill in the blanks, identify, label, list, name, obtain, prove (studied theorem, studied method), recall, recite, recognise, reproduce, show (studied fact, studied method), and state.

Level 2 - Comprehension: arrange, associate, categorize, change, clarify, classify, compare, convert, describe, discuss, distinguish, draw, exemplify, explain, illustrate, interpret, match, outline, rephrase, represent, restructure, rewrite, sort, summarize, tell, and translate.

Level 3 - Application: apply, calculate, compute, demonstrate, determine, estimate, evaluate (computation), experiment, find, practice, show (understanding fact in the direct context of studied material), solve, and transform.

Level 4 - Analysis: analyze, conclude, contrast, debug, deduce, detect, differentiate, discriminate, examine, extend, extrapolate, generalize, infer, justify, point out, predict, rearrange, select, specify, test, and verify.

Level 5 - Synthesis: build, combine, comment, compose, constitute, construct, correlate, create, define (new things), design, develop, devise, document, formulate, implement, integrate, modify,

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organize, plan, prepare, present, produce, propose, prove (unstudied things), reorganize, report, revise, schedule, sketch, and synthesize.

Level 6 - Evaluation: appraise, argue, assess, decide, evaluate (the options), judge, question, review, revisit, standardize, validate, value, and weigh.

A survey was conducted amongst two groups of engineering students and professional engineers. These three groups were requested to respond to three different but complimentary questions around a unified and alphabetically sorted list of activity verbs. The first group of about fifty 2nd year Computer Science and Information Technology students was asked to select and individually rank the identified verbs based on the frequency of their usage in teaching-learning-evaluation process. A second group of sixteen students was asked to rank the verbs according the learning effectiveness of the verb. Thirteen professional engineers were requested to select and rank 10-15 verbs, that if used more often by the faculty, will help in better preparing the students for professional life.

Their responses were collated into three different groups, and a group rating was calculated for every verb. A combined rating of group perception about a verb was statistically extracted from individual ranks: where a large numerical value of the combined rating by the first group of students would imply a perception of high usage of that verb, and a smaller numerical value would imply infrequent or zero usage. A high numerical value for the combined rating assigned by the second group of students would imply that most of them learn more when that verb is used to communicate the activity for evaluative or non-evaluative tasks, and a small numerical value would imply that few or none of them experience effective learning when that verb is used. Similarly, a high numerical value for the combined rating assigned by professional engineers' would imply that most of them want the verb to be used often, and a small numerical value would imply that few or none of them recommend it to become or continue as a commonly used verb in administering evaluative or non-evaluative tasks.

Table 1 gives a sample of the data extracted from the respondent feedback. Respondents assigned contiguous natural numbers starting from 1 without any upper limit as ranks to the verbs of their choice. Some chose to give a unique rank to every verb thereby assigning ranks in the range of 1 to around 50. Many chose to give a common rank to many verbs in the range of 1 to around 10. They had the freedom of not assigning any rank to some verbs. A lower numerical value implies higher ranking, 1 being the highest rank. A student respondent from the first group of 50 students assigned the rank of 1 to verb(s) that (s)he felt are most often used by the faculty. On the other hand students from the second group of 16 students assigned the rank of 1 to the verb(s) that they consider to facilitate maximum learning and professional engineers assigned the rank of 1 to the verb(s) that they felt should be used most often by the faculty.

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Activity Verb (j =1 to 128)	**Bloom Cognitive level (i =1 to 6)**	$Rank_{kj}$ by first group of Students as per the verb usage (k = 1 to 50) Blank entries indicate that k^{th} respondent did not give any rank to j^{th} verb **[What students think they get]**						$Rank'_{kj}$ by second group of students as per verb's learning effectiveness (k=1 to 16) Blank entries indicate that k^{th} respondent did not give any rank to j^{th} verb **[What students think works well for them]**					$Rank''_{kj}$ by Professional Engineers as per their recommendation (k=1 to 13) Blank entries indicate that k^{th} respondent did not give any rank to j^{th} verb **[What professional engineers recommend]**				
		1	2	3	4	.	50	1	2	3	..	16	1	2	3	..	13
…..	……	..	.	..	..	.	..	.	.	..	..	..	.	.	..	..	..
2. Analyse	Analysis (4)	8	8	8	5	.	20		2	2	..	1	1		4	..	2
…..	……	..	.	..	..	.	..	.	.	..	..	..	.	.	..	..	..
10. Calculate	Application (3)	3	3	3	1	.	1				..				7	..	
…..	……	..	.	..	..	.	..	.	.	..	..	..	.	.	..	..	..
37. Design	Synthesis (5)	12			3	.			4	3	..	4		1	1	..	
…..	……	..	.	..	..	.	..	.	.	..	..	..	.	.	..	..	..
54. Explain	Compre-hension (2)	2	2	2	1	.	8				..					..	11
…..	……	..	.	..	..	.	..	.	.	..	..	..	.	.	..	..	..

Table 1: Extracted samples of Activity Verb-Rank Survey

Verb Specific Group ratings, $V_{Rj\text{-student-I}}$, $V_{Rj\text{-student-II}}$, and $V_{Rj\text{-professional}}$, are defined as follows:

$V_{Rj\text{-student-I}}$ is the sum of multiplicative inverse of valid ranks for j^{th} verb by first group of students, i.e.:

$$V_{Rj\text{-student-I}} = \sum_{k=1 \text{ to } 50} (1/Rank_{kj})$$

Where $Rank_{kj} \neq 0$, and represents the perceived usage rank given by k^{th} student to j^{th} verb. There were 50 student respondents.

$V_{Rj\text{-student-II}}$ is the sum of multiplicative inverse of valid ranks for j^{th} verb by second group of students, i.e.:

$$V_{Rj\text{-student-II}} = \sum_{k=1 \text{ to } 16} (1/Rank'_{kj})$$

Where $Rank'_{kj} \neq 0$, and represents the perceived learning effectiveness rank given by k^{th} student to j^{th} verb. There were 16 student respondents.

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$V_{Rj\text{-professional}}$ is the sum of multiplicative inverse of valid ranks for j^{th} verb by professional engineers, i.e.:

$$V_{Rj\text{-Professional}} = \sum_{k=1 \text{ to } 13} (1/Rank''_{kj})$$

Where $Rank''_{kj} \neq 0$, and represents the recommended usage rank given by k^{th} professional engineer to j^{th} verb. There were 13 professional respondents.

Verb Specific Group ratings, $V_{Rj\text{-student-I}}$, $V_{Rj\text{-student-II}}$, and $V_{Rj\text{-professional}}$ were then normalized with respect to the maximum values of $V_{Rj\text{-student-I}}$, $V_{Rj\text{-student-II}}$, and $V_{Rj\text{-professional}}$ respectively to calculate activity verb-specific normalised group ratings as follows:

$$V'_{Rj\text{-student-I}} = V_{Rj\text{-student-I}} / \max_j \{V_{Rj\text{-student-I}}\}$$
$$V'_{Rj\text{-student-II}} = V_{Rj\text{-student-II}} / \max_j \{V_{Rj\text{-student-II}}\}$$
$$V'_{Rj\text{-professional}} = V_{Rj\text{- professional}} / \max_j \{V_{Rj\text{- professional}}\}$$

Hence, $V'_{Rj\text{-student-I}}$, $V'_{Rj\text{-student-II}}$, and $V'_{Rj\text{-professional}}$ all have a value between 0 to 1. Values close to 1 indicate that most respondents from the specific category have assigned a high rank to jth verb, whereas low values indicate low ranks by most the respondents. Table 2 shows the samples of $V'_{Rj\text{-student-I}}$, $V'_{Rj\text{-student-II}}$, and $V'_{Rj\text{-professional}}$.

Activity Verb (j =1 to 128)	**Bloom Cognitive level (i=1 to 6)**	What students think they get **$V'_{Rj\text{-student-I}}$**	What students think works well for them **$V'_{Rj\text{-student-II}}$**	What professional engineers recommend **$V'_{Rj\text{-professional}}$**
…..	……	…..	…..	……
2. Analyse	Analysis (4)	0.37	0.79	1.00
…..	……	…..	…..	……
10. Calculate	Application (3)	1.00	0.03	0.24
…..	……	…..	…..	……
37. Design	Synthesis (5)	0.20	1.00	0.72
…..	……	…..	…..	……
54. Explain	Comprehension(2)	0.78	0.13	0.13
…..	……	…..	…..	……

Table 2: Extracted samples of Activity Verb specific normalized group ratings

Based on these activity verb-specific normalised group ratings ($V'_{Rj\text{-student-I}}$, $V'_{Rj\text{-student-II}}$ and $V'_{Rj\text{-professional}}$), the following three lists were created in descending order of their numeric ratings:

i. Ordered List of activity-verbs as per their usage rating: Students' normalized group rating $V'_{Rj\text{-student-I}}$ by the first group of students, representing their experience of the verb usage was found to be in the following descending order:

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calculate, explain, prove (studied theorem, studied method), define (studied definitions), write, solve, compute, show (studied fact, studied method), evaluate(computation), derive, state, describe, determine, find, analyse, justify, comment, distinguish, consider, illustrate, compare, apply, classify, identify, fill in the blanks, differentiate, conclude, examine, discuss, develop, implement, name, create, deduce, obtain, exemplify , construct, specify, design, categorize, estimate, propose, draw, generalize, demonstrate, recall, cite, summarize, convert, predict, formulate, argue, prepare, list, tell, point out, combine, sort, modify, represent, rearrange, devise, clarify, transform, compose, change, present, outline, rewrite , match, show (unstudied fact in the direct context of studied material), contrast, evaluate (the options), interpret, validate, organize, translate, label, build, decide, discriminate, produce, relate, recognise, synthesize, standardise, integrate, extend, plan, assess, recite, associate, document, reproduce, select, detect, arrange, infer, and judge.

This ordered list is a consolidation of what students think they get to do as part of teaching-learning-evaluation process. The activity verbs not appearing in this list were not given any rank by any student. This list indicates that most faculty members assigned activities directly asking students to calculate, explain, prove (studied theorem, studied method), define (studied definitions), write, solve, compute, show (studied fact, studied method), evaluate (computation) or derive.

ii. Ordered List of activity-verbs as per their learning effectiveness: Students' normalized group rating $V'_{Rj\text{-}student\text{-}II}$ by the second group of students, representing activity-verb's learning effectiveness was found to be in the following descending order:

design, analyse, understand, build, apply, adapt, implement, create, develop, demonstrate, validate, define (new things), show (unstudied fact in the direct context of studied material) , illustrate, compare, enjoy, correlate, argue, research, evaluate (the options), compile, propose, derive, summarize, evaluate(computation), find, discover, explain, suggest, submit (deadline), show (studied fact, studied method), question, present, modify, devise, compute, construct, debate, solve, incorporate, focus, critique, improve, justify, examine, differentiate, prove (unstudied theorem), change, contrast, organize, associate, experiment, utilise, study, integrate, express, challenge, act, survey, transform, establish, interpret, grade, collaborate, administer, describe, progress, produce, duplicate, discuss, decide, contribute, conclude, teach, support, determine, prove (studied theorem, studied method), calculate, perform, accept, use, quote, negotiate, deduce, formulate, consider, categorize, simulate, relate, expand, chart, view, test, standardise, judge, document, combine, clarify, assemble, arrange, trace, rewrite, generalize, experiment, sketch, plan, perceive, exemplify , define (studied definitions), write, structure, restructure, memorise, convince, classify, anticipate, state, revise, reconstruct, restate, invent, simplify, convert, communicate, reason.

This ordered list is a consolidation of what students think results in more effective learning for them. The activity verbs not appearing in this list were not given any rank by any student. This list indicates that most students experience maximum learning when asked to design, analyse, understand, build, apply, adapt, implement, create, develop, demonstrate.

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iii. Ordered List of activity verbs as per professional engineers' recommendations: The professional engineers' normalized group rating $V'_{Rj\text{-professional}}$, representing their recommendations was found to be in the following descending order:

> analyse, design, develop, implement, evaluate (the options), integrate, build, conclude, define (new things), acquire, demonstrate, justify, assess, organize, formulate, estimate, summarize, categorize, validate, document, standardise, identify, appraise, calculate, manage, represent, review, reproduce, devise, apply, comment, generalize, specify, explain, extend, state, schedule, compare, present, classify, compute, consider, constitute, debug, decide, define (studied definitions), distinguish, examine, extrapolate, interpret, modify, name, point out, prove (unstudied theorem), recognise, reorganise, rephrase, report, revise, revisit, solve, synthesize, test, transform, transmit, weigh, create, prove (studied theorem, studied method), show (unstudied fact in the direct context of studied material), change, illustrate, practice, verify, question, clarify, discuss, propose, restructure, compose, recall, differentiate, and find.

This ordered list is a consolidation of what professional engineers recommend should be done more often as part of teaching-learning-evaluation process. The activity verbs not appearing in this list are the ones not selected by any professional engineer. As per this list, professional engineers recommended that the faculty should repeatedly direct or ask students to analyse, design, develop, implement, evaluate (the options), integrate, build, conclude, define (new things) or acquire (knowledge).

There is a significant similarity between the second and the third list. This demonstrates that most of the students preferred learning style is in alignment with the demands of the post university professional life. However, there are very serious difference in the first and other two lists, so much so that none of the top ten verbs of the first list also appears in one of top ten slots of either of the other two lists. While universities focus on regularly updating their curriculum, the differences in these lists demonstrate the need for transforming the teaching-learning-evaluation processes from a content-based curriculum to a process-based curriculum.

These three lists were further distilled using Bloom level to verb list mapping. All the verbs belonging to one Bloom level were grouped into one unit and Bloom Level Specific Consolidated ratings $L_{R\text{-student-I}}$, $L_{R\text{-student-I I}}$ and $L_{R\text{-professional}}$ were computed as follows:

$L_{R\text{-student-I}}$, $L_{R\text{-student-I I}}$ are the sum of $V_{Rj\text{-student-I}}$ and $V_{Rj\text{-student-I I}}$ respectively for all the verbs belonging to the i^{th} Bloom level, i.e.:

$$L_{Ri\text{-student-I}} = \sum_j V_{Rj\text{-student-I}} \qquad \text{Where the } j^{th} \text{ verb belongs to the } i^{th} \text{ Bloom Level}$$

$$L_{Ri\text{-student-II}} = \sum_j V_{Rj\text{-student-II}} \qquad \text{Where the } j^{th} \text{ verb belongs to the } i^{th} \text{ Bloom Level}$$

$L_{Ri\text{-professional}}$ is the Sum of $V_{R\text{-professional}}$ for all the verbs belonging to the ith Bloom level**,** i.e.:

$$L_{Ri\text{-Professional}} = \sum_j V_{Rj\text{-Professioanl}} \qquad \text{Where the } j^{th} \text{ verb belongs to the } i^{th} \text{ Bloom Level}$$

Bloom Level Specific Consolidated ratings $L_{R\text{-student-I}}$, $L_{R\text{-student-I I}}$ and $L_{Ri\text{-professional}}$ are then normalised as follows:

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$$S_{R\text{-student-I}} = \sum_{i = 1 \text{ to } 6} L_{Ri\text{-student-I}}$$

$$S_{R\text{-student-II}} = \sum_{i = 1 \text{ to } 6} L_{Ri\text{-student-II}}$$

$$S_{R\text{-professional}} = \sum_{i = 1 \text{ to } 6} L_{Ri\text{-professional}}$$

$$L'_{Ri\text{-student-I}} = L_{Ri\text{-student-I}} / S_{R\text{-student-I}}$$

$$L'_{Ri\text{-student-II}} = L_{Ri\text{-student-II}} / S_{R\text{-student-II}}$$

$$L'_{Ri\text{-professional}} = L_{Ri\text{-professional}} / S_{R\text{-professional}}$$

The next stage of this research investigated verb usage in question papers. The sample comprised fifteen question papers of different subjects, given to around 1200 engineering students of 1st, 2nd and 3rd year Electronics, Computer Science (CS), and Information Technology (IT) and Biotechnology disciplines. Bloom level specific consolidated ratings, $L_{Ri\text{-Exam}}$ were computed from this data as follows:

$L'_{Ri\text{-Exam}}$ is the Fraction of i^{th} Bloom level questions across all question papers.
Where,

$L_{Ri\text{-Exam}}$ = Number of Questions belonging to i^{th} Bloom level

$$S_{R\text{-Exam}} = \sum_{i = 1 \text{ to } 6} L_{Ri\text{-Exam}}$$

$$L'_{Ri\text{-Exam}} = L_{Ri\text{-Exam}} / S_{R\text{-Exam}}$$

Table 3 tabulates $L'_{Ri\text{-student-I}}$, $L'_{Ri\text{-student-II}}$, $L'_{Ri\text{-professional}}$ and $L'_{Ri\text{-Exam}}$ where large values indicate high ranks by most of the respondents.

Bloom's Cognitive levels(i)	What students think they get **$L'_{Ri\text{-student-I}}$**	What students get in examinations **$L'_{Ri\text{-Exam}}$**	What students think works well for them **$L'_{Ri\text{-student-II}}$**	What professional engineers recommend **$L'_{Ri\text{-professional}}$**
Knowledge	0.24	0.36	0.04	0.09
Comprehen-sion	0.24	0.16	0.11	0.10
Application	0.22	0.40	0.13	0.10
Analysis	0.14	0.04	0.15	0.19
Synthesis	0.14	0.05	0.46	0.38
Evaluation	0.02	0.00	0.11	0.15

Table 3: Comparison of Bloom Level specific normalized consolidated ratings

Table-4 gives the correlation coefficients between these three ratings (each can be viewed as an arrays of 6 elements) using "Correl" function of MS-Excel. Correl function calculates the correlation coefficient $\rho_{x,y}$ as a measure of similarity between two arrays X and Y as follows:

$$\rho_{x,y} = \text{Conv}(X,Y) / (\sigma_x \,.\, \sigma_y) \quad ; \text{ where } -1 \le \rho_{x,y} \le 1$$

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$$Conv(X,Y) = (1/n) \sum_{i= 1 \text{ to } n} (x_i - \mu_x)(y_i - \mu_y)$$ where
σ_x and σ_y are the variance of X and Y respectively
μ_x and μ_y are the mean of X and Y respectively.

	What students think they get $L'_{Ri\text{-}student\text{-}I}$	What students get in examinations $L'_{Ri\text{-}Exam}$	What students think works well for them $L'_{Ri\text{-}student\text{-}II}$	What professional engineers recommend $L'_{Ri\text{-}professional}$
What students get in examinations $L'_{Ri\text{-}Exam}$	0.77		-0.25	-0.57
What students think works well for them $L'_{Ri\text{-}student\text{-}II}$	-0.22	-0.25		0.96
What professional engineers recommend $L'_{Ri\text{-}professional}$	-0.38	-0.57	0.96	

Table 4: Correlation between different consolidated ratings

Correlation

In Table 4, a high correlation of 0.77 is observed between the perception of fifty 2nd year CS and IT students and the data collected from the fifteen question papers that were administered to around 1200 students of different seniority in Electronics, CS, IT and Biotech disciplines. This implies that in spite of the differences in disciplines, subjects and seniority, there is not much difference in the cognitive level of activities that engineering students are engaged in. The professional engineers place high emphasis (combined rating of 0.71) on engaging the students in activities that require higher order cognition at the level of analysis, synthesis or evaluation as compared to the emphasis (combined rating of 0.29) on simpler activities requiring lower level cognition at the level of knowledge, comprehension or application. Interestingly, most of the engineering students experience more effective learning (combined rating of 0.72) when they are engaged in activities that require higher order cognition as compared to much lower perceived effectiveness (combined rating of 0.28) of the learning that occurs as a result of their engagement in activities requiring lower order cognition. This demonstrates that most of the engineering students' preferred learning style is in alignment and having a very high correlation of 0.96 with the recommendations of the professional engineers. However, The prevailing practice amongst the majority of engineering educators demonstrates an opposite preference leading to negative correlation of -0.22 and -0.25 with the preferred learning style of their students and -0.38 and -0.57 with professional engineers' recommendations.

Thus, the kind of the activities that a typical engineering student is generally engaged in, do not help in enhancing creativity, critical thinking and innovative problem solving. It is clear that most of the activities students formally engage in as part of teaching-learning-evaluation process promote rote-learning and conformity rather than creativity, critical thinking and innovative problem solving. This view was expressed by faculty as well during informal discussions.

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What Do Students Need?

From the last section we can conclude that professional engineers want the students to be engaged in learning processes that promote creativity. The students also experience much higher learning when engaged in such processes. According to Arney (1999), the conception of creativity includes an interrelated set of intellectual skills of creative thinking, critical thinking, and innovative problem solving; personal characteristics of versatility, tolerance for ambiguity, willingness to take risks, open-mindedness, confidence, and curiosity, and values of discipline, perseverance, and responsibility. Further, Arney (1999) defined three intellectual skills:

1. **Creative thinking** is defined as the consideration of a broad range of new, sometimes abstract, ideas and the establishment of new connections and relationships among these ideas.
2. **Critical thinking** is the performance of careful and exact analysis, ultimately leading to a deeper understanding of an issue.
3. **Innovative problem solving** is defined as combining knowledge with imagination to produce solutions to problems.

Orthodox teacher centric lectures tend to cover a set of topics, and experiential development of these skills. Personal characteristics or values are not a committed goal of a typical lecture driven education system.

According to a survey reported by Goel (2004), an overwhelming majority of responding students and faculty members felt that:

- Creativity is very important for engineering profession.
- Creativity can be fostered through instruction and training.
- Current engineering education, in general, does not enhance creativity.
- Design assignments, real-life like assignments and discussions play a very important role, while written exams do not contribute much in fostering creativity.

This survey provided an interesting insight: that along with the students, most of the engineering faculty are also concerned about current educational system's weakness in fostering creativity. Therefore, it is imperative that the reasons of this weakness need to be isolated and creativity fostering aspects of teaching-learning-evaluation process identified, promoted and used more frequently.

ABET (2002) recommends that engineering graduates must have the following abilities:

1. Ability to apply knowledge of math, science, and engineering.
2. Ability to design and conduct experiments, as well as analyze and interpret data.
3. Ability to design a system, component or process to meet desired needs.
4. Ability to function in multidisciplinary teams.
5. Ability to identify, formulate and solve engineering problems.
6. Understanding professional and ethical responsibilities.
7. Ability to communicate effectively.
8. Understanding the impact of engineering solutions in a global and societal context.
9. Recognition of need and ability to engage in life-long learning.
10. Knowledge of contemporary issues.
11. Ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

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Hence, it can be deduced that engineering curriculum needs to be crafted to promote the reasoning process and creativity rather than carefully visiting a set of topics. Gary (1999) argues that curriculum should provide opportunities for transforming a problem statement into a model, conjecturing solutions, selecting or developing the appropriate mathematics, examining the analysis, and continuing to transform the conjecture into a solution. Bruner (1996) proposed that preparing students for solving real life problems require a different paradigm of education and learning skills, including self-directed learning, active collaboration, and consideration of multiple perspectives. Problems of this nature do not have "right" answers, and the knowledge to understand and resolve them is changing rapidly, thus requiring an ongoing and evolutionary approach to learning.

Conclusions

This study shows that engineering students report more effective learning when they are engaged in higher order cognitive activities through active learning. Even in the opinion of professional engineers, faculty should engage students in higher level cognitive activities like analyse, design, develop, implement and so on. However, as this study also demonstrates, most of the engineering faculty give assignments and activities that engage students in lower level cognitive activities like calculate, explain, prove (studied theorem, studied method), define (studied definitions) and so on. While universities keep updating the content list of the curriculum, the learning deficiency of most popular teaching and assessment techniques demonstrate the need and scope of transformation of the teaching-learning-evaluation processes from content based curriculum to process based curriculum. In order to foster creativity, critical thinking and innovative problem solving amongst engineering students and make the engineering education more in alignment with the suggestions of professional engineers, faculty need to bring a strategic transformation and flexibility in the curriculum to engage the students in higher level cognitive activities. Changing the activity verb set offers a way to realise this strategic transformation.

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Effects of access modes upon students' perceptions of learning objectives and outcomes

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***Abstract**: The web was first used as a telecontrol medium in 1994. In recent times, web-based telecontrol is being used as an educational option, providing students with remote access to laboratory hardware. The literature reporting the initial studies into telelaboratories speaks of encouraging anecdotal responses from students, but there is little literature actually systematically addressing the quality of learning outcomes from this alternative access mode. A recent comparative study at the University of Melbourne allocated a cohort of third year students to one of three separate access modes – proximal, web-based remote, or simulation – to perform the same laboratory class. A range of tools were used to measure the students' learning outcomes, and their perceptions of their learning outcomes. This paper details the tools used to measure the students' perceptions of the learning objectives of the laboratory, and their perceptions of their learning outcome, and reports on the variation of outcomes between the three groups. Significant differences between students perceptions of the objectives of the laboratory and of their learning outcomes have been found.*

***Keywords**: Remote Laboratories, Learning Outcomes, Student Perceptions*

Introduction / Background

The web was first used as a telecontrol medium in 1994 (Goldberg, Gentner, Sutter, & Wiegley, 2000). Telecontrol is an increasingly viable control option, and it is being applied more and more in the educational context. Web based labs have been offered by universities in undergraduate engineering courses since 1996 (Aktan, Bohus, Crowl, & Shor, 1996), with the number and sophistication of these efforts growing each year (Trevelyan, 2003).

There are a number of good motivations for providing students with remote access to laboratory hardware, which can largely be divided into three categories:

Providing labs where it would be otherwise impossible to do so

With an increase in distance mode students, and online-only courses, the traditional mode of proximal access is no longer always an option. Remote laboratories allow for students who are not conveniently located to their institutions to still participate in laboratory classes.

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Another example of this kind of opportunity is for universities to share laboratory hardware, either with each other or with industry. Laboratory hardware can be difficult to relocate, entire cohorts of students even more so – but a remote telelaboratory offers the ability to bring the two together for a learning opportunity, without having to physically co-locate the two.

A third example of this category of motivation is the issue of laboratory safety. A number of potentially desirable laboratory classes involve potentially hazardous materials and situations, and as such are unsuitable for use in an engineering course. The ability to perform these experiments without the need for exposing students to the risk elements of the hardware allows for these experiments to be retained or added to the undergraduate curriculum.

Substitution for existing labs

The second category of motivations for telelaboratories are those where the remote access is used as a substitute for the traditional proximal mode of access – where the decision to use the alternative mode is a choice, rather than a necessity.

Increasing cohort sizes places additional stress upon laboratory resources. The task of scheduling each and every student access – in particular appropriately supervised access – to laboratory hardware is becoming more difficult, and more expensive. Offering remote access allows for greater flexibility in this scheduling, and can alleviate the need for direct supervision from lab demonstrators.

Improving Learning Outcomes

The third category of motivations – which has been largely unexplored in the literature at this time – is that of quality of outcomes. The primary drive to this point has been the use of remote laboratories as an alternative mechanism for achieving the same outcomes, but little research has been done into whether the remote access modality may in fact enhance certain learning outcomes. Prior publications of this study have shown that there are significant differences in learning outcomes based upon the access mode (Lindsay & Good, 2004). Rather than focussing directly upon the outcomes, however, this paper focuses upon the students' perceptions of their learning outcomes.

The Laboratory Class

The laboratory that was investigated in this instance was the calibration of a piezoelectric accelerometer.

In this laboratory, the accelerometer is mounted on an electrodynamic shaker, which is excited using signals generated by a Spectrum Analyser. A Laser Doppler vibrometer also measures the velocity of the accelerometer. This velocity signal, and the accelerometer's own acceleration measurement, are analysed using the Spectrum analyser. The hardware is shown in Figure 1 and Figure 2:

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Figure 1: The Laboratory Hardware



Figure 2: The Accelerometer mounted on the magnetic shaker

The spectrum analyser compares the voltages produced by the accelerometer circuit and the Laser Doppler circuit using the frequency response $H(\omega)$, which is defined as:

$$H(\omega) = \frac{V_{\text{ACCELEROMETER}}}{V_{\text{LASER DOPPLER}}}$$

The theory of the experiment suggests that the relationship between the magnitude of $H(\omega)$ and the operating frequency ω will be a straight line: $H(\omega) = B\omega$, with B being a constant related to the calibration constant of the accelerometer. In reality, however, the dynamics of the test equipment make the relationship more complicated, as shown by the experimental measurement in Figure 3.

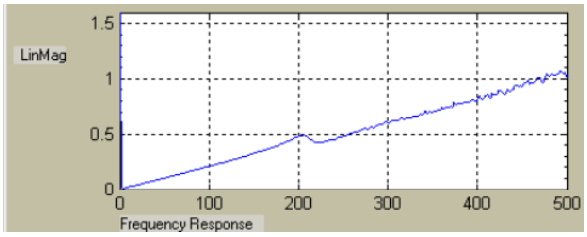


Figure 3: Experimental Frequency Response

This laboratory is conducted primarily through a single point of control, the Spectrum Analyser. As such, the alternative access modes were simply a matter of providing a remote mechanism for controlling the Spectrum Analyser – which was achieved using a GPIB bus connection.

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A MATLAB GUI (shown in Figure 4) was constructed to represent the spectrum analyser, and to provide the user with access to the functionality of the spectrum analyser that was necessary to perform this experiment.

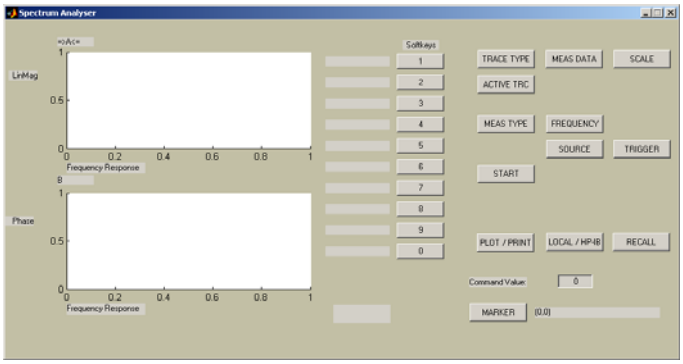


Figure 4: GUI Interface

A simulation of the system was also constructed, using the same GUI interface as the remote interface. This simulation used recorded data from the system to interactively generate responses for the user.

The Measurement Tool

Students were asked to complete a seven question post-test at the completion of the laboratory class. These post-tests were anonymised through the use of a participant number, and the responses collated and attributed to the appropriate access mode. This paper deals with their responses to two of these seven questions:
Question Four – "What did you think the learning objectives of the laboratory class were?"
Question Five – "What was the most important thing you learned from the laboratory class?"

Grouping of Answers

There were a wide variety of responses from the students, with the open-ended nature of the questions causing very few answers to match other answers. Whilst there were few direct matches, however, it became evident that the responses could be meaningfully grouped into categories. For instance, whilst one student may have focused upon use of the Spectrum Analyser, and another upon the use of the Laser Doppler system, both can be considered Hardware-focused outcomes, and grouped accordingly. The seven groups were as follows:

Hardware Specific Outcomes

Responses categorised in this group indicated students who had focused upon the hardware used in the experiment – the Spectrum Analyser, the Piezoelectric Accelerometer etc. Their perceptions were that familiarity with and understanding of the equipment was their primary achievement.

Off-Topic Outcomes

Responses categorised in this group indicated students who had not focused upon the laboratory itself – rather, some more general, incidental event within the laboratory had proven more important than any of the intended course material. Many of these responses were matters of general experimental procedure – repetition of data collection etc. Interface issues also accounted for some of these responses, as did understanding of prerequisite knowledge such as Bode plots.

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Theory of the Specific Lab

Responses categorised in this group indicated students who had focused upon the theory involved in the laboratory class – how the specific frequency response operated, attributes of the transfer functions involved, etc. This category did not show an application of this theory beyond their laboratory class.

Calibration Principles

Responses categorised in this group extend upon those from the Specific Theory – rather than demonstrating an understanding of this particular experiment, these outcomes were those that suggested an understanding of Calibration in a wider sense. These outcomes indicated learning that was transferable to contexts outside that of the original experiment.

Practical links to Theory

Responses categorised in this group all shared the common theme of applying the theory to a practical application. The students responding in this category showed that they felt the experience with a "real-life" situation in which the theory could be used was their most valuable learning outcome. Also included in this category were responses of the "Reality differs from expectations" type.

Signal Analysis

Responses categorised in this group were all predominantly based around Signal Analysis based understandings – manipulation of transfer functions, and the equivalence of the responses of the system to chirp and white noise signals were the most common example of this.

Miscellaneous

Not all of the students' responses fell into one of the above categories. All of the remaining outcomes were grouped under miscellaneous – discussions of errors and assumptions fall into this category.

Perceptions of Objectives (Question Four)

"What did you think the learning objectives of the laboratory class were?"

This question is important because it address the students' perceptions of their own learning, and what it was that they were expected to take away from the laboratory class. Some students did not answer this question, whilst some students gave more than one answer. Each of the answers was weighted equally in the collation of data. A total of 61 Proximal answers, 69 Remote answers and 62 Simulation answers were obtained.

Distribution of Responses

The proportions of answers which fell into each of the categories varied between the access modes, with definite differences in the distributions between the three modes, as are shown in Figure 5, Figure 6 and Figure 7 below:

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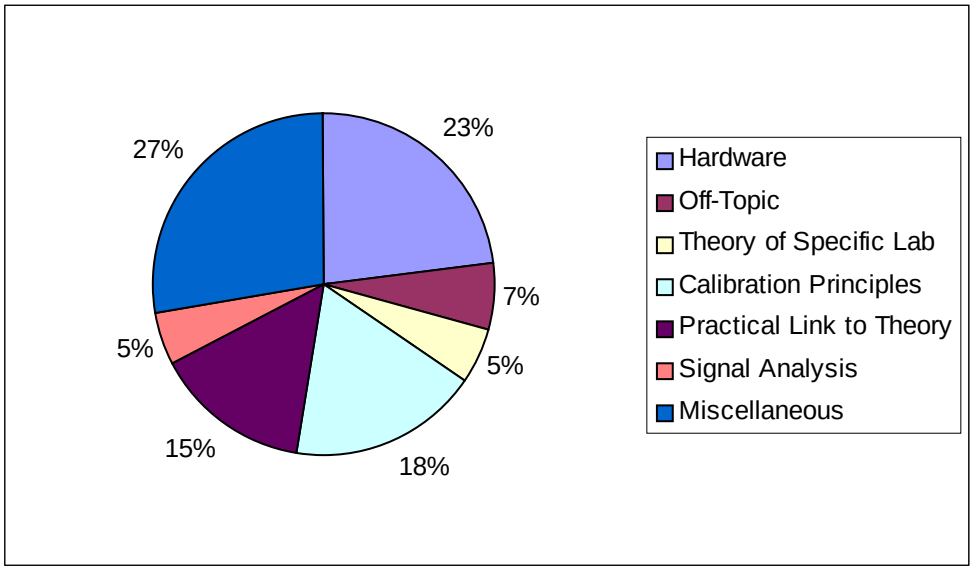


Figure 5: Distribution of Q4 responses – Proximal

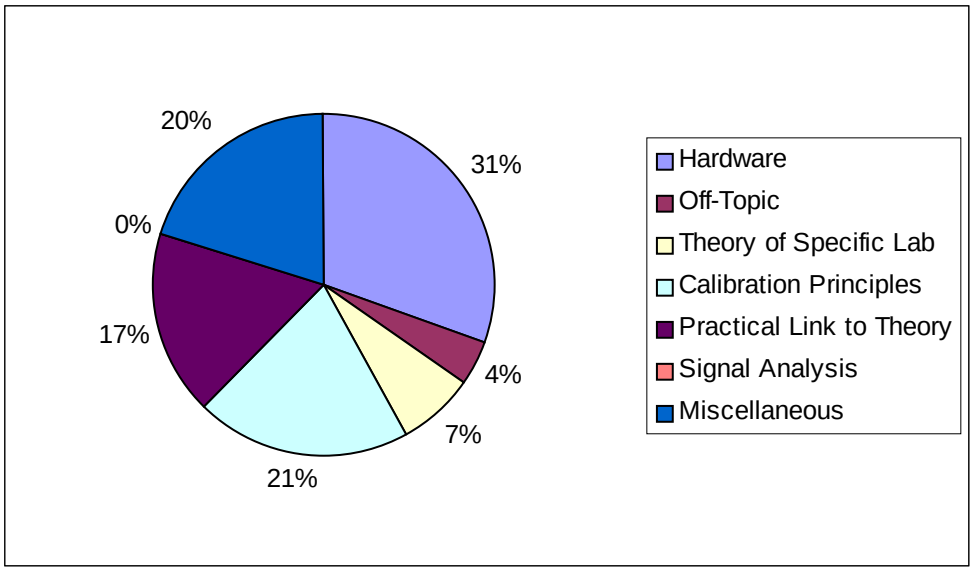


Figure 6: Distribution of Q4 Responses – Remote

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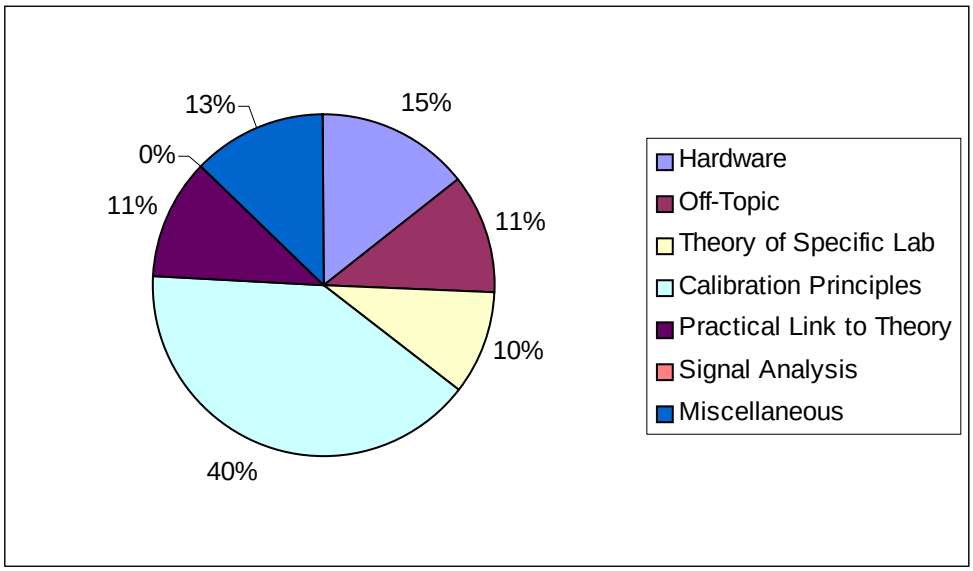
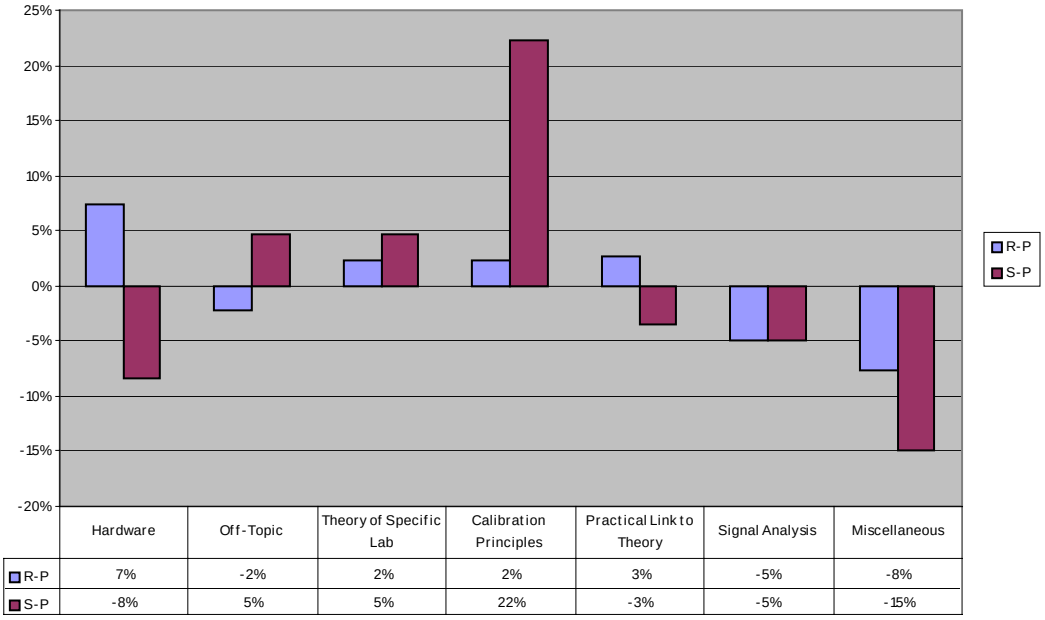


Figure 7: Distribution of Q4 Responses – Simulation

These groupings were investigated using the contingency table technique of (McNemar, 1969), which tests the hypothesis that the responses are equally distributed between the seven groups for the three modes. A χ^2 test statistic of 24.694 was calculated for the 3 x 7 table, indicating that the responses are not equally distributed between the groups and modes at a significance of $p < .02$ for $df = 12$.

To further investigate the differences between the modes, a chart displaying the difference between the proportions for the control (proximal) group and those for the remote and simulation groups was produced (Figure 8):



	Hardware	Off-Topic	Theory of Specific Lab	Calibration Principles	Practical Link to Theory	Signal Analysis	Miscellaneous
R-P	7%	-2%	2%	2%	3%	-5%	-8%
S-P	-8%	5%	5%	22%	-3%	-5%	-15%

Figure 8: Q4 Proportion Differences

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Z-tests were also performed to compare the proportions in each group. Pairwise comparisons were performed over the three groups, and the following significant differences were found:

- Calibration Principles: Simulation proportion larger than both the Remote ($p < .007$) and Proximal ($p < .004$) proportions.
- Hardware: Remote proportion larger than Simulation proportion ($p < .015$)
- Miscellaneous: Proximal proportion larger than Simulation proportion ($p < .02$)

Remote Implementation

The remote implementation seemed to emphasise the Hardware in the students' minds, with hardware-related outcomes being more strongly represented in their responses.
The theory-related outcomes appear to have been slightly more emphasised, with both the shallower, laboratory specific theory, as well as the deeper Calibration principles and practical links being emphasised more than in the proximal mode.
The bias in Signal Analysis is caused by the presence of signal analysis responses in the Proximal group – the only group in which they are represented.
The decrease in the miscellaneous outcomes category suggests that the students in the remote mode might have been more focused towards the intended goals of the laboratory class.

Simulation Implementation

The simulation implementation leads to a large bias towards Calibration Principles in students' perceptions of the objectives. This shift in proportions – more than 20% higher than the other groups, with nearly half of the responses falling into this category – shows that the simulation mode serves to significantly change students' perceptions of the laboratory.
There is a substantial reduction of the number of responses in the hardware-specific goals category, suggesting that the use of the simulation serves to dissociate the students from the underlying apparatus of the experiment. This is also supported by the decrease in the Practical applications category – students do not seem to have as prevalent a recognition that they are applying the theory to a practical situation.
The bias in Signal Analysis is again caused by the presence of signal analysis responses in the Proximal group – the only group in which they are represented.
The significant decrease in the miscellaneous outcomes category suggests that the students in the simulation mode are again more focused towards the intended goals of the laboratory class – mostly the Calibration principles goals.

Perceptions of Learning (Question Five)

"What was the most important thing you learned from the laboratory class?"

Again, some students did not answer this question, whilst some students gave more than one answer. Each of the answers was weighted equally in the collation of data. A total of 47 Proximal answers, 53 Remote answers and 49 Simulation answers were obtained.
It is noteworthy that the Miscellaneous category was more heavily populated in this trial, suggesting that the students' perceptions of what was actually learned varied more than their perceptions of the goals.

The Distribution of Responses

The proportions of answers which fell into each of the categories again varied between the access modes. Some of these variations were mild, whilst some were more pronounced, as shown in Figure 9, Figure 10 and Figure 11, below:

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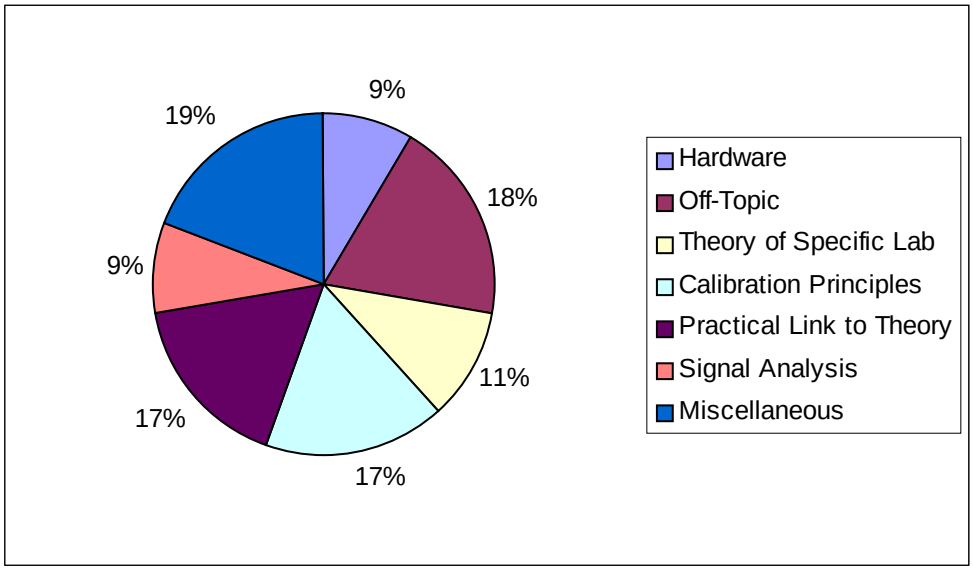


Figure 9: Distribution of Q5 Responses – Proximal

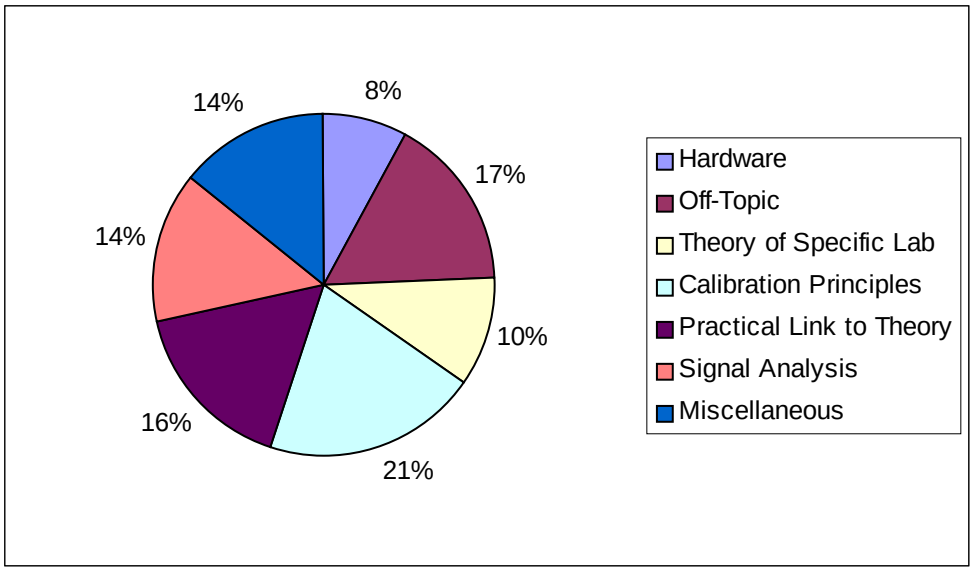


Figure 10: Distribution of Q5 Responses – Remote

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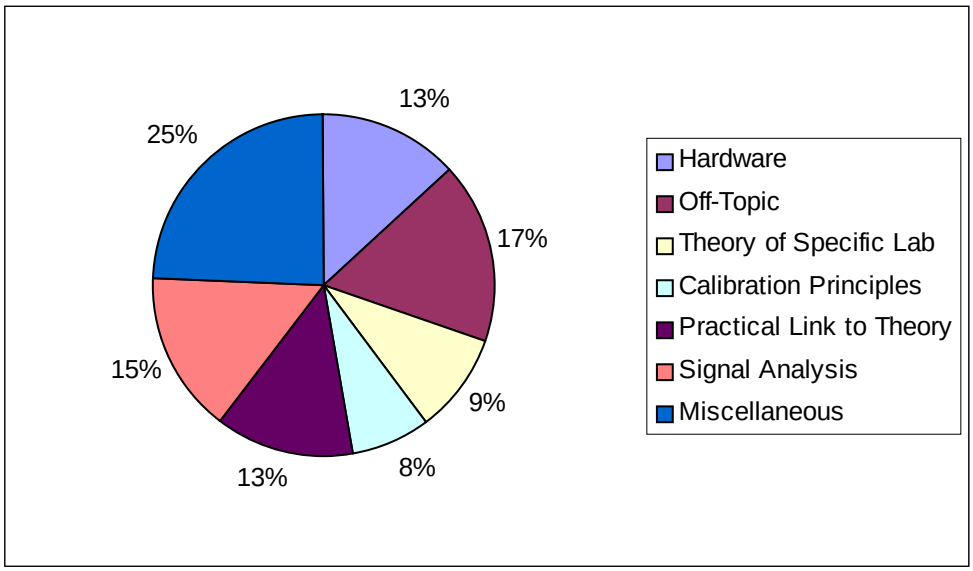
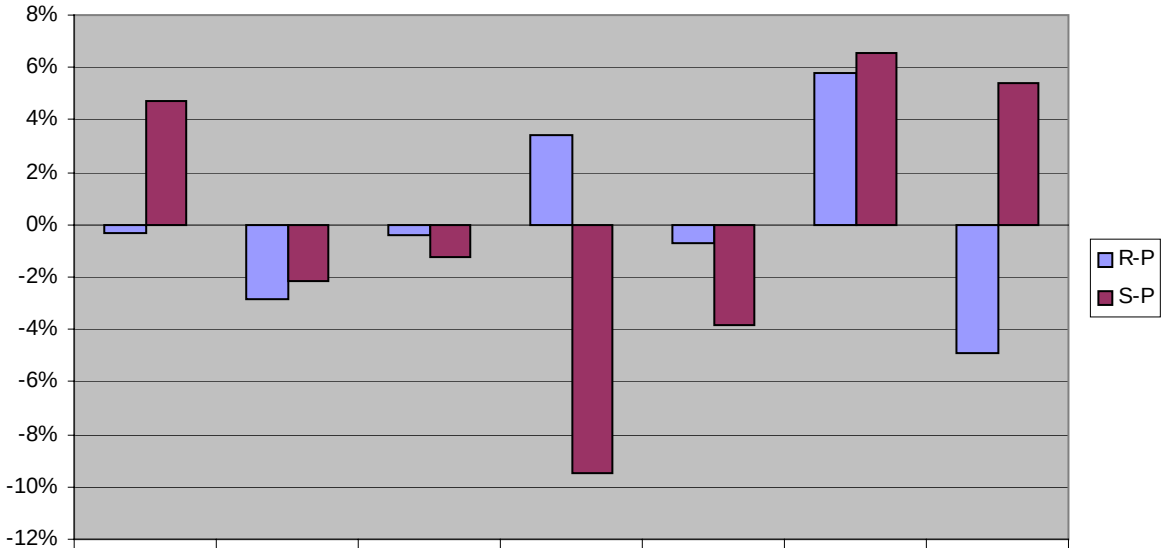


Figure 11: Distribution of Q5 Responses – Simulation

These groupings were again investigated using a 3 x 7 contingency table. A χ^2 test statistic of 6.267 was calculated, indicating that the differences in the proportions are not significant ($p > .90$ for $df = 12$).

Whilst there was no overall significant difference, a category-wise comparison was again performed (Figure 12):



	Hardware	Off-Topic	Theory of Specific Lab	Calibration Principles	Practical Link to Theory	Signal Analysis	Miscellaneous
R-P	0%	-3%	0%	3%	-1%	6%	-5%
S-P	5%	-2%	-1%	-9%	-4%	7%	5%

Figure 12: Q5 Proportion Differences

Pairwise comparison z-tests found only the one significant difference:

- Calibration Principles: Remote proportion larger than Simulation ($p < .04$) proportion.

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Remote Implementation

The Remote implementation served to emphasise the principles of Calibration and of Signal Analysis to the students, with a bias in their perceptions towards these two outcomes. It is also noteworthy to see that both the off-topic and miscellaneous categories are less pronounced, suggesting that the students are focused more on the intended outcomes of the laboratory.

Simulation Implementation

The simulation implementation shows a bias away from the Calibration Principles and the Practical links to the Theory, again suggesting that the students are not focusing upon abstracting their learning experience beyond the immediate laboratory situation. The outcomes that students most commonly perceived as their primary outcomes were their knowledge of the hardware, and of the manipulations of the equations that represent it.

Perceptions of Objectives vs Learning

A comparison of Figure 8 and Figure 12 shows that for most of the answer categories, the changes in distributions is opposite in direction for the two questions – that there is a dissonance between the students perceptions of the objectives and of their actual learning outcomes. To investigate this dissonance, the Q4 and Q5 outcomes for each mode were compared in a 2 x 7 contingency table. The results are shown in Table 1:

Mode	χ^2 test statistic	P value
Proximal	9.460	> .10
Remote	21.870	< .005
Simulation	24.434	< .001

Table 1: Dissonance Significances

Table 1 shows that there are significant dissonances between the students' perceptions of the objectives and the outcomes for the Remote and Simulation modes, but that the dissonance is not significant for the Proximal mode. These differences were further investigated using z-tests.

Proximal Mode

Despite the absence of an overall significant difference, there were significant differences between the perceived objectives and outcomes for the Hardware ($p < .03$) and the Off-topic ($p < .03$) groupings, with the hardware emphasized in the objectives, but the Off-topic responses emphasized in the outcomes.

Remote Mode

There were again significant differences between the perceived objectives and outcomes for the Hardware ($p < .002$) and the Off-topic ($p < .02$) and Signal Analysis ($p < .001$) groupings. Hardware was again emphasized in the objectives, with the Off-topic and Signal Analysis responses emphasized in the outcomes.

Simulation Mode

There significant differences between the perceived objectives and outcomes for the Calibration Principles ($p < 0.0002$) and the Signal Analysis ($p < .001$) groupings. The Calibration Principles were substantially emphasized in the expectations, whilst the Signal Analysis group was emphasized in the outcomes.

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The presence of the hardware appears to focus the students' attention and their expectations. Both the Proximal and Remote groups show a significantly larger proportion of hardware-based expectations than outcomes, whilst in the Simulation mode, where the hardware is entirely absent, there is no substantial difference between the expectations and the outcomes.

The separation from the hardware serves to promote signal analysis outcomes, whilst simultaneously discouraging signal analysis expectations. The signal analysis concepts deal with abstractions such as transfer functions, rather than the tangible apparatus that is present in the proximal laboratory.

Conclusion

The data suggest that there may be substantial differences in student perceptions of learning objectives and outcomes depending on the access mode to experimental equipment. Students infer different objectives for the laboratory class depending upon their access mode, and they also emphasise different outcomes depending upon their access mode. Statistical significance of these differences could only be demonstrated for the perceptions of the objectives.

For students involved in the non-proximal access modes, there are significant differences between their perceptions of the objectives of the laboratory and their perceptions of their learning outcomes.

These results indicate that students engage differently with the laboratory experiment based upon their access mode, and that this change in engagement serves to change their perceptions of what they are expected to learn, and also their perceptions of what they have learned. This paper gives some insight into how these perceptions have changed, providing pointers for us to compensate for these changes to ensure that the perceptions match the reality in future laboratory classes.

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Flexible Delivery of Mechanical Design

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***Abstract**: In this paper review of available text books on mechanical design is given, results of years of development of teaching and learning resources for flexible delivery of mechanical design at QUT are discussed. Examples of printed, Web-based materials, interactive software packages are given. Teaching approaches for flexible delivery of Mechanical Design are also presented.*

***Keywords**: mechanical design, flexible delivery, teaching and learning resources*

Introduction

Mechanical Design is one of the most difficult subjects to teach because it brings together different disciplines and areas of study, such as, Mathematics, Applied Mechanics, Mechanics of Solids, Dynamics, Finite Element Analysis, Materials Study, Manufacturing and Industrial Automation, Tribology, Fluid Mechanics and Thermodynamics. It is almost impossible to find an engineer or an academic that has an expertise in all these areas, which makes teaching of Mechanical Design challenging and demanding.

There is a large number of textbooks on Mechanical Design. They focus on different aspects of design and suffer from the following shortcomings:

- They describe 'classical' design solutions that were widely accepted 10...15 years ago and fail to reflect new knowledge and development. Some new types of drives, such as harmonic drives, cyclodrives are not mentioned at all.
- Most of these textbooks are published in USA and use imperial system of units. Despite the publishers' claim that both imperial and metric systems are used, in most cases manly imperial system is used in solved examples and only the final answer is converted into metric system, which makes it difficult to use in countries that adopted metric system long time ago.
- Reliability, maintenance, machine condition monitoring, machinery safety and risk analysis are not normally covered.
- Most textbooks focus on design of mechanical components and overlook creative problem solving in concept development. Even if problem solving is mentioned, it does not go beyond brainstorming and lateral thinking. Such advanced method as the Theory of Inventive Problem Solving (the Ideation – TRIZ Methodology) remains little known to the engineering community.

This puts additional pressure on educators and requires development of teaching and learning resources for flexible delivery of Mechanical Design and new teaching approaches to shorten the learning curve and facilitate students' study, and also cover stuff missing in textbooks.

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Brief Review of Text Books on Mechanical Design

In this section a brief review of textbooks on Mechanical Design that are widely available in Australia is given. Positive aspects and limitations of each textbook are discussed.

Machine Elements in Mechanical Design / Robert L. Mott. – 3rd ed., Prentice Hall, 1999
Good coverage of design principles, basics (materials in design, stress analysis, load analysis), machine elements and supplementary material on tolerances and fits, machine frames and electric motors. The book is based on imperial system of units. The author uses an interesting approach: each chapter starts from a paragraph "The big picture" to engage the reader in a dialog, and then under the heading "You are the designer" the content of the chapter is given. The book is suitable for subjects covering mechanical components design.

Fundamentals of Machine Component Design / Robert C. Juvinall, Kurt M. Marshek – 3rd ed. John Willey & Sons, 2000.
Good coverage of basics of design, mechanical components design, machine components relationship. Introduction into Finite Element Analysis is given. Web site addresses are provided to enable students to access additional information. Open-ended design problems are used to develop decision-making skills. Ashby's methodology is introduced as an aid in materials selection section. Both imperial and metric system of units are used. The book is suitable for subjects covering mechanical components design.

Mechanical Design: an Integrated Approach / Ansel C. Ugural – 1st ed. Mc Graw Hill, 2004
Good coverage of design procedures and mechanical components design. Besides of traditional topics Deflection and impact, reliability in relation to failure criteria, pressure vessels, cylindrical and spherical shells are covered. This is a metric edition. The book is suitable for subjects covering mechanical components design.

Mechanical Engineering Design / Joseph E. Shigley – 3rd ed. Mc Graw Hill, 2004.
This textbook is similar to other textbooks mentioned above. This is a metric edition. The book is suitable for subjects covering mechanical components design.

Design of Machinery – an Introduction to the Synthesis and Analysis of Mechanisms and Machines / Robert L. Norton – 3rd ed. Mc Graw Hill, 2004.
The book focuses on kinematics and dynamics of machinery. Cams and gears are covered from the standpoint of kinematics and dynamics (no stress calculations are given). Force analysis for different mechanisms is given. Could be useful as an additional source.

Mechanical Design of Machine Elements – A Failure Prevention Perspective / Jack A. Collins - John Willey & Sons, 2003. The book is based on non-traditional approach – mechanical components design is given from a standpoint of safety, reliability and failure prevention. The book also covers such topics as design for function and performance, design for manufacturing and assembly, inspectability and maintenance. This is arguably one of the best textbooks from the standpoint of scope and thoroughness of coverage. The only limitation – this is an imperial edition.

Engineering Design: A Project-based Introduction / Clive L. Dym and Patric Little – 2nd ed. John Willey & Sons, 2004. The book covers introductory topics to engineering design, such as design process, understanding the client's needs, functions and specifications, managing design process, reporting, as well as design for manufacturing, reliability, affordability and

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maintainability. At the end of the book an extensive bibliography on different aspects of design is placed. The book contains a chapter on 'Finding answers to the problem' where different thinking tools are described, but creative problem solving is not covered at all.

Engineering by Design / Gerard Voland – 2nd ed. Prentice Hall, 2004. The book provides good coverage of introductory topics to engineering design and a comprehensive description of problems solving methods (except of the Ideation / TRIZ methodology). Other topics covered are abstraction and modelling, design synthesis, ethics and product liability, hazard analysis and failure analysis, and implementation. There is a large number of case studies described in each chapter. The book does not focus on mechanical design only and could be a useful source for introductory engineering design units.

Introduction to Engineering Design: Modelling, Synthesis and Problem Solving Strategies / Andrew Samuel and John Weir – Butterworth Heineman, 1999. This is an exercise book with brief theory and solved examples on different topics of mechanical design. A separate chapter is devoted to creative problem solving where different obstacles to creative thinking are discussed, but very little is given on methods of creative problem solving – manly thinking tools are described. This book could be very handy for design tutors.

As is seen, all these textbooks suffer from shortcoming outlined in the introduction. This puts additional pressure on design lecturers in terms of development of teaching and learning resources for flexible delivery of mechanical design.

Teaching and Learning Resources for Flexible Delivery of Mechanical Design

Teaching and learning resources for flexible delivery of Mechanical Design at the School of Mechanical, Manufacturing and Medical Engineering (MMME) at QUT are as follows:

- Lecture notes (available for students from the Design Web-site).
- Manuals for AutoCAD and Solidworks (available for students from the Design Web-site).
- Tutorials with solved problems (available for students from the Design Web-site).
- The Design Studio with numerous demonstrational and test rigs, posters, networked computers with specialised software packages.
- Computer class with software packages.
- Library with textbooks and additional resources.
- Course Materials Database (CMD).

Lecture notes

Lecture notes (Kosse, 2000), (Hargreaves, 2001) are available for students from the Design Web-site. They cover the content of all three Mechanical Design units: MMB281 Fundamentals of mechanical design; MMB381 Design of mechanical components; MMB382 Design and maintenance of machinery. As is shown in the previous section, design textbooks cover only fragments of the design units' content and usually do not reflect the latest developments. Even if students buy several textbooks (that most of them cannot afford) it is still not sufficient. Lecture notes that are regularly updated are probably the only solution. Students access them online from home or while at the university. They can also print them and have a hard copy. The course notes besides of traditional topics contain materials on specific topics that are not normally covered in design textbooks. For example, creative problem solving methodologies, tolerancing, surface texture, QFD, MCM, Value analysis, Universal design, etc.

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Manuals for AutoCAD and Solidworks

Published manuals for drawing and solid modelling packages are expensive and very large in volume (usually more than 600 pages). They are not fully suitable for beginners. At QUT introductory manuals for AutoCAD and Solidworks are available for students online from the Design Web-site. Students use them during classes or print as a hard copy.

Tutorials with solved problems

Tutorials with solved examples are available from the Design Web-site and are used by students during classes and outside contact hours for self-study. They cover most topics of the design units and often contain material not available from any other sources.

Design Studio

The Design Studio contains numerous demonstrational and test rigs (see Figure 1 below), posters, networked computers with specialised software packages, handouts, catalogues and standards. Wherever possible tutorials and design projects are scheduled in the Design Studio. It is highly valued by students as a unique opportunity to gain hands-on experience.

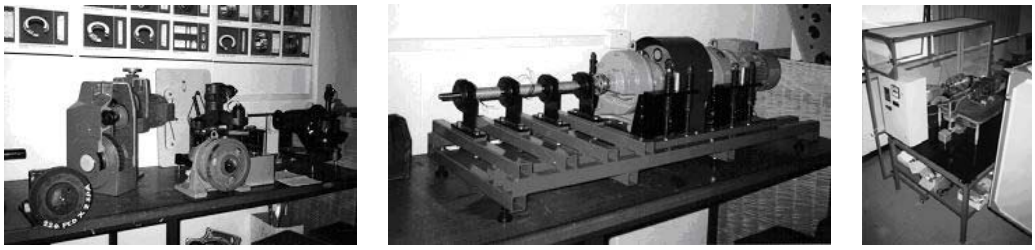


Fig.1: Demonstrational and test rigs in the Design Studio (from left-to-right): Sectioned gearboxes; Cyclodrive test rig; Machinery Fault Simulator

It can be seen from students' responses, for example:

> "I would like to give some very positive feedback regarding the Design Studio. Since introduction of the Design Studio, many students including myself have had the opportunity to share and explore many of the on display features and equipment provided. This opportunity has a very important impact on how we learn, interpret and draw conclusions on the topics we study in class. The Studio provides students with an actual hands on, and visual experience, that may not otherwise be obtained by all students. The various equipment on display helps identify many very common, and some very unique machinery / mechanical items. The sectioned items and numerous hands on scaled models, help clearly identify to students how things work, through a new and exciting format, as compared to traditional lecturing.
>
> These important opportunities gives students more confidence in being able to identify machinery and also explain and understand how they work and look. This helps draw quick and easy conclusions on their advantages and disadvantages as opposed to just studying them from a text for example.
>
> I would like to congratulate the Design Studio initiative, and the continuous improvement of its clear features and benefits for student's learning".

In the Design Studio a number of specialised software packages are also available to students. They are used for interactive learning and in design projects. During classes tutors demonstrate the software packages and then, students can use them during tutorials in the Design Studio and outside contact hours in the Computer class. The following software packages are available to students: "*i-Learn*" for interactive learning of vibrations and machine condition monitoring; gearbox, lubricant and bearing selection software from SKF, Bonfiglioli Redutori (Italy), SEW Euro-Drive; "*Innovative Workbench*" for creative solving of engineering problems from the Ideation Int. Incorp. (USA); "*FMECA Gold*" for Failure

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Mode Effect and Criticality analysis. Materials developed with the use of software packages students can E-mail home from the Design Studio and include in assignments and design projects. As an example, the *"i-Learn"* software package is described below.

The ***"i – Learn"*** software package has been developed by Mobius Ltd. (Australia) for interactive learning of vibrations and machine condition monitoring (MCM). It has the following modules (see Fig.2 – 7): "***i*** – Learn Vibrations" with complete set of illustrated and animated lectures on all aspects of machinery vibration and machine condition monitoring. Students could read the content and also listen to lectures through headphones or speakers. "***i*** – Learn Signals" for simple signal processing. Up to 100 harmonics could be superimposed, and the software produces time- and frequency-domain signatures. Students can change parameters, such as frequency, amplitude and phase, and observe the effect it makes upon signatures. There are tutorials built in this module on specific topics. Software can generate sound corresponding to the resultant signal. "***i*** – Learn Hands On" module contains a virtual machinery fault simulator. A student can select a fault, pick a test point and bring up on screen vibrational signatures typical for this fault. "***i*** – Learn Machine Faults" module enables on screen modelling of different drive trains by dragging and dropping images of different components. As soon as their parameters are specified (e.g. pulley diameter, centre-to-centre distance) the software calculates characteristic frequencies and updates the vibrational signatures. "***i*** – Learn Case Histories" module stores dozens of case histories of machinery failure. This interactive package is highly beneficial and students use it for learning MCM basics and working on projects.



Fig.2 Main menu



Fig.3 Mini-lectures (with voice)

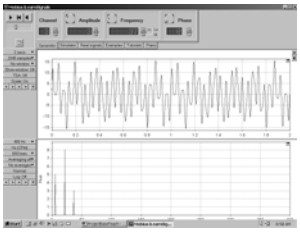


Fig.4 "i-Learn Signal' module

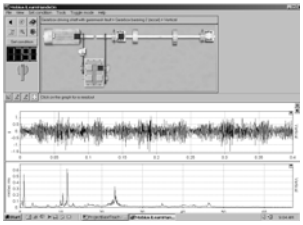


Fig.5: 'i-Learn hands on" module with signatures

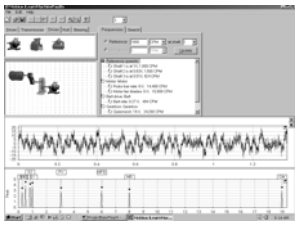


Fig.6: "i-Learn machine faults" module with signatures

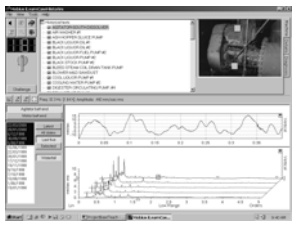


Fig 7: "i-Learn case histories" module with signatures

Another example is shown in Fig. 8 with the use of "Genius" software from Bonfiglioli Redutori (Italy) for gearbox selection.



Figure 8: Selection of the drive concept using Genius software (from left-to-right) Data input; Possible drive concepts; Service factor selection.

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Figure 9 illustrates the use of the Innovation Work Bench software developed by the Ideation Int. Inc. and based on the Ideation / TRIZ methodology. The software includes analytical and knowledge-based tools. Fig. 9 illustrates the main menu and the Contradiction Matrix method with suggested inventive principles.

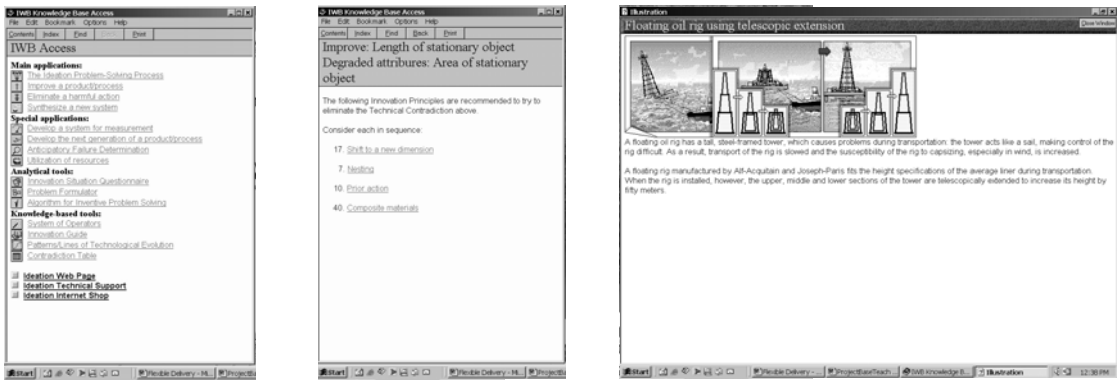


Figure 9: Innovation Work Bench software (from left-to-right)
Main menu; Contradiction Table with suggested inventive principles;
Illustrations to suggested inventive principles

Computer class with software packages

In the computer class sessions on AutoCAD and Solidworks are conducted during scheduled classes. Outside the contact hours students use specialised software packages for self-study and assignments preparation.

Library with textbooks and additional resources

In the library students can use additional sources for in depth study, such as textbooks, periodic publications, books on specialised topics, such as engineering creativity (Kosse, 2004), friction, wear and lubrication (Hargreaves, 1995). Direct access is available from the library to online standards. Hard copies of some design and drawing standards are available in the Design Studio (SAA HB6 – 1991), (SAA HB1 – 1992).

Course Material Database (CMD)

The CMD is an on-line facility where supplementary materials can be placed. For example, gearbox design procedures with tables, graphs and reference materials.

Teaching Approaches Utilising Resources for Flexible Delivery of Design

Teaching and learning resources described above are used for flexible delivery of mechanical design at QUT. Mechanical design at QUT is taught in three core units: MMB281 Fundamentals of Mechanical Design; MMB381 Design of Mechanical Components; and MMB382 Design and Maintenance of Machinery. The following teaching approaches are used. The first Mechanical Design unit MMB281 is common for almost all degrees offered by the School of Mechanical, Manufacturing and Medical Engineering (MMME) at QUT. Lectures are conducted in lecture theatres equipped with modern audiovisual facilities that enable the use of computers, transparencies, educational films, demonstration of physical objects, etc. Students are encouraged to have a hard copy of the course notes that they can print from the Design Web-site and bring to lectures. The main reason for this is that in teaching of mechanical design hundreds of illustrations are used that students cannot reproduce taking lecture notes themselves during lectures. Lectures are supplemented with tutorials in the Design Studio where specialised software packages are demonstrated and

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students have an opportunity to see and use numerous demonstrational and test rigs, posters, catalogues, standards, etc. In MMB281 unit drawing / AutoCAD classes are conducted one hour per week (for five weeks free-hand drawing, and for seven weeks introduction to AutoCAD). In the second design unit MMB381 solid modelling classes are conducted two hours per week. An industry consultant has been invited to deliver solid modelling classes. Exposure to real-life solid modelling examples is highly beneficial to students. Outside the contact hours students continue self-study using course notes, software manuals and other teaching and learning resources available online. They can access the Design Studio if necessary.

In-class teaching and self-study is supplemented with industry visits where students can see practical application of theoretical materials they have learned. Special emphasis is placed on the importance of the Occupational Health and Safety. One of the design tutors is the Chief Safety Engineer from the Division of Workplace Health and Safety of Queensland Government. Being regularly involved in investigation of industrial accidents he is capable of giving real-life examples and also made valuable contribution in the development of teaching and learning resources.

All three units contain design projects. In the first unit students in small groups of 3 to 5 members participate in the Design and Build competition (it can be Warman Competition arranged by the Institution of Engineers, Australia, or internal Design and Build Competition arranged by the School of MMME). Since this unit is common for different degrees across the School, multidisciplinary teams are encouraged.

In the second design unit students in small groups of three members work on a gearbox design project. As a team they select a concept of the drive using Genius and SEW Eurodrive software packages, and then individually work on the gearbox design for different operating conditions (e.g. arctic, tropical and dusty coal mine with elevated temperatures). During solid modelling classes students develop a solid model of their gearbox and attach it to the project report. The project report is written by each team member individually.

In the third design unit MMB382 student in the same groups of three members work on a lubrication project, which is an extension to the gearbox design project. For the same operating conditions as in the gearbox design project students select lubricants, develop lubrication system and select maintenance system.

Continuing and team projects with individual component expose students to the development of multidisciplinary teams and help to strengthen understanding of the system aproach to design. Classes in the Design Studio are highly beneficial for the development of hands-on and practical skills. Interactive software packages, course materials database, on-line instructional materials, teaching and learning resources facilitate students' learning and shorten the learning curve. The author worked at several Australian and overseas universities having opportunity to compare different approaches to teaching design and collected responses from students, recent graduates, visiting students and postgraduate student that did undergraduate study at other institutions. Comparison with 'traditional' approach to teaching (lectures, tutorials, text books and in some cases printed lecture notes available for purchase) and analysis of students' responses strongly indicate that teaching and learning resources for flexible delivery of Mechanical Design introduced at QUT and teaching approaches used made studying both 'easy and enjoyable to learn' and also made students more confident and better prepared for work in industry.

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Below some of the typical feedback responses from students are placed:

> "I have found the units MMB381/MMB382 to be the best learning experience of the units I have covered at university...".
>
> "I write this e-mail to inform you of how much I enjoyed the Design of mechanical components unit this semester. The unit content and your teaching and tutoring style has made the unit both easy and enjoyable to learn..."
>
> "I have just completed a 12 month (paid) work experience contract with Holden Ltd in Melbourne as a student mechanical engineer. I was assigned to Powertrain Reliability section, ... I would like to say I found both design subjects 1 and 2 were highly beneficial to the work I carried out during my time at Holden. I have just begun design and maintenance of machinery and this is highly relevant to the work I was performing at Holden. I believe to produce good engineers the university needs to take a more practical focus as I found I relied more heavily on the practical - "real world" application, which your design courses address".
>
> "I am writing regarding the feedback on your design classes. I wish to express my gratitude for your hard work. First of all, the stuff you had covered in your design classes was extremely helpful. I am currently working in American Bureau of Shipping in Singapore as an engineer. Sometimes we have to do design review of pressure vessels etc. (ASME or BS code). The design 3 really enhanced our knowledge on pressure vessel calculation. For the rest of students from Singapore, they are doing well. Some of them got a job with Hewlett Packard. At the interview some questions asked were about Design Optimization related to Lagrange method. Needless to say, they did well at the interview. In conclusion, the coverage of the design 1 to 3 is excellent."
>
> "...I have been an Engineer for 21 years and your ideas and knowledge would have been very helpful had I been taught similarly when I went to University in UK in the 80s", (PhD student).

Conclusions

In this paper facilities, teaching and learning resources for flexible delivery of Mechanical Design at QUT have been discussed. It has been demonstrated that:

- Means of flexible delivery of design units and the use of interactive software packages enable students' early exposure to the latest samples of mechanical equipment from leading manufacturers and shortens the learning curve.
- On-line teaching and learning resources developed facilitate students' learning and their work on design projects.
- Involvement of industry and Government experts in tutoring is highly beneficial to students giving them exposure to real-life examples.
- The use of laboratory facilities such as the Design Studio fosters students' learning with hands on experience.
- New teaching approaches introduced in teaching of mechanical design at QUT, and means of flexible delivery, have been highly welcomed by students. Responses from students and recent graduates indicate that Mechanical Design at QUT is 'easy and enjoyable to learn', and also they found themselves well prepared for work in industry.

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Methodology for Evaluating & Selecting Constraint Based Modeling Software for Engineering Design Graphics Courses: First Phase

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***Abstract**: Presently, Computer Aided Design (CAD) systems with constraint based modeling features have become a design tool for engineering graphics and advanced CAD courses in the department of engineering technology at Western Washington University. It is important to find software that provides a user-friendly interface that will help a student understand modeling concepts and procedures. Therefore, the software interface must be able to easily communicate between a student and the CAD system. A highly sophisticated CAD interface may decrease learning efficiency or create a steeper student learning curve. Using system-usability criteria, two popular solid modeling applications packages will be evaluated by 25 students performing a basic solid model exercise. The applications to be evaluated are CATIA V5, R13 and Pro/ENGINEER Wildfire 2.0. The 25 students will be selected from local high school and can be classified as beginners who are just learning the system. The purpose of each of the two applications is primary for mechanical design. Each application will be evaluated on the basis ten different usability criteria: visual clarity, consistency, compatibility, informative feedback, appropriate functionality, flexibility and control, error reduction and correction, user guidance and support, system usability problems and sketching characteristics. The major issue that educators need to consider when selecting software for CAD courses is how to lead students from menu to menu and provide an accurate way to determine where the student is in the system at any stage. Using a questionnaire approach will provide significant data that can be used for making usability decisions. Usability is an important criterion for software selection committees to be able to make decisions about the suitability of software for first year students in an engineering or engineering technology program. The higher usability of a CAD system should be emphasized as a way of helping students to begin conducting design tasks successfully with minimum difficulty.*

***Keywords**: constraint based modeling, evaluating, selecting*

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Introduction

Developments in computer technology over the last twenty years have significantly changed the way products are designed and manufactured (Branoff, Hartman and Wiebe, 2003). Constraint based modeling software has been developed through a series of evolutions to improve the geometric representation of a 3D (three dimensional) physical part. The software provides significant data that can be used at each stage of the design process, from concept to final part, including part documentation.

The Department of Engineering Technology at Western Washington University currently utilizes two high-end constraint-based 3D modeling software programs for engineering graphics and advanced CAD courses. Since these courses emphasize the use of CAD as an engineering design tool, it is important to find software that provides a user-friendly interface that will help students readily understand modeling concepts and procedure. Therefore, the software interface must assist communication between a student and the CAD system. Sophisticated CAD interfaces may decrease the student learning efficiency. The following methodology was developed to survey and evaluate the usability of two commercially available and widely used constraint-based, 3D modeling software packages that have similar functional capabilities: CATIA® V5 R11© and Pro/ENGINEER® Wildfire™. Following is a brief description of each of these packages.

CATIA® V5R13©

Dassault Systemes CAD software CATIA® Version 5 is an integrated suite of Computer Aided Design (CAD), Computer Aided Engineering (CAE), and Computer Aided Manufacturing (CAM) applications for digital product definition and simulation (IBM, 2004). CATIA® is a fully parametric modeling tool with the additional capability of traditional Boolean operations found in prior versions of CATIA®. This gives the user multiple options when it comes to part creation. Parts begin by sketching the basic shape of the part. The part then takes on form through operations such as cuts, slots, ribs, etc. Being an integrated suite, the user can model the part, generate engineering drawings, and move into a finite element analysis to test for mechanical properties, generate machine code within the NC manufacturing application, or use kinematics to simulate motion. These are just a few of the multitude of options available within CATIA®. CATIA® V5R11©, the version of the software used for this study, also has the ability to save to many different formats for transferring data to other CAD packages.

Pro/ENGINEER® Wildfire 2.0™

The latest mechanical CAD offering from PTC (Parametric Technology Corp), represents the twenty-fourth major release of the software that incorporates several hundred improvements and its user interface is drastically update (Huxley, 2003). A fully parametric constraint based solid modeling software product, Pro/ENGINEER® uses feature-based modeling to create a part. This means the designer creates all the features that make up that part. Similar to CATIA®, the designer typically begins with a base feature, which is a solid object roughly the shape of the part he/she wants to create. Then, the designer can add features (cuts, slots, holes, chamfers, and other features) that shape the base object into the part. With Pro/ENGINEER®, it is possible to examine the final part in a number of ways including wire frame, hidden line, and shaded versions. Several application modules such as Pro/SHEETMETAL, Mechanism Design, and Design Animation are available within the

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packages too. Pro/ENGINEER® Wildfire 2.0™ also provides different formats for exporting a file to the different application software packages.

Evaluation of Two Packages

The CAD packages currently used at Western are very similar in basic function. However, the faculty have concerns about the user-friendliness of each and therefore which package should be used in the beginning course. Since the faculty are quite familiar with both packages, it difficult to make this choice and a fresh look by inexperienced users is deemed to be very useful for this purpose.

The usability survey of the two packages (CATIA® V5 R13© and Pro/ENGINEER® Wildfire 2.0™) will be evaluated by 25 participants from a group of randomly selected high school students (sample) in Bellingham, Washington. High school students will be used in this study to insure a limited amount of CAD experience by the participants. Since the authors do not have access to students campus wide, a study of university students would have to consist of department majors. By the time a student declares a major in the department, they will have already taken at least one CAD class. One of the limitations of the study is the low number of participants. However, the CAD lab is limited to 25 workstations and time constraints limit the experiment to one trial at this time. The sample group will be invited to Western's campus and the experiment will be conducted in the CAD lab in the department of Engineering Technology. A step-by-step modeling procedure for both program applications was developed for this experiment. The tutorial will be provided to the sample group upon arriving at the CAD lab. The use of two applications is primary for basic mechanical design only.

Sample

Students from three local high schools in Bellingham, Washington will be selected to participate in the project with the help of Technology Education instructors at each of those schools. Most of the participants will have taken at least one high school CAD class and will be familiar with such programs as Rhinoceros® (3D NURBS software) and/or AutoCAD®. It is highly unlikely that any of the participants will have had experience with a constraint-based system although Solid Works is available in at least one of these schools. Demographic data will be gathered on each participant in order to correlate previous CAD experience with survey results. Students will originally volunteer to be involved in the experiment. The sample group will be selected from the group of volunteers. An attempt will be made to use random techniques to select participants in the study to keep volunteer bias at a minimum. Student selection will however, depend somewhat on the students' ability to secure transportation to the university since the software being used is only available in the engineering technology department's CAD lab.

Modeling Procedures

The authors selected the "shoulder stop" component from Bertoline and Wiebe (2003) as the part for this experiment (see Figure 1). The part contains many of the standard operations one might use within a CAD program. This allows the student to utilize different commands to create the part and allows for better interface with the command structure/icons within the program. The part consists of a basic extrusion or revolves, depending on choice of method, followed by revolved cuts, stiffeners, holes, rounds/fillets, and geometry manipulation. A basic tutorial will guide the student through the appropriate commands, using text and visual prompts, to create the part. These students come with a vary range of CAD familiarity as mention in previous section, but no prior use of CATIA® or Pro/ENGINEER®. The students

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will be given 2 hours to complete each tutorial, after which they will complete a survey to rate the software of a given set of criteria. The same group will complete both tutorials. The intent is to compare the response to each package from the same group. The following table (Table 1) is a brief outline of what the tutorial will contain and the steps used to create the part. The steps will be the same for both software packages to keep the results consistent.

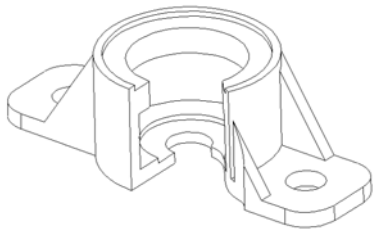
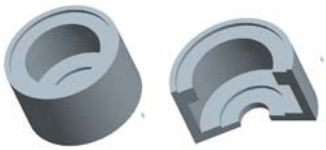
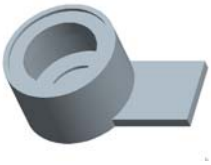


Figure 1: Shoulder stop (part for this experiment) model by Veekit O'Charoen, broken view was created for reference only

Process	"Shoulder Stop" Modeling Steps For reference only	Tools in CATIA V5 R11	Tools in Pro/E Wildfire
1) Extrusion		 (Pad)	 (Extrude)
2) Internal Cut Revolve	 For reference only	 (Groove)	 (Revolve)
3) Extrusion		 (Pad)	 (Extrude)
4) Rib		 (Stiffener)	 (Rib)
5) Hole		 (Hole)	 (Hole)

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6) Round		 (Edge fillet)	 (Round)
7) Mirror		 (Mirror)	Copy-Mirror Under Feature Operation (Pull down menu)

Table 1: Modeling procedures for this experiment and features from both software applications

Evaluation Survey Instrument

An evaluation instrument will consist of set of ten specific questions based on the intended evaluation of usability of each software program. Each set of questions refers to ten different usability criteria: visual clarity, consistency, compatibility, informative feedback, appropriate functionality, flexibility and control, error prevention and correction, user guidance and support, system usability problems and sketching characteristics. The checklist was based on questions reported in previous work by Ravden and Johnson (1989) and Mital, Anand, and Kopardekar (1993), modified slightly to apply to the need of the study. The questions appear in Table 2; responses are indicated using a 5-point Liekert scale where 1 represents "Poor", 2 Below Average, 3 "Average", 4 Above Average, and 5 "Excellent". Thus, high scores represent positive judgments in respect to the quality in question.

Item	Question Content	CATIA scale	Pro/E scale
1	How would you rate the system in terms of Visual Clarity (information on the screen should be legible, well organized, unambiguous and easy to read)?	1 2 3 4 5 (This scale will be used for each item)	
2	How would you rate the system in terms of Consistency (the way the system looks and works should be consistent at all times)?		
3	How would you rate the system in terms of Compatibility (the way the system looks and works should be compatible with user conventions and expectations, for ex, icons or symbols easy to recognize and understand)?		
4	How would you rate the system in terms of Informative Feedback (user should be given clear, informative feedback on where the user is in the system, what actions they have taken, whether these actions have been successful, and what actions they		

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	should take next)?		
5	How would you rate the system in terms of Appropriate Functionality (the system should meet user needs; for ex, 3 buttons on mouse are appropriate for the tasks that you must carry out)?		
6	How would you rate the system in terms of Flexibility and Control (the system should be flexible in structure and present information suitable to control the system; for ex, can you easily undo an action, and step back to a previous stage or screen)?		
7	How would you rate the system in terms of Error Prevention and Correction (the system should be designed to minimize user errors: it must also have the facility to detect and check errors)?		
8	How would you rate the system in terms of User Guidance and Support (informative, easy-to-use and relevant guidance and support should be provided; for ex, does system clearly explain the possible actions that can taken in the context of what you are currently doing)?		
9	How would you rate the system in terms of System Usability Problem (lack of guidance, help, too hard to understand the steps, etc.)?		
10	How would you rate the system in terms of Sketching Characteristics (Do icons represent the function or the task, does system allow you to specify snap and grid-lock)?		

Table 2: Survey questions

Data Analysis

The t test for non independent samples will be utilized for this study after the collection of all data from the evaluation checklist. According to Gay (1996), non-independent samples are samples formed by some type of matching. The ultimate matching is when the two samples are really the same sample group at two different times. For example, one group has received two different treatments at two different times. The t-test for non independent samples is used to determine whether there is probably a significant difference between the means for one

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sample at two different times. For this study, the authors will treat the same group of high school students with two different CAD systems at two different times.

Conclusion

After the data collection session, participants will be interviewed about the clarity of the survey response items with the goal of revising the items. A follow-up study will be conducted with the revised response items for the purpose of verifying the results. During the second session, a third software program, Pro/DESKTOP®, Pro/ENGINEER® companion software will be added. Pro/DESKTOP® is currently being made available to high school programs under very favourable conditions in order to make a constraint-based modeling program available to high school students. The addition of this software will expand the potential audience for this project to include high school teachers desiring to make an appropriate choice for 3D, constraint-based modeling software. The results of the survey will be made available in various publications and at various conferences including the Engineering Design Graphics Division (EDGD) of American Society of Engineering Education (ASEE), Australasian Association for Engineering Education (AAEE) and International Technology Education Association (ITEA). Using a questionnaire approach will provide significant data that can be used for making usability decisions. Usability is an important criterion for software selection committees to be able to make decisions about the suitability of software for first year students in an engineering or engineering technology program.

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Choosing PBL Paradigms: experiences and methods of two universities

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Abstract: *Problem Based Learning (PBL) has been implemented in many engineering education institutions world wide. There is a continuum between the faculties which have PBL in a single course (subject) through to other institutions which have PBL as a major curriculum focus. A continuum between the introduction by an individual academic solely with an interest in educational theory and a desire to stem falling grades and interest levels through to a major teaching focus of all staff. University of Southern Queensland (USQ) and Aalborg University (AAU) are 2 universities on either ends of this continuum. They have different student profiles and different implementation strategies but both have found PBL an effective way of meeting academic objectives. Engineering Accreditation agencies world wide have recently moved to a greater focus on generic graduate attributes such as teamwork, communication and problem solving skills (ABET, 2003; IEAUST, 1997) and PBL seems the ideal way to include these skills in the curriculum. In this paper the authors will show a diversity of implementation strategies modified to individual institutional needs and resources can still lead to success.*

Keywords: *Problem based learning, engineering, international*

Introduction

AAU in Denmark and USQ in Australia are very different institutions with differing student profile and resources. AAU is recognised world wide for their expertise over 30 years in project oriented team organized problem based learning (POPBL) in engineering education. AAU has now transformed this experience to on-line education. USQ is a regional university whose expertise lies in distance education. To varying degrees they have both utilised the advantages of PBL and modified implementation strategies to suit individual institution needs. Both have been successful with this approach showing that PBL, with rigorous planning and consideration of academic objectives, is flexible and can be modified to be successful in a wide variety of situations including on-campus and distance education.

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AAU

Aalborg University was inaugurated in 1974 as the fifth Danish university and has more than 12000 students registered in three faculties - Humanities, Social Sciences, and Engineering and Science.

The Faculty of Engineering and Science has approximately 4850 students. It is an innovative faculty offering a wide range of educational programmes all using a PBL pedagogy leading to degrees at bachelor, master and doctoral levels within the fields of engineering and science. Its approach to education is innovative and has lead to recognition of its programs and teaching expertise at an international level. It has a strong international outlook and participates in a series of partnerships with regional, national and international business and public sector organisations. (Jensen H, 2003; Jakobsen K. (ed), 2003)

The faculty's priority is to be responsive to the needs of all students, maintain collaboration in partnerships and offer continuous access to education and lifelong learning (Kjaesdam F, 2003)

USQ

USQ began 32 years ago as an Institute of Advanced Education and gained university status in 1990. The university has five faculties, Engineering and Surveying, Science, Education, Arts and Business. As at August 2003, the University has approximately 23,000 enrolments, including over 6,400 international students. The university offers three modes of study on-campus, distance and online. The majority of students (approximately 75%) study off campus by distance education, making it one of the international leaders in distance education (University of Southern Queensland, 2003)

The Faculty of Engineering and Surveying has approximately 2500 students of which approximately 600 study on campus. The remaining students use the flexible education offered by the university to work and study simultaneously at locations across Australia and the world. The faculty offers 26 programs of study over 1, 2, 3 and 4 year programs through to Doctoral studies. There are 9 majors offered including agricultural, surveying, GIS, electronic, civil and mechanical. (University of Southern Queensland, 2003)

The University and the Faculty have a commitment to providing accredited tertiary education through flexibly study arrangements to students from a diverse range of social, economic, and cultural backgrounds (University of Southern Queensland, 2003)

History and Definition of PBL

Most current literature points to McMaster University in Canada with the introduction of PBL into its medical schools in the 1960's, but its intellectual history is much older. Thomas Corts of Samford University sees PBL as "a newly recovered style of learning"(Rhem, 1998).

The educational and philosophical theories underpinning PBL were not explicit in early PBL literature (Rideout, 2000, Newman et al, 2001) and the pioneers of the McMaster program had no background in either education or psychology. They simply thought that learning in small teams using authentic cases and problems would make medical education more interesting and relevant for their students (Barrows, 2000; Newman et al, 2001). This current PBL methodology is now currently used in more than 80% of medical schools in the USA (Vernon & Blake, 1993).

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From these beginnings PBL has been incorporated into a wide range of professional studies including nursing, dentistry, social work, management, engineering and architecture (Boud & Feletti, 1997) and spawned a plethora of educational terminologies with an almost unclassifiable array of categories (Barrow, 2000).

For the purpose of this paper we will define PBL as a constructivist learning paradigm where small groups of students, engage in cooperative learning and collaborative problem solving to solve problems in complex and authentic projects. These projects pursue specified learning outcomes that are in line with academic standards and course objectives with assessment focusing, to a varying degree, on the project outcome versus team process.

PBL in Engineering Education

Interest in problem-based learning (PBL) arose in engineering higher education in response to criticisms that programs failed to equip graduates with collaborative problem-solving skills required for a life long learning and the reality of the work place (Wilkerson & Guselaers, 1996; Boud & Feletti, 1997; Brodeur et al, 2002). In many cases educational outcomes have focused on the technical and quality aspects of design and neglected the professional skills necessary *for* design (Davis et al, 2003). Problem based learning has now become a widespread learning method in disciplines where students must learn to apply knowledge not just acquire it. The need for problem solving skills, teamwork and communication skills, skills and knowledge acquired through problem based learning, have been highly prioritized in recent reports from major engineering accreditation and professional bodies (ABET, 2003; IEAUST, 1999; IEEE 2002; Kjaersdam & Enemark, 1994; Knudsen et al, 2000)

AAU has a long history PBL and began its 'experiment' in 1974 and has PBL thoroughly interwoven in its curricula such that its students working in this methodology spend roughly half their time in team projects. Conversely USQ began introducing PBL in 2002 and while some courses may utilise team work only approximately 12.5% of the program is in formally structured PBL courses (4 of 32 credit points for a 4 year degree program).

From Supervisory Role to Facilitator Role

Transitioning from a traditional didactic educational model of education to a learner-centred model is critical to the long-term success of educational institutions (Spender, 2002). This is a significant and radical change. A major barrier is staff attitude and uneasiness with change (McNamara, 1999). The PBL educational paradigm means that the roles of academic staff will change with a greater emphasis on designing and preparation; guidance and support; managing and delegating rather than lecturing and tutoring.

The programs at AAU have been designed from the beginning in the PBL paradigm. USQ, like many Australian universities, is currently undergoing this transition. Despite the differences in the implementation of PBL similar levels or types of supervising roles exist. The challenge at both institutions is to encourage staff to continuously rethink their roles as educators and redefine the traditional concepts of teaching. These supervisory roles, regardless of the implementation strategy, could be defined in terms of didactic, technological and pedagogical. However the focus should be on moving from a supervisory role which has responsibility for the end product to that of a facilitatory role which helps the team process to reach the desired goal.

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Didactic instruction traditionally has been conceptualised as the transmission of facts to students, who are seen as passive receptors. Knowledge in this situation is symbolic and isolated; learning does not typically motivate students or provide them with problem-solving skills they can apply to other situations (Dewey, 1902). Academics typically use a lecture format, writing notes on a board and presenting knowledge as facts. It is the lecturers who are active and the students passive; lecturers are the distant authoritive figure showing the 'right' way to solve problems and which 'facts' to learn (Smerdon et al 1999). Most literature hints that the old didactic model of learning is out of date and educators are challenged to transform the educational experience so that it is meaningful to the information-age learner. The role of the educator/lecturer in PBL does however still need some didactic supervising, but in a modified form. Active participation from the lecturer in the learning process, guidance on problem solving and the presentation of 'facts' and information still form a vital part of the PBL learning experience. In PBL these elements of didactic teaching are preserved and are necessary for perhaps one of the most vital aspects of education in this paradigm:- the structuring of the problem or project.

Gijselaers & Schmidt (1990) have shown that the problem design itself has the greatest overall effect on student learning outcomes. A good PBL problem or project is engaging and orientated to the real world; is ill structured and has multiple outcomes or hypotheses; requires team effort; builds upon previous knowledge and experiences; is consistent with desired learning outcomes and curriculum objectives and promotes development of higher order cognitive skills. In the facilitator mode the skill of the academic is not in the presentation of facts but the weaving of specific learning objectives into an ill structured real world complex problem. The lecturer is active and preparation of the project/problem requires significantly more technical skill, knowledge and time than the traditional lecturer. The didactic teaching still takes place, in PBL it happens behind the scenes.

Experience from AAU shows when transforming on-campus education into distance education that the didactic supervision used is the same. Project support courses (P-courses) are offered in the beginning of the semester. Students find the project work more enjoyable and often do not engage in the subject matter (Knudsen et.al. 2003, Helbo et.al.,2003). Thus the facilitator must be active in the so called 'course focus' period. The facilitator must process email and reflective sessions within 24 hours and also comment on the problem solutions submitted by the students in an appropriate time frame. If students are not active, the facilitator must take action to prevent the student dropping out.

USQ has similar evidence to support the need for didactic supervision with both on campus and distance cohorts. Facilitators must constantly monitor student emails, weekly reports and team activities to ensure active participation by all team members.

Closely tied to the project/problem design and formation is the consideration of the technological aspects of supervision. In this technological age supervising a team in PBL also requires significant academic input. Facilitators must ensure appropriate levels of technology are available and appropriately integrated into projects. At lower levels of a program technology is a "cognitive tool" where the incorporation of computer hardware and software extend student capabilities allowing access to data and information; expanding interaction and collaboration with others via networks (Krajcik et al., 1994). It can make the knowledge construction process explicit, thereby helping learners to become aware of the process (Brown & Campione, 1996). At higher levels of a course, technology can be integral to the project. Its inclusion is a core element in the knowledge acquisition and it emulates tools experts use

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to produce artifacts (Krajcik et al., 1994). Competence development of facilitators in managing new technology is very difficult due to established staff autonomy in using IT in the teaching and learning process. In on-campus and class room driven sessions we see a great variety of IT in-use, which is non-fatal since the lecturer and other students are 'right here' to help if things goes wrong. When it comes to distance education, the students are typical on there own, and the use of IT must be well considered, chosen and adapted by the facilitator/ lecturer, so autonomy is only allowed from a certain level of chosen common denominator.

Pedagogical aspects of PBL supervision relate to the mechanics of team supervision. This includes the motivational aspects of PBL, encouraging participation and self learning; team dynamics, effective communication and conflict resolution; and the annotation and review of team work. This is the area where most staff feel the most apprehensive and traditional engineering faculty have the least experience (Hansen and Jensen, 2003). Hansen (2000) and Langeland (2000) documented that by adequately addressing group dynamics, the team is more effective both in team and individual outcomes from the process. Specialized for distance learning and courses, the transformation from well known class room teaching to a virtual class room learning environment is difficult. The developer must turn the class teaching process into a self-learning process. This can be done by guiding and motivating the student along with self tests, team reflections and peer problem solving (Borch et. al., 2003).

Sample Implementation Approaches

AAU - Project oriented problem based learning (POPBL)

The teaching program at Aalborg University has been using POPBL paradigm since its inception in 1974. It is based on research and is organised at two levels - lecture courses and projects. These are related to the framework of the individual semesters and form the *theme* of the semester.

Students from a specific study programme work in self-selecting teams of 3 – 5. Together with a facilitator they formulate the topic and framework for a practical or theoretical project.

The project work accounts for 50% of student time. The remaining 50% is devoted to lectures, tutorials and laboratory work. The P-courses (sometimes called PSC – Project Support Courses), serve as direct support to the project work, whilst others relate to the theme of the semester (S-courses sometimes called NPSC –Non-Project Support Courses). Project unit is the collection of all project activities. Refer to Figure 1.

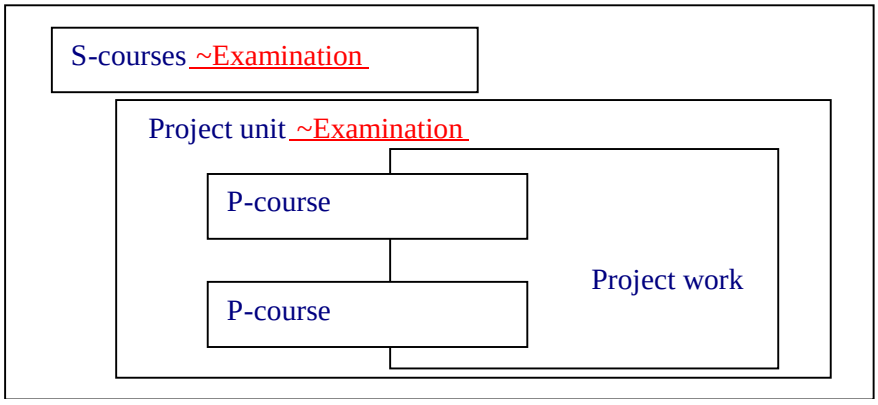


Figure 1 One full-time semester activities at AAU

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Assessment of the semesters work is via examinations for the S-courses and a written report and oral examination for the team project report and the supporting P-courses. (The P-courses are evaluated via the project). The team's facilitator and external or internal examiners conduct this project examination. This mechanism allows the allocation of individual marks for the project. The project report is a comprehensive document of between 75 to 150 pages (22500 to 45000 works) depending on the team size (Aalborg University , 2003).

AAU primarily recruits students from the County of North Jutland and secondarily from the counties of Aarhus and Viborg and has a relatively homogenous student population. Students entering the university must have one of the following qualifications or equivalent:

1. HF Higher Preparatory Examination
2. HHX Higher Commercial Examination
3. HTX Higher Technical Examination
4. DK University Entrance Exam (sometimes called Danish A-level Exam)

When students register, they must decide between a bachelor and a master-candidate education. It is important that the students are aware that the education is performed in a POPBL environment and organized in teams.

Students enjoy the team work. It forms a tight social community for studying, but the work is also 'problem based' and students gain a sense of achievement in working on and completing the 'real-life' project. The team is also a forum for peer assistance and strengthens the responsibilities for progress in work. Most of the working hours are on campus leaving little time for individual work like reading and personal reflections. Project teams able to plan correctly and reserve time slots for individual study activities have an advantage if the self study is evaluated later in the team. Distributing the workload and responsibilities strengthens the learning process and increases progress on the project. The facilitator monitors this.

The majority of the graduates obtain employment relatively quickly by Danish standards and more than half the graduates are recruited to larger metropolitan areas and companies. 64 percent are employed 3 months after graduation and only 6 percent must wait more than 12 months to get their first position. 79 percent of all graduates obtain employment within the main area of their major qualifications.

The graduates that have had a student job, internship or projects prepared in cooperation with external partners obtain employment considerably faster than those who have not had this experience. Half of those graduates that have had a student job related to their profession obtain employment before graduation.

The graduates, based on a number of characteristics, rate the applicability of their education very positively. In particular, the project oriented learning paradigm is seen as very valuable in the professional working context. The graduates state that as part of their education they have learned to work innovatively and independently.

Many students also continue their professional development after graduation with 60 percent of students undertaking supplementary courses of a short duration (less than 8 weeks) and 25 percent taking longer courses. Less than 2 percent of students believe they do not require further professional development (www.auc.dk/dimittend/resultater/html/rapport/resume.html).

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Future strategies

Problems with the P-courses have been identified and solutions have been proposed. A P-course designed to support the project work is given as a scheduled lecture series for all students. Many students are not motivated to learn the material covered in the lecture. Later when the students see the applicability of the lecture content to the project their motivation changes and they consult the lecturer who has to repeat the material. A solution to the this problem is to turn the P-lecture sessions into self studying team activities facilitated by a professor and replace teaching with reflections (individual, team and plenary). This will solve the motivation and synchronization between P-courses and project work. Another solution is to develop courses in a flexible delivery mode similar to courses offered for students at remote location, so the students can take them when needed.

The second problem is the need for the P-course topics seen from a project work point of view. Research staff focusing on interesting research activities mostly offer suggestions for projects and less on study plans involving major topics for the semester. In this case, the students do not necessarily need major parts of the PE courses and thus might not attend. This is a problem since all courses (S and P) are part of the curriculum.

One solution to this problem is to force staff to propose projects closely linked to the curriculum and moderate proposals before submitting them to the students. Student project proposals are also acceptable but are seldom submitted due to a lack of knowledge about the curriculum and time to sufficiently moderate the proposals.

USQ implementation strategy

In a major course review 4 new courses using PBL were implemented. These courses were planned to introduce new 'content' to students including basic physics, statistics, programming in MATLAB as well as a systems approach to engineering and the generic skills of communication (written formal and informal), problem solving strategies, team work, conflict resolution, research skills, and basic computer skills including word processing, spreadsheets, internet and email. The first and, to a smaller extent the second course, would focus on the team work and communication skills of the students. It is hoped that by the third and fourth courses students are proficient in the teamwork aspects and can focus on the technical engineering objectives. These four courses have a capstone course of an individual research project and are integrated into the articulated study program offered by USQ as shown in Table 1.

Course	Student cohort – all majors
Research Project (individual)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 4(Teams of 4 students)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 3(Teams of 4 students)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 2(Teams of 6 students)	Bachelor of Engineering, Bachelor of Surveying, Bachelor of Technology, Associate Degree
Engineering Problem Solving 1(Teams of 8 students)	Bachelor of Engineering, Bachelor of Surveying, Bachelor of Technology, Associate Degree

Table 1 Problem Solving Courses and Associated Programs of Study

USQ has a unique student profile. It has large numbers of mature age students who combine study at a distance with full time work. Students have a diverse educational background often

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without the normal prerequisite studies of math and physics required for engineering studies but with a range of both professional and life skills (Brodie & Porter, 2004). USQ also has large numbers of international students from over 80 countries. The introduction of PBL courses was seen as one method of using this diversity of educational, age and cultural backgrounds to advantage particularly in the core courses that all students, regardless of their program or major, must undertake.

The assessment strategy adopted varies slightly for each of the four PBL courses and the final capstone course. In the first course students are assessed on four team projects and the project mark is modified to an individual mark based on peer and self assessment reports (Brodie & Porter, 2004). This constitutes 75% of the total mark for the course with the final 25% from an individual reflective portfolio. The second PBL course has three projects and teams can 'share' the team mark within certain limits based on team consensus. The students also keep a reflective portfolio. The third PBL course uses an exam (60% weighting) to test individual knowledge in addition to the three team projects. Assessment for the fourth course is yet to be finalized and the final capstone course of an individual project is assessed by thesis.

USQ has yet to graduate students from the new course structure but preliminary reports from accreditation bodies, faculty review committees and employers have been very supportive. USQ has been the first university world wide to become fully accredited for its distance education programs and visiting members of the Washington Accord have held up the education strategies as "world's best practice". However the major cultural change for both staff and students continues to be a major problem. The increasing cost of higher education in Australia has had a tendency for students to focus on the quality of 'teaching' rather than the quality of their 'learning'. A course with no lectures and with out the traditional study book, which contains all information to pass the examination, is not seen as providing 'the service paid for'. This is natural, but moving to POPBL with a problem to solve and a project as the driving factor, this will change and move the focus to the project while courses may more or less stand alone. This requires a new style for courses to support a learning mode either individual or in teams (Borch O et al, 2004). The need to focus students on *learning* rather than passing the examination is a pressing need for the Faculty.

This is however focusing on the negative aspects and to a certain extent underestimates the students. Many of the mature students, through their reflective portfolio, have seen advantages in PBL. The future aim is to encourage all students to take responsibility for individual and life long learning.

Proposed future strategies

Resource implications limit the time facilitators can spend with individual teams helping to facilitate learning and teamwork. The majority of staff are uncomfortable with the pedagogical aspects of supervising and feel this is outside their role as academics. This change in roles has come quickly and without effective training. USQ is investigating the AAU model where teams in their first semester of PBL have two facilitators – technical and 'teamwork'.

Further difficulties arise with asynchronous team meetings in both the use of technology (chat rooms and discussion boards) and the 'virtual' facilitation process. A standard platform of communications suitable for *all* students needs to be set. Additional training in facilitating distance teams meeting asynchronously will be employed.

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Conclusions

This technological age of electronic communication, the Internet and access to a huge amount of data in an instant is having a huge impact on traditional teaching methodologies. Students often have no need to come to lectures. Lecture notes are available electronically and traditional 'chalk and talk' lectures do not hold the interest of students. A major paradigm shift in education is required not only to cope with these factors but also the effect rapidly changing technology is having on the engineering profession. What will professionals of the 21st century need to know in order to contribute to society? What skills knowledge can universities give their students in order to meet these unknown needs and changing values? How can universities cope with the changing face of the student population and its diversity? Incorporating PBL as a major component of engineering curriculum does not answer all these questions, but it can play an important role. It is important to realize the following paradigm based on Fink (2002): *"In the university, learning is a goal and the problem is a tool. Students develop project skills. In the industry, these skills are the tool, and the product is the goal".*

In the two case studies presented of PBL at AAU and USQ, shows that PBL is a flexible educational paradigm which can be adapted to suit the requirements and resources of different institutions. Both Faculties have slightly different interpretations of PBL and the implementation strategies have been varied to suit the student profile and curriculum requirements. The curriculum and homogeneity of students at AAU allow for students to be streamed into majors very early in the program. This allows for highly discipline specific projects with development of in depth technical knowledge and skills. The courses at USQ have students form all majors and thus projects are broad and multidisciplinary. This makes projects harder to formulate and plan but student gain a broad range of skills and knowledge. The diverse student background and individual educational goals are used to advantage. This flexibility is one of the many advantages offered by PBL. PBL does meet with educational success. Many institutions and many professional areas of study demonstrate this. Careful planning of the curriculum with respect to staff and student profile, desired outcomes, resources and constraints, PBL offers challenges and advantages which future educators can no longer afford to overlook.

Rather than feeling threatened by the changing roles and the "loss of power" in the classroom, faculty must realise that their contribution to curriculum planning, project formulation and team facilitation in POPBL is critical to the learning outcomes and success of the teams and programs. It does not diminish their expertise, but rather their expertise both as professional engineers and educators are vital to the education process. Davis and Harden (1999) refer to the student behaviour, individually or in a team, is expected to progressively mirror that of the relevant professional. As educators and professionals we expect practicing engineers to maintain and practice the philosophy of "life long learners". Society expects engineers to keep up with technology, community trends, needs and best practices. It is therefore expected that educators must evolve by changing teaching paradigms to mirror the requirements and expectations of professional engineers. PBL, in its many forms, offers an opportunity both to effectively educate future professionals and maintain and expand faculty expertise.

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A Project Based Teaching Approach for International Exchange Students to Create Learning Models for AUT Students

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***Abstract**: An exchange programme involving Auckland University of Technology (AUT) in New Zealand and Wismar University in Germany was established in 2000 to foster international relationships between both universities, to encourage programme benchmarking and to facilitate student exchange through a five month internship programme. The students are engaged in activities such as creating visual and mathematical learning models to be used by AUT undergraduate students. They also learn how to successfully operate within a foreign environment (language/culture/social). Academically, the internship encourages a project based and independent teaching and learning style. Therefore, a problem based teaching and learning approach is used in the supervision of these students.*

The learning models are created using tools such as computer aided design 3D solid modelling applications (SolidWorks), computer aided engineering static and dynamic analysis software (COSMOS) and mathematical software such as MATLAB and Mathcad. Examples of learning models developed include the simulation of dynamic motion of a governor and robotic transformation of the end-effector. These models have been successfully integrated into the curriculum and are used as teaching and learning tools in undergraduate classes at AUT. This approach has proven to be extremely useful to motivate both exchange and undergraduate students.

***Keywords:** project based learning, problem based learning, teaching and learning models*

Introduction

A student centred approach to project based learning was introduced in the Faculty of Science and Engineering at Auckland University of Technology (AUT) in Auckland, New Zealand, for international exchange students following a student exchange programme and partnership agreement with Wismar University in Germany. The exchange programme was established in 2000 to foster international relations, programme benchmarking and student exchange.

As part of the compulsory requirement for their mechanical engineering degree at Wismar University, German students have to find a placement for their internship for the period of one

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semester in year three. This can either be with a German engineering company or at a university overseas. The aim of the internship is to engage the exchange student into academic activities such as creating visual and mathematical learning models to be used by AUT undergraduate students, to obtain a better understanding of complex mechanical engineering interactions and to learn how to successfully operate within a foreign environment. The projects are designed at an appropriate level and are assigned to the students to facilitate the integration of their prior learning with the aim to develop new knowledge leading to the creation of learning models of engineering systems.

Studying overseas has become an increasingly popular option amongst the German students and the demand has long exceeded the provision of placements. Therefore, the selection process for scholarship is based on the students' history of academic achievements by their Faculties in Germany.

As the host of these exchange students, the AUT Faculty of Science and Engineering had to develop a teaching and learning approach that attempts to address and resolve all of these issues, or 'drivers'. The influence of theses drivers together with domestic drivers relating to the provision of engineering education has resulted in the design of a project based teaching and learning approach being adopted for this group of exchange students. These drivers are discussed in the following section.

Drivers in the Design of a Project Based Teaching and Learning Approach

International Considerations

Since the academic year in New Zealand (February to November) does not coincide with the academic year in Germany (September to June), Wismar University students are unable to study 'formal' mainstream courses at AUT. In addition, the availability of suitable courses of study which meet the required learning outcomes of the internship (viz the development of self directed, independent learning in an unfamiliar engineering environment) are difficult to provide via mainstream courses of study. Rather, a project based approach is more suited to deliver these outcomes.

Fiscal Limitations

There are two main issues related to funding. Firstly, studying is free for German students in Germany and at present no funding for AUT is available for exchange students when they are in New Zealand. Subsequently, there needs to be an incentive for the host university to invest resources in these students. Secondly, changes under our current New Zealand funding regime have contributed to the need for engineering education to shift from traditional teaching methods to a flexible learning environment. Teaching and learning in the tertiary sector are increasingly about doing more with less. While lectures remain the most cost effective way of teaching large groups of students, the challenges of the flexible environment and its accompanying learning-by-research method requires more openness by students and teachers than conventional teaching methods in the engineering sciences (Willgalis, 2002). This shift and the barriers encountered are discussed below in more detail.

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Barriers to Dissemination in Innovative Education

At many universities, the classroom today is still almost like it was in the beginning of the 20th century (Kazachkov et al., 2003). Engineering education has historically focused on structured lectures and labs designed to deliver scientific and technical information with little or no opportunities to the student for discovery and independent learning.

All teachers have their own style of teaching and learning and traditionally they have learned by watching others (Kolari and Savander-Ranne, 2002). Therefore, most educators are inclined to teach how they were taught. Formal lectures are also the easiest and most economical way to teach large groups of students, while a project based discovery learning approach requires more time, flexibility and openness by academic staff and students than conventional teaching methods. Although some technical equipment such as slide projectors, overhead projectors and video projectors have evolved over the years, "chalk and talk" is still the preferred option. Also, with the introduction of personal computer systems and advanced software applications some innovative teachers have incorporated this technology into the curriculum and have used it as part of their teaching and learning material. However, others have totally avoided this new medium (Kazachkov et al., 2003).

Using computers in the classroom can be a frustrating experience for the educator as often lack of confidence and skills becomes obvious to the students. Also self motivation and extra hours are required in preparing the material, the students often don't appreciate the significance of this and consequently the lecturer gets discouraged and gives up. In addition the fact that most classrooms even today are not equipped for teaching with the aid of computers is certainly another contributing factor to the many failures in "electronic learning" (Kazachkov et al., 2003). Another reason is that engineering educators today have to deal with increasingly complex and fast evolving engineering software applications and it is impossible for academic staff to keep up to date with the vast variety and complexity of these new tools and to become a competent user of them.

Today, much more material is available to the student in electronic form through access to multimedia resources in the university's online systems or on the internet. These resources promote self paced learning and learning by repetition, whereas conventional up front teaching methods do not give the students theses opportunities. A contemporary approach to overcome this problem is to get the students to learn how to solve their problems and to learn a particular software application on their own.

Shift to Problem Based Learning

Flexible learning at AUT relates to the increased access and modes of delivery available to support engineering education. The project approach adopted for the exchange students focuses on the development of key teaching and learning tools (both online and physical) for incorporation into the curriculum. They are based on current lab or practical based resources available to the engineering programmes. The learning outcomes of the internship relate to the development of self directed and independent learning. The timing of Wismar students' arrival at AUT also necessitates that they will need to work independently, as our own students are on summer vacation or work experience during much of the time the exchange students are with us.

The aim of the internship is to expose the students to good engineering practice, in particular, to develop the students as engineers who solve problems – irrespective of the environment in

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which they are operating. Problem solving is an essential component in an engineer's life and the majority of today's graduates will be in one way or the other involved in the development, design and/or implementation of new products, maintenance of equipment or systems, or other project based activities in customer service or sales. A project usually consists of a series of problems. These problems may be interrelated and interdependent as depicted in Figure 1. Thus so far, engineering education has mainly focused on structural learning and conducted labs to deliver scientific and technical information with little or no opportunity to the student for discovery and independent learning.

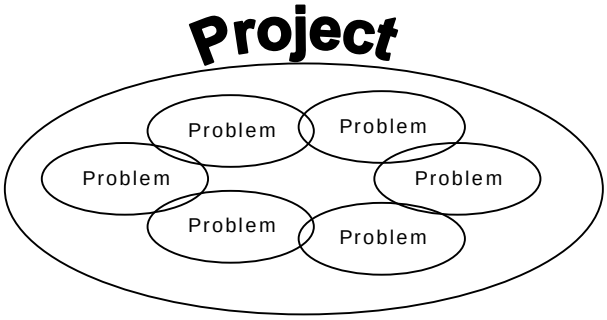


Figure 1: A project comprising interrelated and interdependent problems

Problem based learning (PBL) has emerged to become an instructional approach that is gaining growing interest within the engineering education community (Hadim and Esche, 2002). Barbara Duch (2002) describes PBL as: "An instructional method that challenges students to "learn how to learn," working cooperatively in groups to seek solutions to real world problems". Hadgraft and Prpic (1999) address the key ingredients of PBL and postulate that it should not be confused with design projects or case studies where the focus is predominantly on the application of existing knowledge and integration of what is already known. PBL goes beyond this, students will encounter some concepts for the first time and therefore they need strategies for acquiring this new knowledge (Hadgraft and Prpic, 1999).

Some other outcomes related to problem based project work include: enhancing student participation in the learning process (active learning and self-learning); promoting team work and problem solving skills related to project management and engineering economics; taking responsibility for the project budget; and developing good communication skills (written and verbal) such as presentation and technical writing skills.

Implementation of a Problem Based Project Approach

The effect of the drivers discussed in the previous section has resulted in a problem based project approach being implemented for the exchange students. While we have some knowledge of the exchange students' curriculum, the students' specific interest and majors, it is often difficult to accurately assess the level of existing knowledge a student is bringing to an engineering task or project. This aside, we attempt to match students and projects relating to their majors and anticipated level of knowledge in a field while deliberately extending the student beyond this level to discover new knowledge for themselves. The projects adopt a 'research' approach to the solution of a multi-faceted engineering problem.
Students 'solve' the interconnected problems within a project through a variety of parallel strategies such as physical construction and experimentation, mathematical modelling and critical analysis using complex engineering design application software. With initial guidance and advice on these strategies from supervisors and allied staff, such as administrators,

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technicians and librarians on how to find and use appropriate learning resources, this project based learning approach prepares students to become critical and analytical problem solvers. The following completed projects will be briefly described in this paper:

- Robot Implementation
- Governor simulation

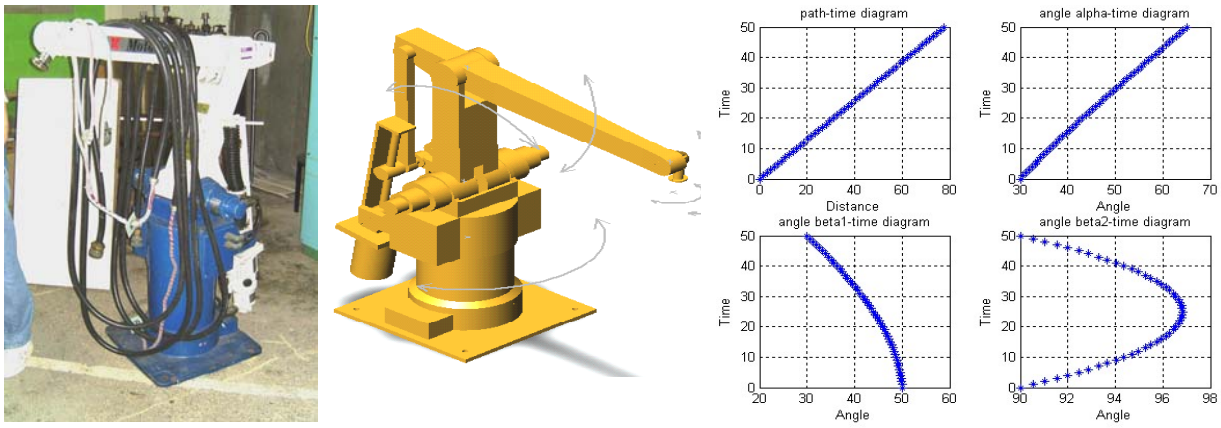
Other projects have included optimisation of the liquid flow in the observation area of a water tank for marine biological investigation and the design and implementation of a computer aided manufacturing (CAM) environment for the AUT workshop. Space limitations in this paper prevent a full description of these projects.

Robot Project: Implementation and Motion Analysis

The objective of this project was to commission a MOTOMAN five axis robot on AUT premises, to prepare user manuals, demo programmes and to perform motion analysis using COSMOS Motion and MATLAB. The robot shown in Figure 2a was put in storage several years ago as the engineering department moved to new premises.

A literature review was carried out on robot technology, history and applications, and a safety protocol was developed in accordance with NZ occupational health and safety act to ensure safe operation. Some initial mechanical and electrical faults were rectified in consultation with the initial supplier and an operation manual was produced. A 3D solid CAD model as shown in Figure 2b was generated and motion analysis was performed on the model using COSMOS Motion.

Equations were set up for translational and rotational motion using MATLAB. Some results are depicted in Figure 2c. The mathematical models can now be developed further to drive stepping motors for any other robotic end-effector. By changing parameters such as displacement, velocity and acceleration of the models (MATLAB and COSMOS Motion), AUT students can now manipulate the robotic motion and can observe the affects of their alterations. The robot is now fully functional and our technicians are trained to generate numerical programmes and to demonstrate the principles of robotic motion to our students.



a) MOTOMAN robot b) 3D CAD solid model c) MATLAB motion plots

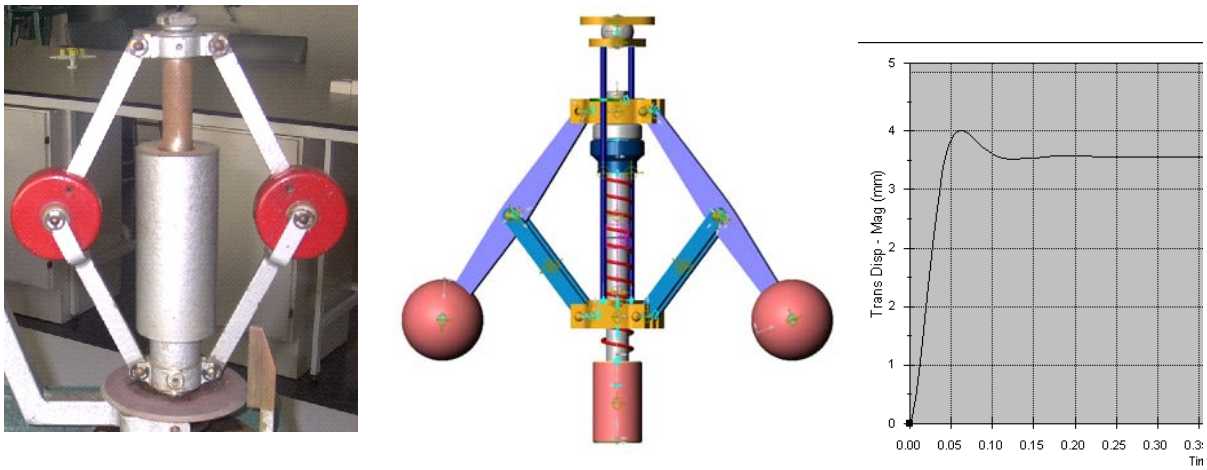
Figure 2: MOTOMAN Robot project

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Governor Project: Simulation of Dynamic Motion

The governor shown in Figure 3a, located in one of our labs, was redesigned using SolidWorks and analysed using COSMOS Motion and MATLAB. With these tools, the affects of inertia, rotational velocity and acceleration on a model like this under the influence of gravity can be clearly explained, observed and manipulated. The CAD model is depicted in Figure 3b and is now available as a virtual and visual learning aid to demonstrate the behaviour of 'flying weights' and how they respond to rotational motion. This 'virtual machine' is now used in dynamics related papers to illustrate these interactions. The assignment for the students is to apply velocity, moments, forces and boundary conditions to the model and to produce an outcome (plot) as shown Figure 3c.

The German student who completed this project took it home for assessment and was awarded a grade of 1.0, which is equivalent to 100%. This work reflects well on a successfully run exchange programme with projects designed to fulfil a lasting purpose for the benefit of AUT students.



a) Governor b) 3D CAD solid model c) Desired outcome (plot)

Figure 3: Governor project

Conclusion and Discussion

A teaching concept of project based learning using exchange students to produce interactive teaching models is presented. Delegating projects to students has been challenging but can be evaluated as a rewarding exercise and an overall success. Since the exchange students are sponsored by their university, they tend to naturally be motivated but in the context of a problem based project design and implementation they also develop ownership of and pride in their work.

Outcomes for the Benefit of the Exchange Student

The student learns to develop the ability to think critically and analytically and a high degree of independence is required as the student has to learn how to identify resources and how to communicate effectively in a foreign language (English). This includes activities such as negotiating with software vendors, hardware suppliers and other staff members from the Faculty such as technicians and administrators. Having been given a specific problem fosters independent learning and stimulates the critical evaluation of ideas and enables the learner to

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formulate his or her own goals. All these aspects provide a useful foundation to develop long-life learning skills.

Outcomes for the Benefits of AUT Lecturers and Students

The benefits for AUT engineering lecturers of the project based teaching approach described include the creation of visual and mathematical learning models which are then used by AUT undergraduate students to obtain a better understanding of complex mechanical engineering interactions. The models are purposeful teaching and learning aids for inclusion into the curriculum, some of them have already been implemented into the mainstream programmes and are now available as resource material for AUT students to experiment with.

Limitations

Unfortunately, the "expert student" who has worked five months full-time on the project leaves with invaluable knowledge. Time in the final stage of the project is often insufficient to pass this knowledge on to academic staff, technicians or future students continuing to work in this area. Therefore, documentation is very important.

There is often a slow start to many of these projects as students struggle with the English instruction medium, but having a fluent German speaking lecturer involved in their supervision helps the students to shift into the highly productive phase of their projects.

Unfortunately to date New Zealand students have been slow to take up the counter exchange opportunities. Language barriers and fiscal limitations are the predominant reasons not to consider the opportunity to study in Germany as they have not access to scholarship funding at the levels supported by the German government for international education and collaboration.

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Combining problem based learning with extra curricula interests

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Abstract: *The international Formula SAE event provides an excellent problem based learning forum for engineering students. The challenge of raising finance, designing, building, testing and competing in an event with a small Formula style car, plunges students into an engineering environment similar to what they may experience in the workforce. However, introducing Formula SAE to an already established degree curriculum can present a number of limitations and difficulties, which would not handicap such a project in a professional engineering environment. Therefore, rather than continue to simply use the Formula SAE event as material for a final year project, the University of Adelaide is now restructuring its Formula SAE involvement into a more vertically integrated venture which combines academic achievement with extra curricula interests*.

Keywords: *design, projects, teamwork*

Introduction

In 1993 Bill Murray starred in Groundhog Day, as TV weatherman Phil Connors, who awoke each cold winter's morning in Punxatawney, to the same day incessantly repeating itself in a seemingly endless loop. Academics who annually supervise large group projects, in which the subject matter remains the same year after year, may be able to relate to this in some small way. While Phil Connors eventually starts to anticipate the events of each day and manipulates them to his own advantage, the supervision of annually repeated projects does not always share the same benefit. Most supervisors would profess to introducing changes for the better each year. However, when commencing with a new group of freshly charged and exuberant young scholars, the underlying problems seem to persistently resurface again and again. It isn't long before the same old mistakes start to reoccur and the same stubborn contrariness to well rehearsed help and guidance rears its ugly head once again.

Wouldn't it be good if the initial period of reciting the basic dos and don'ts became redundant? Wouldn't it be good if the new students had somehow evolved, so that the mistakes that were made and lessons that were learnt by the preceding groups, had somehow redefined their genetic engineering makeup? Wouldn't it be good if they had inherited an instinct for what was better by design from their predecessors?

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The University of Adelaide (UoA) is now in its fourth year of participating in Formula SAE (Society of Automotive Engineers) in which university teams raise finance, design, manufacture, test and compete in an event using a Formula styled vehicle. Each year UoA have risen to the challenge with a brand new team of 4th year students, none of whom have ever had any prior exposure to, or involvement with, Formula SAE (FSAE). Consequently, a pattern has emerged which shows the same problems and pitfalls occurring year after year.

The following sections will therefore describe the immense benefits of FSAE participation as an extremely valuable problem based learning exercise; highlight the limitations imposed by our existing organisational structure and present details of how we are now redefining our whole approach to this excellent learning experience.

Project based learning through FSAE

Problem based learning (as opposed to conventional teaching) empowers students to progressively determine what they do or do not understand. Cannon and Newble (2000) stated that if students are faced with a true-to-life example in which they practice methods that they are destined to use in their future employment, they are more likely to learn. If a problem (or project) is carefully chosen so that it strengthens the attributes that students will require for their career, the knowledge of their experiences is more likely to be retained. FSAE offers one such example in which students develop many of the skills that they are expected to master, in an environment that closely replicates a real professional engineering situation. Karri et al (2001) believe that it provides a strong foundation on which students can master engineering principles and design philosophies; it promotes team work and leadership; it encourages lateral thinking; it develops project management skills and exposes its members to harsh economic realities, all of which are core issues for the practicing professional engineer.

The Formula SAE Rules (2003) define many strict guidelines to which each team must rigidly adhere. These directly influence design decisions and budget constraints and define the milestones and deadlines for the project. Teams are awarded points for innovation, presentation, the cost of the final product and how well the product (and team) perform throughout an end of year international competitive event. At this event judges assess the design and build quality of the vehicle and cross-examine the team to see how much they truly understand. Oral presentations, design reports and cost reports are used to determine the team's communication abilities. Safety is paramount and so every detail of the car is meticulously scrutinised via inspection, a brake test, a noise test and a tilt test. The dynamic events are all designed to highlight the strengths and weaknesses of each vehicle. These include skid pan, acceleration, auto-cross, fuel economy and endurance (Figure 1). However, one of the most underestimated aspects to FSAE (which probably occupies most of each team's initial few months) is the financial side of the project. The author was once manager of a small engineering department and his company's accountant preached that "engineers are great at spending money, but lousy at earning any". While it remains a lovely accountants' revenge cliché, it is of course rubbish, since the product that was engineered paid both the accountant's and the engineers' wages. Never-the-less, it embodied a perception that engineers are not always as cost conscious as they could be, despite a healthy understanding of business economics. FSAE embodies principles that are designed to change this. Each team must finance the project and effectively market themselves to ensure that their sponsorship funding is sufficient to meet their initial budget estimate. Once funds have been

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secured, teams must work to a genuine financial limitation. One other important point is that the supervisor is not in charge, although the author (in his role as a FSAE academic supervisor) readily admits that this is a difficult concept to adhere to when the project forms the basis of an academic assessment. However, while the students should receive guidance from their supervisor and mentors alike, the structure is such that students are encouraged to develop a total sense of project ownership.



Figure 1: The University of Adelaide 2002 and 2003 FSAE car.

FSAE participation has many obvious benefits. Anecdotal evidence suggests that it provides an experience of equal value to that acquired in the first year of a graduate's professional experience. At each FSAE opening ceremony (which is hosted by one of its four major sponsors: Holden, Mitsubishi, Ford and Toyota) there is now a recurring statement suggesting that FSAE participation is considered to be equivalent to the initial year of an automotive engineer's training.

Existing structural limitations

The University of Adelaide first competed in FSAE in 2001 when it was recognised as an ideal problem based learning exercise. Since then, between fifteen and twenty of our final year students now regularly compete, using it as their final year project (30% of the level 4 requirement).

The team is structured in such a way that it reproduces the operational sections of a small race car manufacturing company. A Technical Manager and a Business and Marketing Manager both assist the Managing Director. Further subdivisions include a Steering and Suspension team, a Shell and Chassis team and a Drive Train team. Each of these sub sections has a team

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leader (or manager) who all report to the Managing Director (Figure 2). Academic requirements dictate that the team regularly report to their academic supervisor regarding the progress of the project. To place this in its professional context: the supervisor's role is perhaps analogous to that of a Chairman of the Board who leaves the business matters to the Managing Director.

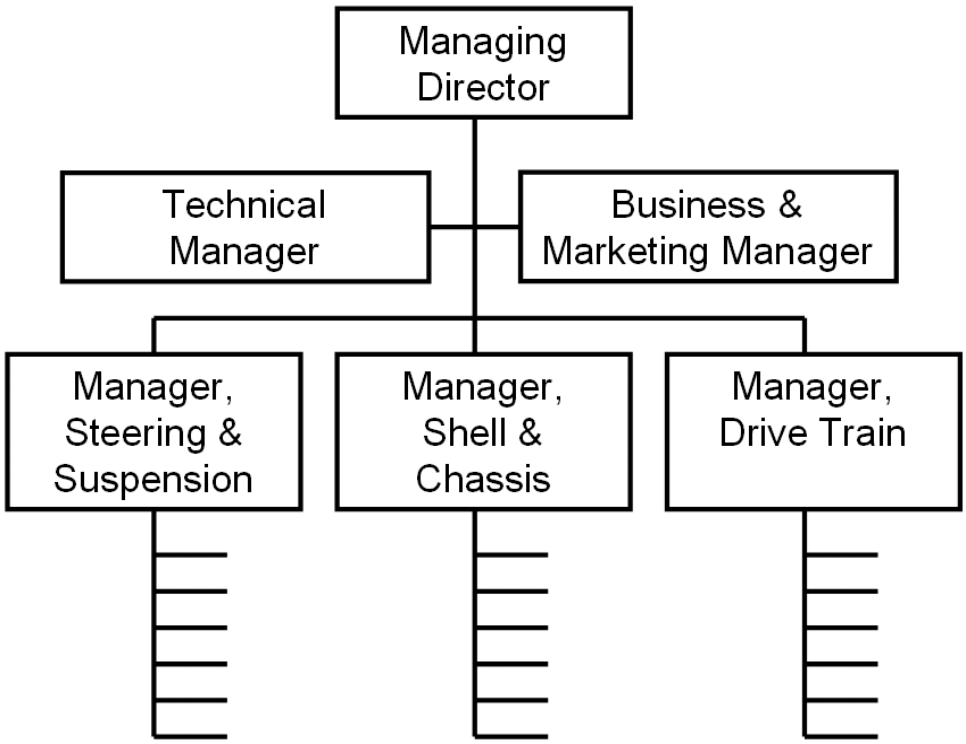


Figure 2: Organisational Structure of the UoA FSAE team

This chain of command offers immense communication benefits for such a large group with only one academic supervisor (such as is the case at the University of Adelaide). Each week the managers have at least one formal meeting with their team (running to a set agenda and recording minutes) and then also report to their academic supervisor in weekly managerial meetings. To assess individual progress, all team members maintain a log book which is periodically inspected by their academic supervisor.

The preceding paragraphs should illustrate the huge task that faces each new team, especially in the context of a final year design project that only lasts for one academic year. Completion of the project marks the end of academe for the majority of the team members, who graduate and move on to commence their professional careers (often in the automotive industry). As a direct consequence of this approach (since only final year students are eligible to participate in final year projects), a new team of raw recruits must commence with the project each and every year. While it provides an excellent problem based learning experience for the final year project, its sole use as such imposes a very real and significant handicap in terms of the team's performance expectations against other FSAE teams. By organising our participation in this way our university has so far competed in FSAE with the equivalent of a first year (*rookie*) team each and every year.

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The alternatives

It was realised that a fresh approach was required to encourage the team's to evolution from one year to the next, while retaining the excellent student attribute developing characteristics of the project. The first attempt to do this was not as successful as was anticipated. Last year, some of the project challenges were introduced as material for the level 3 Design Project (a single *second* semester subject). While it served as a good opportunity to present potential FSAE team members with some excellent design problems (the primary objective of the subject), the benefit in terms of adding value to the FSAE project were limited to merely providing possible future (as opposed to current) design alternatives. This was simply because the level 3 Design Project is a second semester subject, by which time the designs of the existing FSAE team were already locked in and production of the car well under way. Also, because the focus of the level 3 design subject promotes fresh innovation and creativeness, new and novel designs are encouraged. This in itself was demonstrated to be contrary to the objective of evolving the strengths of the existing car design, by inadvertently encouraging the next generation of final year students to progress with their level 3 design ideas (which they more personally related to) instead. It also alienated the 3rd year students from the existing team of 4th year students who each believed that their ideas were superior. The experience however did have a very positive outcome, since the 3rd year students recognised that a new approach was needed and that their "juniors" should not end up in the same, somewhat ostracised, situation they found themselves in. A structure was needed that allowed students at every year level to participate and that allowed all to experience a sense of single project ownership. It was also vital that the value of the project as a problem based learning experience was retained.

Many of the more successful international teams such as Georgia Institute of Technology from the USA, last year's winners for example, use an entirely different approach. At last years event the author had spoken with Dr. Ken Cunefare (Georgia's academic supervisor) who described their methods and the advantages of such methods. Their team's involvement is purely extra curricula (via a student sports and social group) and as such, has no connection to the team's academic performance. This approach offers very real and distinct advantages. Because team membership is open to all year levels and because students often remain as team members for a number of years, the team as a whole continually mature and their designs evolve each year rather than start afresh. It helps to develop a strong vertically integrated organisational culture (Snyder 2002).

While some members obviously and invariably leave, as do new and younger members join, a residual core ensures that knowledge flows seamlessly and continuously between the team's senior and more junior members, developing a team history and an environment of exchange. The vertical interaction develops a sense of single product ownership where all are united in striving to achieve the same common set of goals and objectives. Gross and Schichman (1987) describe this as a sense of oneness and belonging. The continual flow of accumulating knowledge and experience, replaces the start-stop scenario and the opportunity to attain a quality product significantly improves. The designs progressively develop from year to year and the end of year event becomes an annual product evaluation exercise rather than an occasion that marks the end of the project. Estrangement from the academic environment, as is done at Georgia Tech, is one disadvantage of the aforementioned approach In such an environment, the effectiveness of the academic supervisor in guiding the students towards

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developing their engineering attributes and in indicating opportunities to employ engineering theory and practice is somewhat reduced. Also, the successes and experiences of the team (on and off the track) are not recognised in their qualifications and therefore do not attract a formal university endorsement for all potential employers to see. Retaining the project as part of an engineering degree curriculum, without doubt, has value and so a combined approach (in which participation in the project is coordinated via an extra curricula interest group, out of which students can utilise their efforts and experience for academic recognition) is now being followed.

While the intended direction may not be new, the definition of the problems experienced at the University of Adelaide, the presentation of a solution and a method of reorganisation, provides a possible alternative route for similar group projects that have fallen into a repetitive rut, rather than realise their true potential of continual improvement.

The new vertically integrated structure

This year's students have now registered FSAE as a sports and social group with their student union and have opened membership to all university students. Whilst membership has been marketed towards mechanical and mechatronic engineering students, anyone that is remotely interested in the project may join. A club infrastructure has also been developed with the intention of allowing the core activities of the club to integrate with a number of academic projects.

The general activities of the club (such as progress meetings, club fund raising events and barbeques etc) are organised and run by the elected president and the members of the executive committee. Club members who simply express an observational interest may join as general members. However, these members, as well as the president and the executive committee, have no direct involvement with the day to day business and engineering aspects of FSAE. They remain separate from this and are analogous to a board of directors staying out of the day to day running of a business. Business and engineering remains the responsibility of the Operational and Engineering Infrastructure (OEI) as shown in Figure 3.

A further subdivision of the OEI provides an "experience based" hierarchy and also allows the teams' work to double as problem based learning examples in a number of their academic subjects.

An "Engineering and Business team" within the OEI consists of the more experienced (level 4) engineering members. These are the leaders and policy and decision makers who are ultimately responsible for the success of FSAE. This team's internal structure follows that previously described (Figure 2) in which various sections or sub-teams are responsible for different aspects of the business and the engineering part of the project. Their work and experience continue to provide ideal subject matter for their final year project.

A second tier (the Future Projects and Technical Support team) consist of level 1, level 2 and level 3 engineering students, who assist in the business and engineering operations under the leadership of the Senior Engineering and Business team. They are also tasked with considering possible future developments of the design, since they themselves will soon be promoted to the more senior influential level. Their technical support may include Finite Element Analysis of various parts, thus providing examples for their level 2 Stress Analysis

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and Design subject or their level 3 Advanced Materials and structures subject. Consideration of future projects and vehicle developments will also provide excellent subject matter for their level 3 Design Project. The same internal subdivisions as in the more senior Engineering and Business team allow vertical integration amongst team members with mutual interests. For example, the leader of the Shell and Chassis team in Future Projects and Technical Support will be included in the meetings of the Shell and Chassis team from Engineering and Business.

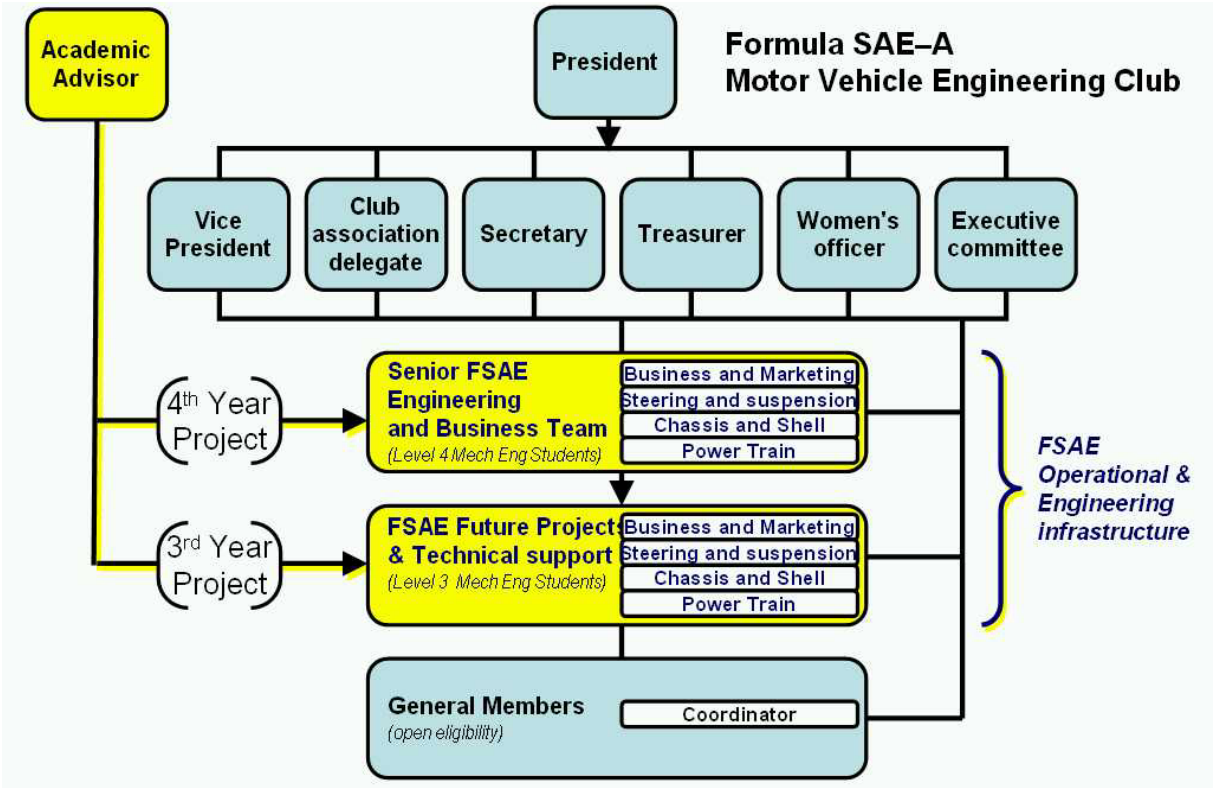


Figure 3: The structure of the FSAE Motor Vehicle Engineering Club

Some guidelines will of course be necessary. One in particular will follow the lead of the automotive industry, which incorporates annual facelifts in its vehicles prior to a total redesign. The number of significant annual design changes in the FSAE car will be restricted, thus encouraging design evolution. When the need for a total redesign is anticipated, it will occur over a number of years with the development of a second car in tandem with the existing competitive vehicle.

As the club progresses it will also provide a potential for other schools (such as electrical engineering), with their students as club members to utilise this as an example for problem based learning.

Conclusion

The Formula SAE project has proven to be an excellent example for problem based learning. However the introduction of the project into an established curriculum has been a non-trivial exercise, highlighting a number of issues that are not representative of a genuine engineering

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environment. The continual product reinvention, associated with new participating students each year (without any residual experienced students), is unrepresentative, frustrating and is not conducive to the successful evolution of a product.

Consequently the University of Adelaide has now harnessed the student passion for FSAE from all year levels, by encouraging the formation of an extra-curricula social group (or club). The vertically integrated organisational structure of the club encourages an evolution of knowledge from one year to the next. Its internal infrastructure has been established so that students may also utilise their work and experiences as problem based learning examples for their academic requirements. This also provides an avenue for formally recognising the immense value of such a project.

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Evaluation of students performance in Engineering Problem Solving Course from a dual mode delivery

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***Abstract**: The Faculty of Engineering and Surveying at University of Southern Queensland (USQ) has introduced a series of Problem Based Learning (PBL) courses as part of the curriculum. The Engineering Problem Solving 2 course was introduced in 2002 as part of this change and had been delivered successfully for two consecutive years. About 250 students enrol in this course annually and over 100 of them are studying externally. This was one of the first courses at USQ to effectively utilise discussion groups using WebCT for on-campus and external students. This course has an emphasis on team-based approach and presents a range of real-life problems that are solved by students working in teams. The course focuses primarily on the use of statistical analysis to solve problems and to evaluate solutions. In addition, students are required to further develop their computer skills to illustrate and present the results of their work. This paper evaluates the performance of teams and individual students in two consecutive years of delivery. It was found that the student performance did not vary much for different problems. The external students' performance was marginally better than the on-campus students. Non-participation of some members in teamwork did not affect the overall team marks. Further development is underway for the next offer of this course, which is also discussed in this paper.*

***Keywords**: Problem based learning, distance education, team performance*

Introduction

The Faculty of Engineering and Surveying at the University of Southern Queensland (USQ) offers a wide range of programs for engineering and surveying students. As part of the accreditation requirements, the review committee concluded that the graduate attributes could best be met by an integrated strand of courses employing a Problem Based Learning (PBL) approach (Dowling, 2001). The foundation course was offered for the first time at USQ in 2002 (semester 1), for external and on-campus modes of study (Brodie & Porter, 2001). Challenges faced in incorporating these courses have been discussed by Porter and Brodie (2001). The second level PBL course was offered in 2002 (semester 2). The annual enrolment in this course is about 250 including over 100 students studying this course externally. This course focuses primarily on the use of statistical analysis to solve real-life problems using a team-based approach. This paper presents preliminary information on team performance, with particular reference to the performance of teams of external students.

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Course Overview

Engineering Problem Solving 2 (ENG2102) is the second PBL course run by the Faculty. It is a requirement for all students undertaking program of studies ranging from Associate Degrees to Bachelor of Engineering Degrees (2, 3 and 4 year programs). Four such courses have been introduced to address the increasing demand by employers and professional bodies for graduates to possess generic attributes such as:

- the ability to contribute effectively as a member of a multidisciplinary team;
- the ability to identify and develop solutions to technical problems, and to evaluate the solutions;
- the ability to communicate effectively;
- organization and time management skills; and
- a capacity for life long learning.

Engineering Problem Solving 1 (ENG1101) is a prerequisite study for this course, where students familiarise themselves with the concept of problem-based learning and how the problem solving courses operate at USQ. Further details about this course have been reported elsewhere (Brodie & Porter, 2004). While ENG2102 closely follow the approach used in ENG1101, ENG2102 differs in some respects. In ENG1101, students devote a considerable amount of time and effort developing teamwork skills, whereas in ENG2102, the focus is on using these skills to propose solutions to more rigorous, technical problems.

Student Teams

Students were allocated into teams of about six students. In 2002, teams were wholly allocated by the course examiner but in 2003 students were invited to form their own teams if they could. Each team was required to be a mix of students from a range of discipline areas (mechanical, civil, etc.) and range of (two, three and four year) study programs. The aim was to create teams, which had to integrate members from a diverse range of backgrounds and abilities. Team membership generally remained fixed for the duration of the course. In some cases, students were reallocated to a different team to accommodate individual needs or due to dropout of team members during the course.

In 2003, when students were allowed to select their own teams, many opted to continue with a majority of members from their previous ENG1101 team. Thus students did not receive further practice at the crucial establishment phase of teamwork. Further, allowing students to select their own teams led to slower administrative processes at the initial stage, which is not desirable. Self-selection of teams will be discouraged in the future.

Each team appointed a team leader and a deputy team leader for each problem. The team leadership was rotated among the members for different problems. This allowed each member of the team to take the role of either team leader or deputy team leader at some stage, giving them a chance to experience leadership responsibilities. A staff member from the course team was appointed as the 'facilitator' for each team. The facilitator was the principal source of assistance and advice whenever the team was experiencing difficulties in identifying or solving problems. Each on-campus team had weekly meetings with their facilitator. External teams communicated using a variety of methods including virtual discussion groups and on-line chat facilities. All teams submitted a weekly progress report indicating team progress, team difficulties and level of contribution from each member. These reports have since been refined to provide more detailed information on how tasks are divided between members.

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Web-based Delivery

This course was largely web-based. Commencing in 2002, this was one of the first courses at USQ that effectively made use of WebCT. To facilitate dialogue between team members, WebCT discussion groups were created for each team. The contents of these discussions were confidential to team members and the team facilitator. This was the main channel of communication between team members, and with the facilitator. A number of teething problems made the WebCT system initially unpopular with many students and staff. By 2003, online submission of assignments at least ran very smoothly. The system is continuing to be refined and our use of the system is becoming much more sophisticated. It is now becoming relatively easy to administer the course entirely online.

Assessment

Students were assessed on the basis of being able to contribute to the work of the team in providing sound technical solutions to realistic problems. This was in the form of three open-ended problems to be solved by the team. Each individual student was expected to maintain their own portfolio of their personal learning; including records of their contribution to their team's solutions. The teams' report on their solutions were submitted electronically through the WebCT discussion groups. The reports were assessed on the basis of:

- technical content;
- communication of data and results in an appropriate professional manner;
- interpretation and solution of the problem, and evaluation of the solution; and
- presentation.

In 2002, each team report was assessed by a marker and moderated by the course examiner. Three markers were assigned for this task. By rotating the markers between teams between problems, the differences associated with the markers were (hopefully) minimised. An attempted improvement in 2003 saw each team report double marked and the average mark was awarded for the report. In the event of a significant disagreement between the two markers, the course examiner provided a third assessment.

To facilitate quicker marking and feedback to students, an electronic marking and feedback system was introduced in 2003. All markers submitted the marks to the examiner together with any specific feedback to individual teams. These were collated by the examiner and fed back as a report posted under the relevant discussion group. General feedback and sample solutions were posted on the general discussion area where all students had access. Electronic marking and feedback system was well received by the students, because each team member was able to access them individually, rather than relying on information relayed through the team leader. A summary of assessment items together with their relative weights is given in Table 1. In 2003, the weighting for the portfolio was increased to 20% and team report for problem 1 was reduced to 20%. This was done to reflect the effort in preparing the portfolio, and reduce the impact of the initial team forming process on overall marks.

Problem No	Weight (for 2002)	Weight (for 2003)	Format of Report
Team Report - Problem 1	30%	20%	Report in Word file
Team Report - Problem 2	30%	30%	PowerPoint presentation
Team Report - Problem 3	30%	30%	Report in Word file
Portfolio of Reflections (Individual)	10%	20%	Reflections in Word file

Table 1: Summary of assessment items and weight

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Team Performance

The team performance was evaluated based on the team report marks for the three problems. The three problems were held reasonably constant between 2002 and 2003 allowing more or less direct comparison between the two years.

Team Results for Problem 1

In 2002, 44 teams had a mark recorded for problem 1 and in 2003, 44 out of 47 teams had a mark recorded for problem 1. The following histograms in Figure 1 show the distribution of team marks for 2002 and 2003 respectively.

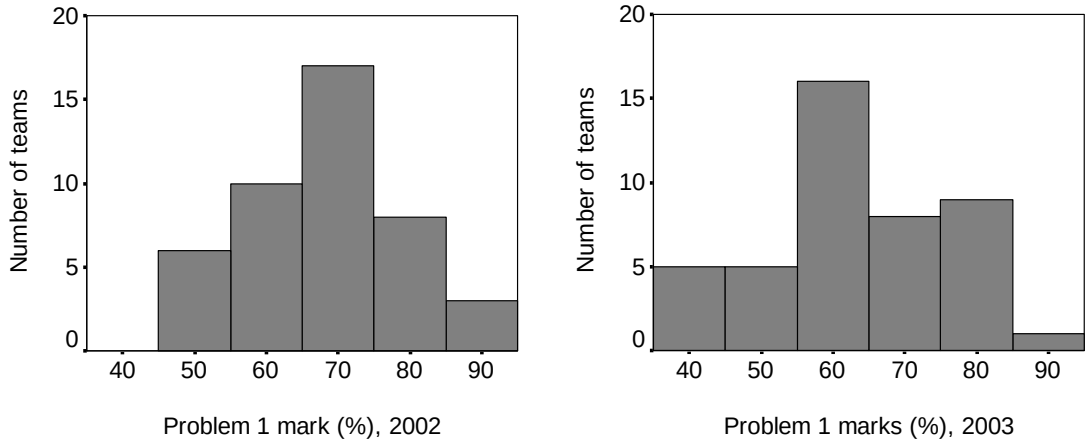


Figure 1: Comparison of team marks for problem 1

In 2002, the mean for marks was 66.0% for internal teams and 68.2% for external teams. This difference is not statistically significant (independent samples *t*-statistic=-0.68, *df*=42, *p*=0.50). In 2003, the mean mark for internal teams was 61.9% compared to the mean mark for external teams of 63.3%. This difference was not statistically significant (independent samples *t*-statistic=-0.39, *df*=42, *p*=0.70).

Team Results for Problem 2

In 2002, there were 44 teams and in 2003, 41 out 42 teams have a mark recorded for problem 2. It should be noted that the number of teams was reduced to 42 in 2003 for problems 2 and 3, because of merger of small teams due to student dropouts. The following histograms in Figure 2 show the distribution of team marks for problem 2 in 2002 and 2003 respectively.

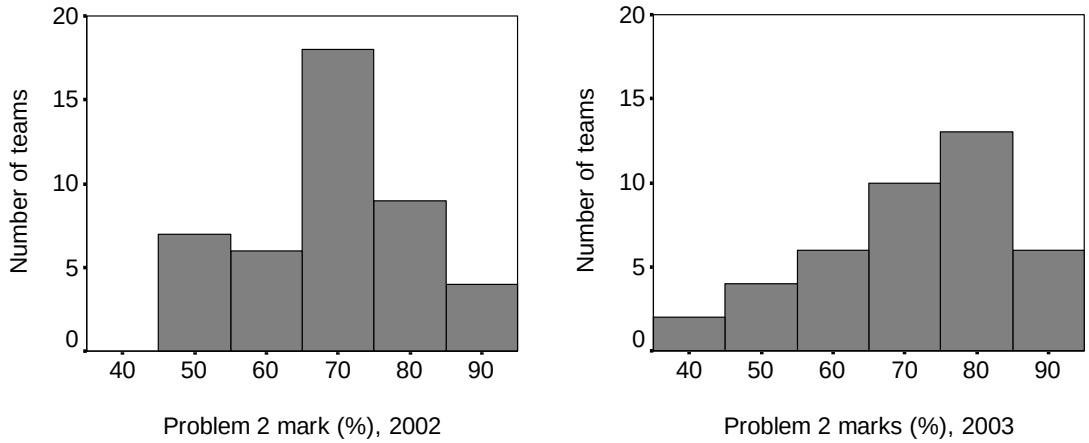


Figure 2: Comparison of team marks for problem 2

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In 2002, the mean mark was 65.3% for internal teams and 71.8% for external teams. This difference displayed weak evidence of statistical significance (independent samples *t*-statistic=-1.89, *df*=42, *p*=0.066). In 2003, the mean mark for internal teams was 70.5% compared to the mean mark for external teams of 73.7%. This difference was not statistically significant (independent samples *t*-statistic=-0.75, *df*=39, *p*=0.46).

Team Results for Problem 3

In 2002, there were 44 teams and in 2003, 41 out of 42 teams have a mark recorded for problem 3. The following histograms in Figure 3 show the distribution of team marks for 2002 and 2003 respectively.

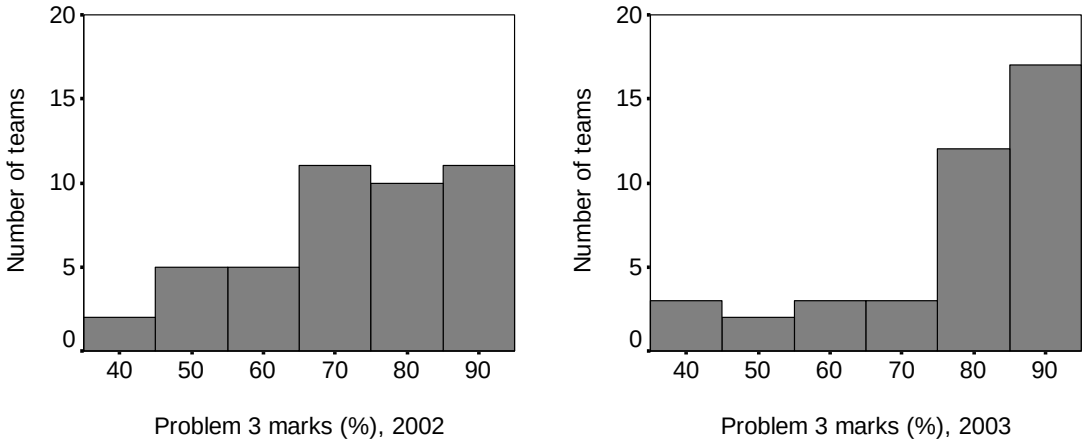


Figure 3: Comparison of team marks for problem 3

In 2002, the mean mark was 71.2% for internal teams and 72.8% for external teams. This difference was not statistically significant (independent samples *t*-statistic=-0.37, *df*=42, *p*=0.71). In 2003, the mean mark for internal teams was 75.3% compared to the mean mark for external teams of 80.2%. This difference was not statistically significant (independent samples *t*-statistic=-0.99, *df*=39, *p*=0.33). Comparison of Figures 1, 2 and 3 shows that the distribution of team marks is not normal in problem 3 and is different to that of problem 1 and 2. A more detailed histogram of the 2002 marks shows that there was a bi-modal distribution as shown in Figure 4. This effect was not found in 2003, possibly due to repeating the same problem given in 2002 with only minor changes.

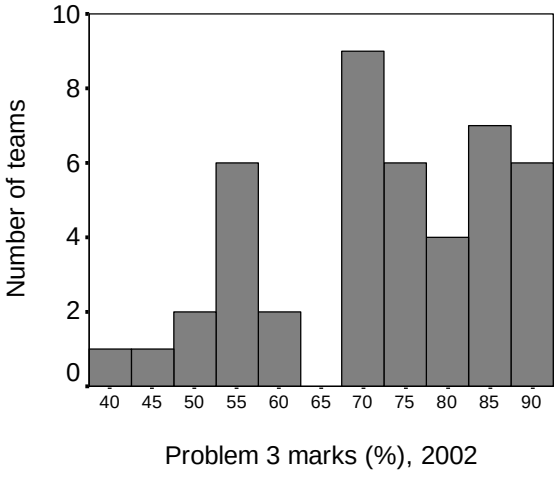


Figure 4: Detailed histogram for problem 3 in 2002

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In 2002, it appears that the teams had separated into two classes: a) those who were successfully working together to solve the problem, and b) those who were not. The poor marks may indicate dysfunctional teams not performing well or possibly that a number of teams misunderstood the requirements of the question due to the complexity of the problem.

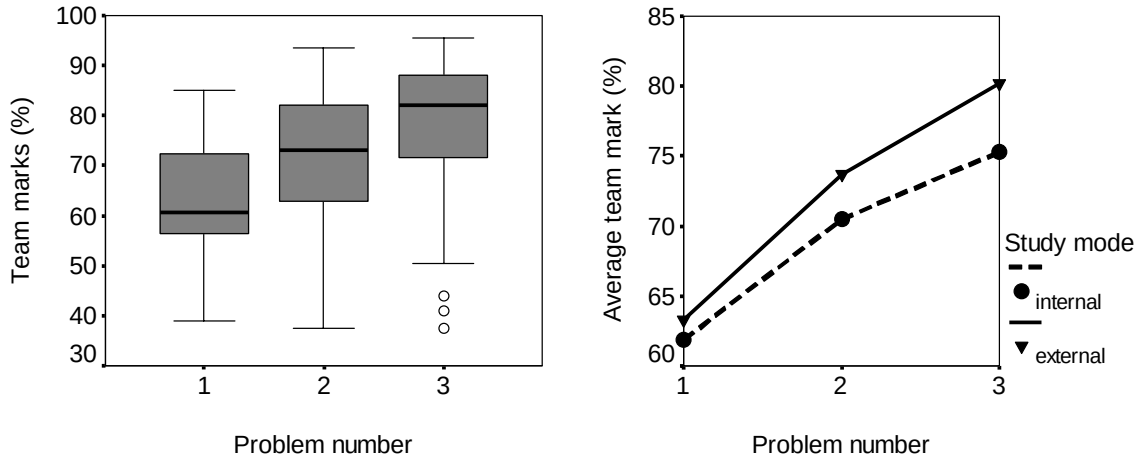
Comparison of Team Marks Across Problems

The mean marks for the three problems are summarised in Table 2 for 2003. These differences are highly statistically significant (One way ANOVA, F=12.68, df=2,123, p<0.001).

Problem No	Mean marks (for 2003)
Problem 1	62.6%
Problem 2	72.0%
Problem 3	77.6%

Table 2: Summary of team marks for the three problems in 2003

The following side-by-side boxplots in Figure 5(a) give a graphical display of these differences. For 2003, after correcting for differences between problems, there are no significant differences in mean marks between study modes (Two-way ANOVA, F=1.65, *df*=1, 122, *p*=0.20). The relationships are demonstrated by the profile plot in Figure 5(b).



(a) Variation of marks **(b) Comparison between mode of study**

Figure 5: Comparison of team marks across problems in 2003

If there were no difference in mean mark across problems, the two lines would be horizontal. The difference between the two lines shows that the external teams mean marks are always a couple of marks higher than the on-campus teams in 2003, but this result is not statistically significant. The fact that the two lines are nearly parallel, says that there is little interaction between mode of study and problem number. In other words, there is no significant evidence that external students have improved relative to on-campus students across the semester.

The chart in Figure 6 compares mean marks in 2003 with equivalent results from 2002. It should be noted that problem 1 was identical and there were only some minor modifications to problems 2 and 3 in 2003. It can be seen that students in 2003 did worse on problem 1 and

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better on problems 2 and 3. This is perhaps due to shortened time period available for problem 1 in 2003 due to delays in team formation by the self-selecting process. Better performance in problems 2 and 3 could be due to advice from previous year students and/or better advice from the teaching staff. None of the pair-wise differences are statistically significant at the 0.05 level because the 95% confidence intervals cross, as shown in Figure 6.

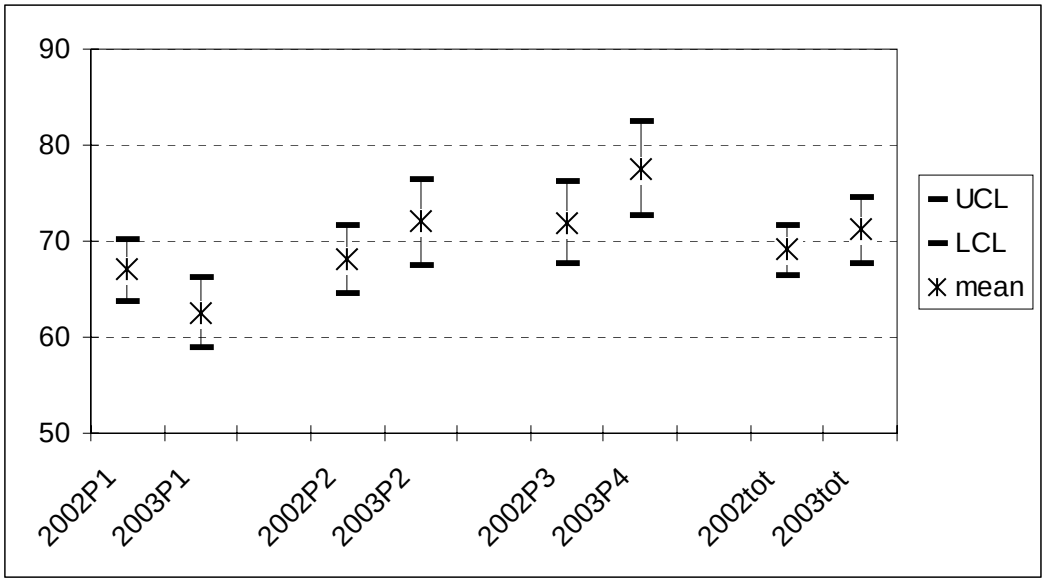


Figure 6: Comparison of team marks across problems in 2003

Individual Performance

The following table compares the distributions of individual student grades between 2002 and 2003. These grades are based on the team marks for the three problems and the portfolio of reflections submitted individually. At the time of analysis, 13 grades from 2003 that were not finalised were excluded from this analysis.

GRADE	YEAR				Total	
	2002		2003			
HD	14	5.6%	33	14.0%	47	9.7%
A	59	23.7%	73	31.1%	132	27.3%
B	84	33.7%	82	34.9%	166	34.3%
C	77	30.9%	24	10.2%	101	20.9%
F	15	6.0%	23	9.8%	38	7.9%
Total	249	100.0%	235	100.0%	484	100.0%

Table 3: Summary of individual grades

The overall grades appear to be better in 2003 than in 2002. Using Pearson's Chi-Square Statistic, these differences are highly statistically significant ($p<0.001$). Several factors could have contributed to this. We would hope that our teaching has improved and that we are helping teams coalesce more effectively. Alternatively, since there were only minor changes to problems, there is some likelihood that the solutions might have been passed down from those who have completed this course in 2002. Moreover, the increased weight given to the individual learning portfolios in 2003 could have resulted in these better grades.

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Self and Peer Assessment

As part of allocating the individual marks, each team member was required to do a self and peer assessment for each problem. Genuine participation by a team member was confirmed by peers using an evaluation with either "Yes" or "No". A detailed self and peer assessment was submitted by the individual members with their learning portfolios. This section looks at the students who were rated as non-participatory by at least one of their fellow team members in the self and peer evaluation.

After excluding the students who dropped the course in 2003 it was found that:

- 26/252 (10.3%) of students received at least one rating of non-participation on problem 1.
- 28/252 (11.1%) received at least one rating of non-participation on problem 2.
- 20/252 (7.9%) received at least one rating of non-participation on problem 3.
- 53/252 (21.0%) received at least one non-participation on at least one of the problems.

Table 4 shows that 26.5% of on-campus students received at least one rating of non-participation on at least one of the three problems, compared to 14.7% of external students. This difference is statistically significant (Chi-square statistic=5.26, *df*=1, *p*=0.022).

GENUINE PARTICIPATION	MODE OF STUDY				Total	
	External		On-campus			
Yes	99	85.3%	100	73.5%	119	79.0%
No	17	14.7%	36	26.5%	53	21.0%
Total	116	100.0%	136	100.0%	252	100.0%

Table 4: Summary of participation based on self and peer assessment in 2003

More detailed analyses of the self and peer assessment reveal that:

- 18/136 (13.2%) of on-campus students received at least one vote of non-participation on problem 1 compared to 8/116 (6.9%) of external students. This provides some statistical evidence of a difference between the two groups (Chi-square test=2.72, *df*=1, *p*=0.099).
- 16/136 (11.8%) of on-campus students received at least one vote of non-participation on problem 2 compared to 12/116 (10.3%) of external students. This is not a statistically significant difference (Chi-square test=0.13, *df*=1, *p*=0.72).
- 16/136 (11.8%) of on-campus students received at least one vote of non-participation on problem 3 compared to 4/116 (3.4%) of external students. This provides strong statistical evidence of a difference between the two groups (Chi-square tests=5.93, *df*=1, *p*=0.015).

In 2002, 19.0% of internal students and 21.4% of external students recorded at least one rating of non-participation. This difference is not statistically significant (Chi-square statistic=0.21, *df*=1, *p*=0.65).

Although not statistically significant, again the tendency is for the external teams to report slightly fewer team problems than on-campus students. Again, we speculate that external students are more mature and better suited to teamwork because of their work experience in team environment. Unlike on-campus students, external students do not meet their fellow team members face-to-face, perhaps minimising their opportunity to form adverse judgement and opinions about their fellow team members. It should also be noted that non-participatory votes for external students most often resulted from work commitments in their employment.

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Effect of Non-participation on Team Results

The effect of non-participating members may have adverse effect on the team performance. We investigated this possibility in this section.

In 2002, data were available for 44 teams. 31 of the 44 teams (70.5%) had recorded at least one vote of non-participation against one of the team members. The mean total mark for those who recorded a vote of non-participation was 68.1% compared to 71.2% for teams, which did not. This difference is not statistically significant (*t*-test for independent samples t=1.13, df=42, p=0.27). However, those teams which recorded a vote of non-participation on the very first problem did end up with a statistically significant worse mean total mark of 63.8% compared to those who did not have any votes of non-participation on the first problem (71.0%). (*t*-test for independent samples t=2.74, df=42, p=0.009).

In 2003, data were available for 40 teams. 24 of the 40 teams (60%) had recorded at least one vote of non-participation against one of the team members on at least one of the problems. There was no significant difference in mean total marks between teams which had recorded a vote of non-participation (mean total mark = 63.8%) and those, which had not (mean total mark=60.4%). (*t*-test for independent samples t=-0.90, df=38, p=0.38).

It is believed that although there were non-participating members in some teams, the other team members compensated by contributing more to the solutions so that the team marks were not compromised. This was observed especially in teams where individual members were aiming for high grades. Those who do not participate appear to become irrelevant to team performance. The performance of the team appears to be determined by those who do participate, rather than those who do not participate.

Further Developments

With the experience of delivering this course for two consecutive years, we are now introducing several changes in the design and delivery. Some of these issues are discussed in this section.

Based on student performance discussed in the previous sections, it is evident that when problems are repeated in consequent years with minor changes, the performance of the students tends to be marginally better in the subsequent year. As such, there is strong justification for developing a completely new set of problems each year. The course team for 2004 has considered this issue in the design of problems.

This course is being run by a multidisciplinary team comprising of seven staff members from two Faculties. As such, applying team strategies to the course staff team has proven to be valuable in the effective design and delivery of this course. This also means that the course team had to work well in advance, at least one semester earlier in problem development. Input from members with diverse expertise has been beneficial in developing open-ended problems to suit students specialising in different disciplines. A set of new problems have been developed for the delivery in semester two of 2004.

One of the issues faced by the course team was assessing the individual performance of students based on a team effort. While the “Peer Group Evaluation Form” and the “Self and Peer Assessment Form” have been useful in assessing to some extent the individual performance, this has been a major challenge to the course team in the past two deliveries.

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For 2004, the method of assessment has been changed to better reflect individual performance. The onus is placed on the team to indicate the individual contribution of each member in their reports, which will be used to adjust the individual marks. In the event of any disputes among team members, it is proposed to resolve the issue from the information obtained from weekly progress reports and self and peer assessments. We believe this will encourage negotiation among team members at the early stages of each project rather than at the end.

The USQ-wide Student Evaluation of Teaching (SET) survey is an important means of obtaining feedback from all students for all academic course. However, the standard SET forms are designed for the traditional teaching based on lectures and tutorials. During the delivery of this course in 2003, the course team realised the need to develop a better evaluation survey for PBL courses. A new evaluation form for PBL courses was developed by the course team and implemented for the first time in 2003. The questions in the new form have greater emphasis on the role of facilitator as opposed to lecturer in the standard SET form. This form is now being used across all engineering problem solving courses at USQ.

Concluding Remarks

The introduction of the Engineering Problem Solving courses has brought radical changes to the curriculum within the Faculty of Engineering Surveying at USQ. The second level course ENG2102 had been delivered successfully for two years, for both on-campus and external modes of studies. Several innovative approaches have been successfully implemented in this course including web based delivery and electronic assessment schemes. Evaluation of team performance and individual student's performance indicate that external students performed equally well or better than on-campus students.

The team-based approach by a multi-disciplinary course team course team with complementary strengths has proven valuable for the successful design and delivery of this course. Building on the experience from the last two years, further developments are underway for this innovative course. With these developments, we believe the Engineering Problem Solving 2 course would be delivered effectively in the next offer bringing in rewards to both students and staff alike.

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Web Interface in Support of Work Integrated Learning

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Abstract: *Supporting the change in students' position from detached observers to involved performers is seen as a cornerstone in addressing the contemporary transition from an industrial to a knowledge-based economy and society. The Faculty of Built Environment and Engineering at QUT is implementing a teaching and learning project aiming at enhancing students' learning outcomes from the workplace components of their courses.*

This paper reports on issues and considerations addressed in designing a web interface in support of work integrated learning. The web interface is designed based on constructivist principles which engage students in ways which required reflection and demonstrated knowledge construction. A multi-disciplinary team was formed with the clear goal of creating a flexible, web based system applicable across a range of courses and work based experiences from site visits to work placements. With sustainability in mind the web interface offers students access to a range of resources while also providing self-paced training for both academic and industry staff in the areas of consultation and negotiation; experiential learning design; supervision and mentoring; and workplace assessment.

Keywords: Work Integrated Learning, Constructivist, Web Interface

Introduction

The capacity of both organisations and individuals to engage successfully in learning processes of various kinds is regarded as a crucial determinant of economic performance (OECD, 1996). As a result of the transition from an industrial to a knowledge based or learning economy and society (Lundvall, 1994), universities and other institutions of higher education where formal education processes occur, should provide learning that reflects the needs of the knowledge economy and society.

For institutions that provide professional and practice based education the implications are especially significant for reasons including: (1) Practice based professional education largely arose from a movement at the turn of the twentieth century in an effort to better meet the employment needs of the industrial economy of the time. In an era when the industrial economy is being overtaken by the knowledge economy it is timely to review the nature of the practice education and the inherent skills developed, and (2) Practice based professional education also implies workplace learning. Learning-by-doing is strongly endorsed because

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it is relevant to learning and innovation. In particular, it stresses the role of learning-by-doing in disseminating existing knowledge (interactive nature of organisational learning) and in the creation of new knowledge (OECD, 2000).

These transitions and their implications on higher education institutions impact on workplace learning. First, it is timely to re-conceptualise and structure the nature and role of workplace learning and the kinds of skills implied and developed through it. Second, it calls into question the precise role of workplace learning and its relationship to university curriculum for professional education.

Students as involved performers

Supporting the change in students' position from detached observers to involved performers is seen as a cornerstone in addressing the contemporary transition from an industrial to a knowledge-based economy and society. The Faculty of Built Environment and Engineering at QUT is implementing this teaching and learning project aiming at enhancing students' learning outcomes from the workplace components of their courses.

The project aims to do this by effecting a change in students' position from detached observers to involved performers. The intention is to facilitate students' progression to build knowledge and capabilities through the integration of academic and workplace curricula, thus improving their standing within the novice-expert dimension.

Recent studies demonstrated that professionals move through a developmental continuum in which they progress from novices to experts (Daley, 1999 and Chi, Feltovich & Glasser, 1980). In addition, the studies suggested that professionals move through five stages of career development namely; "novice," "advanced beginner," "competent," "proficient," and "expert" (Dreyfus & Dreyfus, 1985). This project will draw parallels between this model of progress and students' progress through the academic curriculum. A study of how students move from the level of knowledge and skills at the start of university education with some degree of exposure to discipline knowledge, to beginning professionals at the end of their courses would be very valuable. This project will explore how progress through the curriculum reflects changes in aspects of students' learning outcomes and performance levels. It seeks to discover if there is a paradigm shift from reliance on abstract principles to concrete understanding and from seeing situations as discrete, unrelated parts to seeing situations and practical problems as part of a whole.

This project specifically targets improving the quality of our courses through a structured and integrated approach to workplace learning with well defined objectives and learning outcomes supported by appropriate assessment. The practical experience and capabilities (generic and discipline-specific) gained by our students will considerably increase their employability.

System Concept

The system concept is shown in figure 1. The student centre will contain details of the specific components of workplace learning, their objectives and criteria for assessment. Descriptions of how these objectives are connected to unit and course objectives will be provided. This will provide students with the "Big Picture" and thus reinforce the integration aspect of student learning. In broad terms, this area will have several sets; one for each of the targeted disciplines. These will in-turn be subdivided into definite requirements as dictated by the specific course. Some industry specific requirements will be made available with appropriate links. For example, this can make use of the available feedback from the Small to

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Medium Enterprise Lifelong Learning project for possible industry placement and details. The students centre will contain self-assessment modules with links to the Online Learning and Teaching sites. Generic skill development and tracking will require the students to link to the QUT Student Portfolio. The students centre will also enable interaction and communication between students and academic and industry supervisors.

System components

The web-based academic and industry staff centres will provide guidance on how to set measurable objectives, how to adapt these to specific industries, and how to adjust them based on student experiences and prior learning. Already determined objectives will be mirrored in the students' centre. Academic and industry supervisors will be able to interact with one another and share experiences. This interaction will further enhance the students' learning experiences and outcomes.

The facility will have the same access restrictions applicable to the students' academic records on the QUT Virtual, the university portal. Upon logging into the system, the main stages of development will be outlined, thus allowing the participant (student or supervisor through their respective centres) to choose the appropriate path. Once the user is identified by the system, access rights and restrictions to specific components of the system will be established. Samples of student skill evaluations and scenarios for industry curricula (including objectives and assessment) will be made available. Templates of guiding questions for establishing academic knowledge and skills, corresponding to students' capabilities and possible industry based tasks will be accessible.

As the project is established, students, academic and industry supervisors will be given opportunities to record the ways in which learning develops, create learning records and obtain feedback through open access to a suite of prompts, hints, aids, probing questions, tools for evaluation, suggestions, and examples.

Building a sustainable system

Developing and sustaining the project outcomes will require the development of flexible, web based systems that will be applicable across the targeted courses covered in this proposal and which take account of a range of work based experiences from site visits to work placements. Experiences gained over the years will then be added to the site to value-add to it. Virtual industry and academic staff centres will provide other resources and links to the existing project sites (as listed on the right hand side of figure 1). The web-based facility will provide self-paced training for both academic and industry staff. This will ensure continuity and will function as a permanent resource for all staff.

The web-based academic and industry staff centres will provide guidance on how to set measurable objectives, how to adapt these to specific industries, and how to adjust them based on student experiences and prior learning. Already determined objectives will be mirrored in the students' centre. Academic and industry supervisors will be able to interact with one another and share experiences. This interaction will further enhance the students' learning experiences and outcomes.

This system will also provide industry supervisors with opportunities to further develop their understanding and skills in various roles including that of mentor or assessor. The web will further be used to implement assessment which links work based learning responding to the desired graduate outcomes. Underpinning sustainable development of an effective system is

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a focus on staff skill development in the areas of (Atchison, Pollock, Reeders & Rizzetti, 1999): (i) consultation and negotiation; (ii) experiential learning design; (iii) supervision and mentoring; and (iv) workplace assessment.

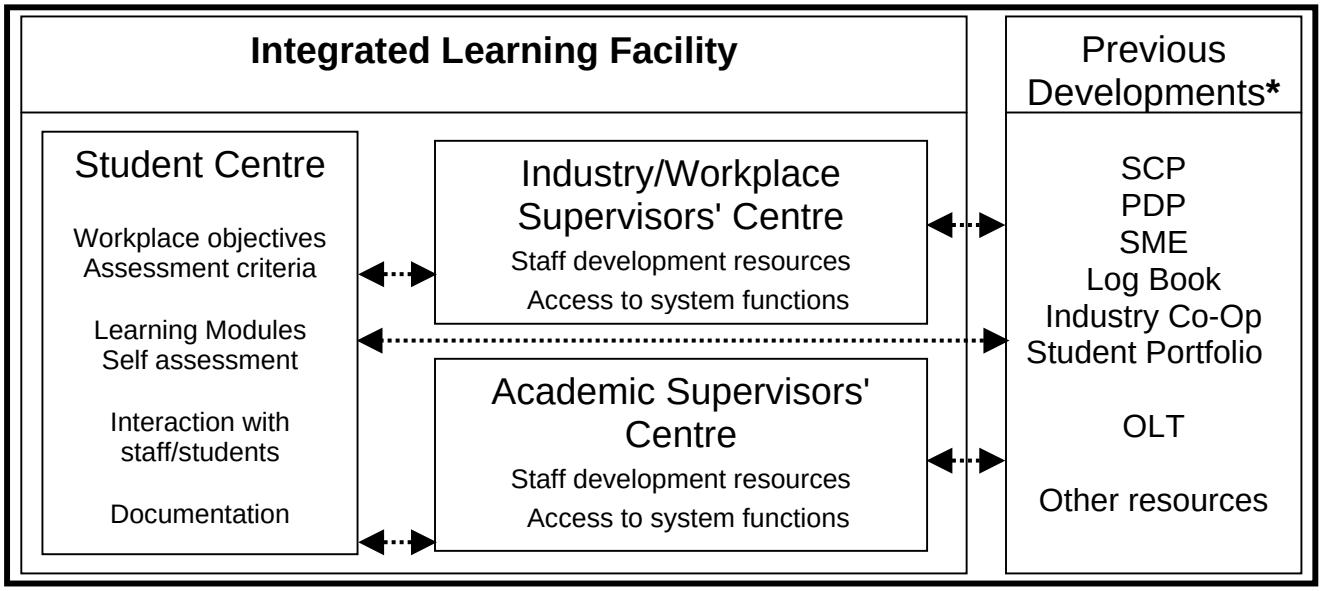


Figure 1: System Concept Block Diagram

SCP:	The Student Capability Profile for the monitoring and assessment of generic skills development;
PDP:	The Professional Development Project that links students into professional practice;
Log Book:	The Electronic Workbook that is being developed with the School of Design and Built Environment for students in Architecture;
SME:	The feedback obtained from the Small to Medium Enterprise (SME) Lifelong Learning project which focussed on determining the relationship between SMEs and work placement students;
Industry Co-Op:	The Electrical and Electronic Systems Engineering Industry Cooperative Program.

The Web interface

The design and development phase of this project involved the development team from Software Multimedia and Internet Learning Environments (SMILE) team as part of the wider Teaching and Learning Support Services department at QUT. A multidisciplinary team was created, drawing upon skills across: Project Management; Instructional Design; Programming; and Graphic Design.

The multidisciplinary team also had access to expertise encompassing multimedia production, educational television and media, open learning services, as well as academic support, advice and consultancy. Interaction between the SMILE team and the project group took place over a series of months developing concepts for discussion and obtaining feedback and advice from the project group. An industry focus group provided excellent feedback to the design team on issues of industry access, simplicity, interaction requirements (time, quantity and complexity) and useability of any software or websites developed. The advice provided by the Software Multimedia and Internet Learning Environments team included:

- Providing scaffolding for the pedagogical assumptions underlying the instructional design process;
- Developing effective web design concepts;

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- Evaluating the impact upon the project of existing/future QUT software systems; and
- Seeking ways in which this project could influence the direction and structure of existing/future QUT software systems.

Instructional design concepts

Instructional design according to Reiser (2001, p. 57) comprises: analysis; design; development; implementation; evaluation; and management phases or practices. The profession of instructional design also incorporates important aspects of: identification of research, theory and practice (Reiser, 2001, p. 57). In terms of this project the work of Janicki and Liegle (2001) provided a foundation for the instructional design concepts incorporating a combination of learning theories from the behavioural psychology, cognitive and resource based theories of learning. The concepts shown in Figure 2 consolidate the *instructional design activities* of Dear (1987), the *events of instruction* proposed by Gagne, Briggs & Wager (1988) and Gagne, Wager, & Rojas (1981) the design guidelines of Hannafin and Peck (1988) and the *strategies of instructional design* by Merrill (1997).

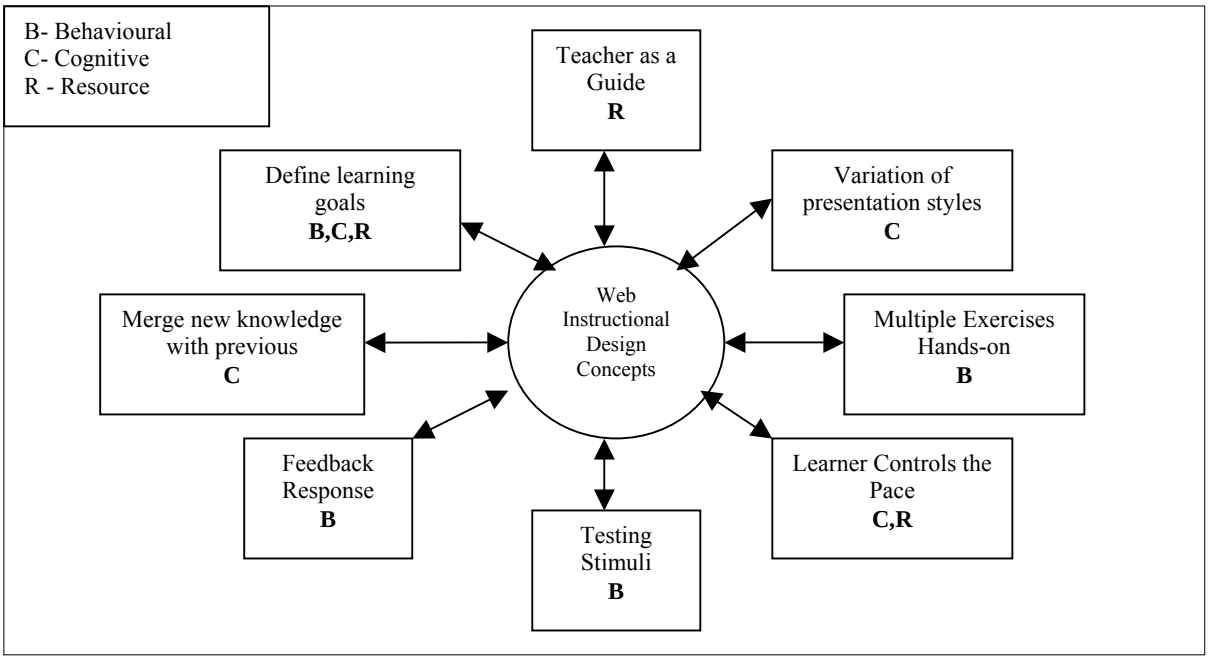


Figure 2: Summary of Instructional Design Concepts

This framework informed the design process by enabling focus on specific concepts, for example, defining the learning goals. Alley & Jansak (2000), argue the existence of ten critical elements in effective online learning that focus totally on pedagogical design, some of which are listed below:

- Learning is more effective if a student can take responsibility for their own learning.
- Student motivation is a strong determinant of the outcomes and success of learning.
- Higher order learning requires reflection.
- Learning is unique to the individual.
- Learning is experiential, and
- Learning is both social and private.

These critical elements influenced the design team towards a learner-centered approach requiring a change in focus from the academic to the learner. Whilst acknowledging that learning is of the utmost importance the questions we needed to ask were realigned: for

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example instead of "What do you need to cover in this course?" we asked "What do your students need to learn in this course?" Rather than "How will you teach this topic?" we asked "What do your students need to do and what cognitive and technical support do they need?"

Initial design concepts were provided to the project group focussing on creating an environment where emphasis was placed on developing higher order learning through reflective practice as a key element of the student reaching their full learning capability (Schon 1987, Kennedy 1998, Phil Race, 2000), the importance of flexibility and quality (Alley & Jansak, 2000, McKavanagh, 1999), and that participation and interaction (Kruh & Murphy, 1990, Herrington, A., et al, 2001) were essential elements of the teaching – learning process. The interface offers students access to a range of resources while also providing self-paced training for both academic and industry staff in the areas of consultation and negotiation; experiential learning design; supervision and mentoring; and workplace assessment.

The design framework builds on the work of Oliver et al (2001) and the three basic elements of interaction: learner ↔ content; learner ↔ instructor and learner ↔ learner as described by Moore (1996), by incorporating interactive and participative links with industry. The subsequent framework (see figure 3) clearly places the student at the centre in order to create an effective work and learning experience. Students are able to interact with both academics and industry through discussion forums, frequently asked questions (FAQ's), and the sharing of experiences. It is this virtual community which will be the mainstay of this facility, and which will also be the hardest to develop and maintain. Motivation of all stakeholders will be a key to the success and longevity of this interface.

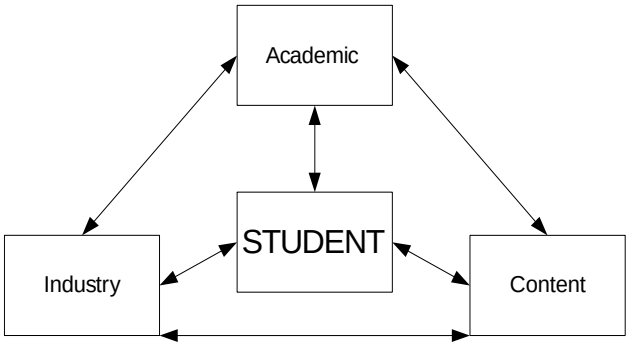


Figure 3: Interactive Framework

Appropriate use of technology

The appropriate use of information technologies has been a critical design issue. Consultation with both an industry focus group and academic staff emphasised the 'keep it simple' principle, in particular for busy industry users whose level of computer literacy maybe an inhibiting factor in the overall effectiveness of the system. The World Wide Web was chosen as the core delivery system in order to provide a means of communicating with large disparate groups of students and industry representatives and as a enabler of flexible delivery (Tinkler, Lepani & Mitchell, 1996).

Web interface design encompasses three distinct, but related constructs; usability, visualisation, and functionality (Vertelney, Arent, & Lieberman, 1990). More recently, a fourth component has emerged as a critical factor; accessibility. The design team followed established accessibility guidelines to ensure a level of responsibility and equitability in web

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design. The design of an accessible web site was not about removing images, video, audio, or interaction; it was about providing alternative access to these resources and interactions for users who would otherwise not have access.

The design team in the development of an effective web-based design made use of the work of Janicki and Liegle (2001) who provide a useful table of interface design concepts that summarizes the web-design concepts as offered by Jonassen et. al. (1995), Schank (1998), Murray (1996), Ward & Lee (1995), Leinder & Jarvenpaa (1993), Tennyson (1989) Bugbee (1996), Anderson & Reiser (1985), and Martin (1995).

• Instructor as a facilitator • Variety of presentation styles • Multiple exercises • Hands-On problems • Learner controls the pace	• Testing • Feedback • Clear Navigation • Help Screens • Consistent Layout

Table 1: Consolidation of Effective Web-Design Concepts

In designing the web interface the team also leant on the work of Cooper (1995:16) who stressed that "*good design makes the user more effective*". The development platform used was QUT's OLT (Online Learning and Teaching system) which provides students with a familiar clear navigation, the use of help screens and utilised a consistent layout.

Working with existing systems

Advice was provided by the design team to the project group on the relevance of existing QUT systems which could be integral to the overall design of the web interface: QUT Web System, the Online Learning and Teaching system, and the QUT Student Portfolio.

The online Learning and Teaching system is an integral component of the interface as the provider of interactive tools (chat and discussion forums) and as the deliverer of content as required by the web interface. It provides tools to develop a web interface without compromising the integrity of the keep it simple principle. It also empowers academics to author and update the content themselves with instructional design support provided by the design team.
The university's portal controls access to QUT's web systems. It has limited guest access and was deemed a major inhibiting factor in the overall viability of the web interface design and usability. This project and the Student Portfolio project have provided strategic influence which has led to the establishment of a parallel project to enhance the provision of guest access to the system.

The student portfolio (Emmett, 2003) is being piloted in 2004 and is due for full release across university-wide in 2005 as an integral part of the QUT Web System, the university portal. The Student Portfolio recognises the importance of reflection as a learning tool and will provide students with the ability to reflect on experiences based around a series of graduate capabilities. These capabilities would be aligned with the objectives of their curricula and the work integrated learning.

The design process

The design team used an evolutionary model of software development (Kennedy 1998) that is iterative, involved the user group at early stages and allowed for a software model that provided flexibility, longevity and updatability. Formative evaluation of designs with

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potential users was achieved using focus groups and design meetings with the design team presenting screen mock-ups and descriptions of functionalities. Users provided feedback on design, usability and provided scenario based scripts to better inform the design team of user requirements. Initial designs were also communicated to the instructional design and programming teams for comment. Feedback allowed the design team to be kept informed of other University projects which could affect this project's design process. Documentation was developed in accordance with the quality procedures used by Software Multimedia and Internet Learning Environments and involved Scope and detailed Requirements documents.

Implementation

While the project has not reached implementation phase, it has already been acknowledged that there is a need to provide support to academics and industry staff to develop the skills and knowledge necessary to exploit the potential for teaching and learning within the interface design. Interface implementation will also be dependant upon the successful conclusions to parallel projects which provide industry access and reflective journaling.

Evaluation

Evaluation of the interface design will follow the broad guidelines as detailed by Rowntree (1982:192): *Evaluation is the means whereby we systematically collect and analyse information about the results of students' encounters with a learning experience. We wish to understand what it is like to teach and learn within the system we have created; to recognise which objectives have been achieved and which not; and to ascertain what unforseen results (beneficial and disastrous) have also materialised.* The design team's methodology will encompass focus groups with all stakeholders and make use of the standard evaluation process at QUT.

Conclusions

In this paper, we presented an approach for designing an interface to support work integrated learning, based on constructivist principles which engage students in ways that required reflection and demonstrated knowledge construction. We have shown how our design focussed on the students as involved performers. We have also shown how we systematically developed instructional specifications using learning and instructional theory to ensure the quality of instruction and interaction. Emphasis was given to the process of analysing learning needs and goals and how those needs are met, while building a sustainable system. We have deployed effective Web design concepts that encourage making the user more effective. An evolutionary model of software development was used that is iterative, involved the user groups at early stages, and allowed for a software model that provided flexibility, longevity and updatability.

The paper addressed concepts, principles, and implementation matters relating to web design that are not only applicable to an interface for workplace learning, but can also be adapted for other applications.

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Project-based self-learning approach to teaching VLSI Design

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***Abstract**: This paper presents a project-based approach to learning in a course on VLSI Design. Rapid developments in VLSI technology and the continuing evolution in design practices means that students need to acquire important qualities of life long learning and self-motivated learning. However, it is indeed a challenge to develop among students a core body of technical knowledge, practical design skills using relevant CAD tools and lifelong problem solving ability in a thirteen week long semester. The project-based approach adopted in this course aimed to assist students to acquire these skills and to enable them to adapt to changes in their professional career. This approach resulted in high student achievements and satisfaction.*

***Keywords**: Project-based learning, learner centric education, self-motivated learning, lifelong learning.*

Introduction

Project-based learning has long been recognised to be very useful in education (Chen et al., 1994). In this approach learning occurs by way of engagement with practical problems the students are required to solve (Aziz, 2003). The key ingredients of this approach are that the students are required to apply their knowledge to solve practical problems and learn by doing (Kerns et. al., 2002). It enables students to become independent learners, to develop important graduate qualities such as problem solving and lifelong learning, and above all it prepares them for a professional career where they would be frequently required to work autonomously. The above two qualities are among the seven qualities a University of South Australia (UniSA) graduate is expected to acquire (UniSA, 2004a). In addition the University advocates the application of knowledge as one of its key commitments (UniSA, 2003).

The rapid developments in Very Large Scale Integrated Circuit (VLSI) technology and the corresponding evolution of design practices and tools warrant a teaching approach where students develop the quality of independent learning. Industry stakeholders look for graduates who are able to adapt to rapid changes in technology and design practices. This is very important since most technical skills appear to become obsolete within five years (ACNielsen, 2000). Therefore, a project-based learning approach whereby students not only acquire a core body of knowledge, but also acquire practical design skills and problem solving/lifelong learning abilities would be most appropriate. The question is how to incorporate all the necessary learning activities in a thirteen week long semester given that the students need to learn to use some CAD tools before they can really start working on the assigned projects. State of the art commercial CAD tools for VLSI design are known to have long learning

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curves. This drastically reduces the amount of time available for the actual learning, i.e., developing a core body of knowledge and problem solving skills. This paper presents a project-based approach including project examples whereby the author has attempted to address some these challenges. The student achievements and satisfaction with the course are also presented in this paper.

Consultation and planning

A number of professional engineers working in the Australian microelectronics sector were consulted in order to ascertain what skills and qualities the industries would look for in a graduate. A couple of senior engineers working in two renowned US design houses were also consulted in order to gain an international perspective and current technological trends worldwide. The following points emerged from these consultations:

- Graduates must develop a thorough understanding of the full-custom design methodology
- Graduates must develop the skills required to effectively apply their knowledge in practical circuit design and must acquire adequate practical skills for circuit design
- They must develop self-motivated learning abilities in order to adapt to the rapidly changing technologies and design methodologies throughout their professional career.

There was consensus among the professionals that such an industry-focused course could be best facilitated using project-based active learning approach. Three separate mini-projects were designed as the main learning activities in the course covering both the design methodologies and the underpinning theoretical knowledge. Assessment in the course was 100% by design projects. Commercial CAD tools were not used due to their long learning curves and high cost. The industry professionals consulted expressed the view that any collection of CAD tools which would facilitate the development circuit design skills and incorporate up to date chip design flow could be used. For a custom VLSI Design course, they recommended that the CAD tools used should have the following features (Pucknell and Eshraghian, 1994; Rabaey, Chandrakasan and Nikolic, 2003; Weste and Eshraghian, 1993):

- Facility for mask layout design and support for structured design methodology.
- Choice of a number of appropriate foundries within the design environment.
- Quick functional simulation.
- Netlist extraction including parasitics for SPICE (for precise simulation).
- Design Rule Checking (DRC).
- Generation of industry standard formats such as CIF or GDSII for fabrication.

A review of the available CAD tools was done. In addition to considering the above items, features such as ease of installation and maintenance, user friendliness, support for Windows based PC platforms etc. were considered. These are issues that can impact on the smooth running of the course. In the end a CAD tool named Microwind2 (Sicard and Chen, 1999; Sicard, 2003a) was selected. This tool includes most of the desired features for the VLSI Design course as outlined above. The most important feature of this tool is its user friendliness and consequent fast learning curve. In addition it has a number of easy-to-use tools which make learning enjoyable. These include a tutorial on MOS devices (Sicard, 2003b) to easily understand the MOS characteristics with a friendly user interface. Changing the model parameters immediately displays the effects on MOS characteristics on the screen.

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2D and 3D views of the circuit designed are available immediately at the press of an icon. These are very helpful for visualizing some of the details of the fabrication process. A built-in device and interconnect extractor is invoked at the press of a single key. There is a built-in analog simulator, which eliminates the need for external simulator for most educational purposes. It uses MOS model 1, 3, 9 or BSIM4 to perform static or time-domain verification of the circuit (Sicard and Bendhia, 2002). Simulation can be performed on a wide range of technologies: 1.2 micron down to 35 nm. On-screen power estimation is also available. The tool supports cutting edge processes including copper interconnects, 7 metal layers, three types of oxides and five types of MOS devices. On top of all these the tool is available for free (Sicard, 2003a).

Design projects

First project: a self-learning exercise

The projects were designed carefully so that students could enhance their understanding of the theory and develop circuit design skills right from the beginning. With this in mind, the first project presented a simple circuit design exercise, that of designing the mask layout of a CMOS (Complementary Metal Oxide Semiconductor) inverter. A step by step guide (project handout) to building the inverter layout was given to the students. Following the steps the students could comfortably navigate through the various features of the software and gradually build the inverter layout without much difficulty. In other words the project handout was designed as a *self-learning guide*. This project achieved two things, first the students learnt how to use the software, and second they got the satisfaction of building a circuit that did something useful. This did a lot of good for student satisfaction and motivation.

Figure 1 shows a monochrome view of the inverter layout and Figure 2 shows the simulation results (voltage vs. time) for checking the functionality of the inverter. Figure 3 shows the transfer characteristics of the inverter. It enables students to determine important parameters such as noise margin (Weste and Eshraghian, 1993). The students are able to extract a SPICE netlist from the layout of Figure 1 and simulate the inverter with SPICE for various aspect ratios of the MOS transistors. This is done simply by editing the SPICE text file rather than having to painfully redraw the inverter layout for various aspect ratios. Repeated simulations with SPICE enables students to optimise the design for output rise and fall times (propagation delay) and noise margin. Students also gain some idea about structured design methodology right from the first project as they are given instructions to build the inverter layout in a way that facilitates automatic abutment (Pucknell and Eshraghian, 1994) with other cells.

Subsequent projects

The projects gradually increased in complexity to provide students with opportunities to develop skills for designing larger and more complex circuits. The second project was on designing the layout of a 4-bit shift register. A structured design methodology was followed. Students built the layout of a CMOS transmission gate and joined it with the inverter layout created in the first project to build a 1-bit inverting shift register cell (Pucknell and Eshraghian, 1994). The layout of the inverting shift register cell is shown in Figure 4. Two of these cells were placed side by side to make a 1-bit non-inverting shift register cell. Two non-overlapping clock signals (Clk1 and Clk2) were added to the two transmission gates. Finally four non-inverting shift register cells were placed side by side to make a 4-bit shift register as shown in Figure 5. Students simulated the 4-bit shift register to verify the shifting operation. In this project students developed structured circuit design skills and also developed understanding of the effect of changes in the two-phase clocking scheme on the operation of

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the shift register. This is important for designing synchronous circuits whose operations depend on active clocks (Rabaey, Chandrakasan and Nikolic, 2003).

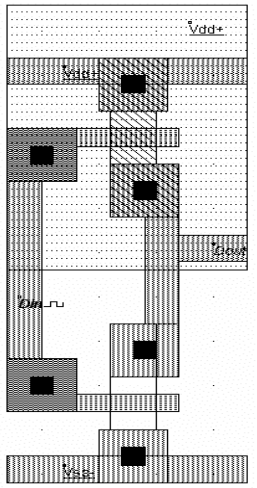


Figure 1: Mask layout of the CMOS inverter

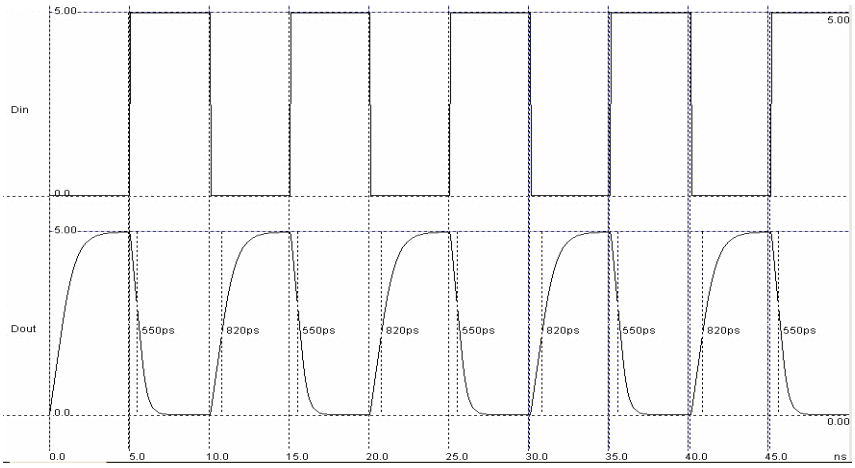


Figure 2: Simulation results for the CMOS inverter: input and output voltage waveforms as a function of time

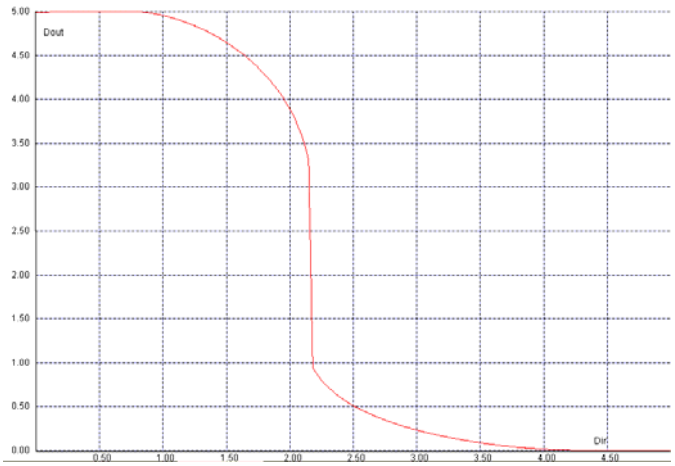
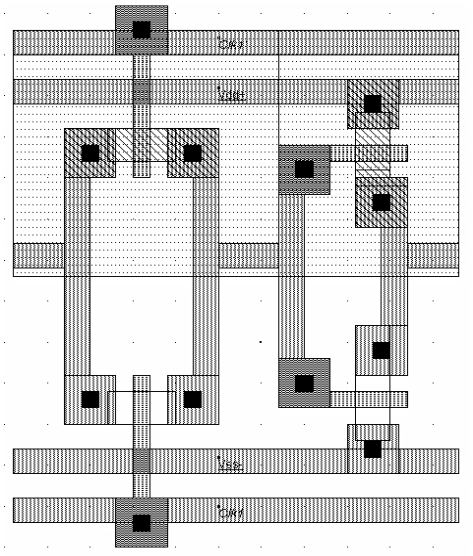


Figure 3: Transfer characteristics of the CMOS inverter



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Figure 4: Layout of the 1-bit inverting shift register cell

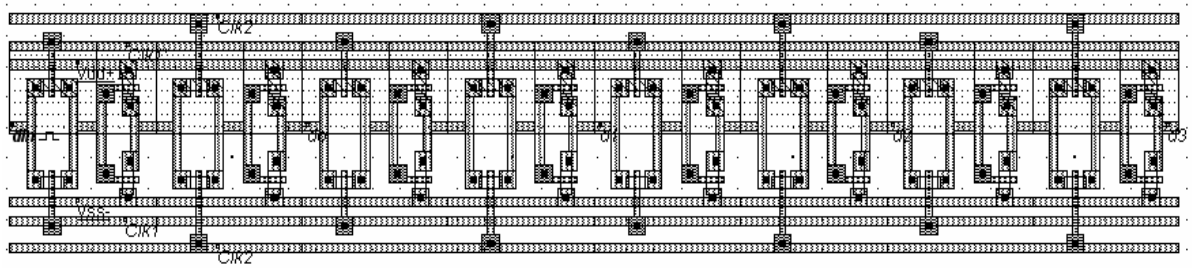


Figure 5: Layout of the 4-bit shift register

The third project was on the design of a complete 4x4-bit static CMOS Random Access Memory (RAM) chip including I/O pads (Pucknell and Eshraghian, 1994). This was aimed at giving students some idea about the overall chip design flow. RAM being a fairly modular structure, the structured design methodology easily adapted to the design. Students faced a number of design challenges in relation to column and row selection (decoding), sense amplifiers, power supply rails and I/O pad ring (Pucknell and Eshraghian, 1994). They were required to work through the problems associated with each of the above modules in order arrive at a design that worked and yielded expected performance. Those who successfully completed this project developed very good understanding of the issues and processes of efficient chip design, developed good design skills, and gained a level of confidence not possible by any means other than the project-based active learning approach.

Thoughts on further projects

Further projects could involve the design of a datapath, for example, a 4x4-bit parallel multiplier (Weste and Eshraghian, 1993), an analogue voltage reference circuit or an analogue-to-digital (A/D) converter. The number of projects and their complexity should be determined by the time available and the student groups for whom the course is being offered, i.e., undergraduate or postgraduate. Nevertheless the students should be encouraged to think about and undertake designs of useful circuits on their own. It would be of enormous benefit to support the students in this respect by pointing them to relevant resources and design examples. It has been the author's experience that there are always some students who would want to do and learn more than what is necessary to simply complete the requirements of the course. It is always good to support their inquisitive minds as some of them might progress to become pioneers in their fields of expertise.

Supporting students' learning

The author experienced the need for good course resources to support students in the project-based learning approach. A good textbook with lots of practical design examples can be a very good resource for students. Students not only get design ideas/tips from a good text, but also get a lot of their questions answered. However, a textbook alone is not sufficient for the students' learning in such an industry relevant problem-based course. Students are bound to encounter problems and have many questions requiring answers. Therefore it is important not only to have good practical (project) handouts to assist the students through their projects, but also to provide references to other useful resources and links to useful web sites. The Internet has a huge collection of information in the area of VLSI Design including notes, tutorials, technical papers, design examples and freeware tools from across the world. Familiarity with these resources would be very useful for the students' learning, and for them to develop an understanding of the potential of the technology, the most recent developments, prospective

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future developments, and above all to develop an international perspective. Students should be encouraged to search and consult these resources. The author developed web-based study resources for the VLSI Design course including project guides. However, these resources need to be developed further. The resources were accessible by the students via the University of South Australia's online learning environment called *UniSAnet* (UniSA, 2004b). These resources would be useful for flexible delivery of the course through the on-line medium. This is in line with UniSA's emphasis on developing web-based resources to support student-centred learning and internationalisation of programmes (Aziz, 2004).

Student achievements and evaluations

The students started with a simple project and the complexity increased progressively as they moved to subsequent projects. This was to ensure progressive development of problem solving and practical circuit design skills among students. The project-based approach allowed students to effectively engage in the active learning process and enabled them to learn by doing. Student motivation was extremely high as seen in their desire to successfully complete the projects. Another reason for high student motivation was that the assessment in the course was based entirely on the projects. The author's role was more of a facilitator then a teacher. This was to perform critical analysis of the students' designs, giving them feedback on a regular basis and encouraging them to think critically about alternate design ideas. It is important though to guide students when they are either stuck, or unsure as to how to tackle a particular design problem. Many students worked beyond the scheduled laboratory hours in order to evaluate alternate design ideas as they progressed with their projects. Out of a total of 19 students enrolled in the course, 18 successfully completed all the three projects and obtained an average grade of above 'Distinction' in the course. Students evaluated the course using University of South Australia's standard course evaluation questionnaire. They ranked the course at 4.2 on a scale of 5.

Majority of the students expressed the view that the project-based approach was very useful for their learning, for development of practical design skills, problem-solving ability and self-learning habit. However, nearly half of the students in the course expressed the view that there should be some exam or quiz in the course to test their knowledge on a broader range of topics covered in the course. Some even thought that the projects were not complex enough to differentiate between the highly capable students and the average students. They felt that one or two exams/quizzes would have achieved that and the distribution of grades in the course would have better reflected the variations in the abilities of the students. Nevertheless nearly all students agreed that the assessment weightings in the projects should be high for motivating and actively engaging students with the projects.

Conclusions

A project based learning approach adopted in a VLSI Design course has been presented. One of the key aspects of the approach is to start with simple projects and gradually increase the complexity to allow students to engage into deeper learning. Selection of a user-friendly CAD tool reduces learning time and motivates students in self-learning. However, it is important to support students' learning by providing them with an easy-to-use guide for the first project. The use of a freeware tool gives students the flexibility to work at home at convenient times and encourages them to do more. The course gained very high student evaluations. The student-centred active learning approach adopted in the course turned out to be very successful in terms of students' learning outcomes, achievements and satisfaction. The

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motivation and interest created among the students coupled with the problem solving skills they developed would assist them in lifelong learning in the rapidly advancing area of integrated circuit design.

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Implementation of Computing Degree Courses in India through the Internet

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Abstract: *India is a fast developing country with a particular specialisation in information technology. However the demand far outstrips the supply for suitably qualified personnel. The* ***Apeejay group*** *is one of the country's larger industrial combines that also maintains an educational wing. It is attempting to satisfy the demand by offering two* ***University of Westminster****, London, UK, undergraduate degree courses at the* ***Apeejay Institute of Information Technology,*** *one of their higher education sites in New Delhi. The two BSc Honours courses, in Software Engineering and Information Systems Engineering, utilise all the teaching, tutorial, coursework and examination material that is produced for the same programmes that run in the UK, and follow exactly the same annual timetable. The only difference is that the material is delivered in New Delhi by local academic staff to Indian students attending the Institute in the normal way of higher education. The costs for the Indian students are therefore considerably reduced as they do not have to attend the Courses in UK to qualify for their degree award. Quality control of the two courses in India is maintained by adopting all of the quality procedures that apply throughout the University of Westminster. The internet, or in reality the intranet, supported by Blackboard for communication, is the chosen medium employed for the exchange of information between London and New Delhi. The course material is available in different formats depending upon the application. The paper discusses the successful implementation of the two University of Westminster undergraduate degree courses in India.*

Keywords: *Education; Computing; Internet*

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Introduction

The University of Westminster (UoW) was established on Regent Street, London, in 1838 as The Royal Polytechnic Institution, by Sir George Caley, recognised internationally as an aviation pioneer (www.wmin.ac.uk). The Cavendish School of Computer Science (CSCS) of the University has a long standing record of innovation in both traditional and off campus modes of delivery. The particular project that is presented here concerns the implementation of two of the CSCS's undergraduate degree courses in Computing at the **Apeejay Institute of Information Technology (**AIIT), in New Delhi, India (www.aiit.edu).

India is the world's largest democratic country with a voting population in excess of 750 million and is widely acknowledged for running a very buoyant and dynamic economy. It maintains a successful satellite programme, it boasts of a substantial defence infrastructure and the biggest computer companies maintain laboratories there, undertaking much of the leading edge development that is happening in the field of information technology.

In the current climate of rapid technological innovation, the demand for computer education exceeds the capacity of the leading technical institutions to satisfy it. Consequently, in 1999, the UoW was invited by the Apeejay Education Society (AES) to cooperate and to offer their BSc undergraduate degree courses in Information Systems Engineering and Software Engineering in India at the AIIT site in New Delhi. It was clear at the outset of the project that the internet would be the primary communication medium and this paper summarises the implementation of the programme.

The AES is a private body and the charitable wing of the giant industrial Apeejay Group in India (www.apeejay.edu). It runs a number of schools throughout India which offer primary and secondary education, a number of colleges which offer higher education up to post-doctoral level in arts, fine arts, humanities, commerce and science, a number of technical institutions which offer higher education up to post-doctoral level in technology and engineering, and a number of professional institutions which offer management and computer science courses at all levels.

India is an ideal partner country for the UK in such a programme because English is the medium for education, the educational and administrative procedures are very similar, and there is a sizeable number of Indians living in the UK with contacts in both regions.

Structure of the Programme

There has been an explosion of late in internet education provision as universities have sought to extend their influence through programmes loosely defined as 'Distance Education'. A key issue in Higher Education, though, has been, and still is, the protection of the quality of the final degree qualification particularly when it comes from an established provider. Many Governments are very defensive of the quality of the title of a degree and, in the UK, the **Higher Education Funding Council** and the **Quality Assurance** Agency for Higher Education maintain a close watch on all overseas programmes. The structure of the degree programme in India, therefore, had to satisfy the existing conditions for quality control of the UoW's on campus degree courses.

With this in mind, it was decided to go for a model whereby the course material generated and utilised at the UoW would be delivered locally at the AIIT following the same time pattern of

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semesters and assessment periods, rather than adopting a totally distance learning approach. This included not just the course notes, but also the courseworks and examinations. Hence the requirement was that the students in India attend the AIIT, much as they would any Higher Education Institute, but that the content of the degree programme they were studying would be provided by the UoW.

Initially the staff and facilities at the AIIT were validated by a team from the UoW. Given that all the teaching material to be used in India had already been developed and approved in London, the primary purpose of the validation visit was to examine the resources offered by the AIIT. It was essential that the all the facilities available in London were mirrored in India. And further that the local staff were qualified to the equivalent level of their counterparts in the UK.

A key issue concerns the independence of the examination board, held at the end of every semester, in other words twice per year. The examination board at the AIIT is considered to be part of the UoW's examination procedures and therefore subject to the same rules and regulations as all the London based courses. The examination board is chaired by an experienced chairperson nominated by the University with the support of an independent external examiner, also appointed by the University. The normal scrutiny of all student work proceeds all examination boards along with student interviews according to well established practice.

Courseworks and examinations are carried out at the same time in India as in London, following the same deadlines.

The structure of this approach has proved to be extremely robust and enabled the UoW to maintain tight control of the academic programme and therefore guarantee the quality of the final degree qualification.

Figure 1 attempts to visualise the mechanisms for the delivery of a degree course by the UoW at the AIIT. The figure includes the position of Course Monitor, an independent person appointed by the UoW to garner student views of their course and to make recommendations accordingly.

Courses on Offer at the Apeejay Institute of Information Technology

Whilst the CSCS of the UoW provides a complete portfolio of computing courses from Foundation through to MSc, it was decided to begin the cooperation with the AIIT by restricting what was on offer in India to just two of the undergraduate degree programmes available, with the possibility for expansion later. These were the BSc Honours course in Software Engineering and the BSc Honours course in Information Systems Engineering. Whilst the two courses are of 3 years duration in the UK, the Indian market and expectation for Engineering degree courses in India is for a 4 year period. Therefore both courses in India were designed to include a Foundation year, with entry qualifications appropriately adjusted.

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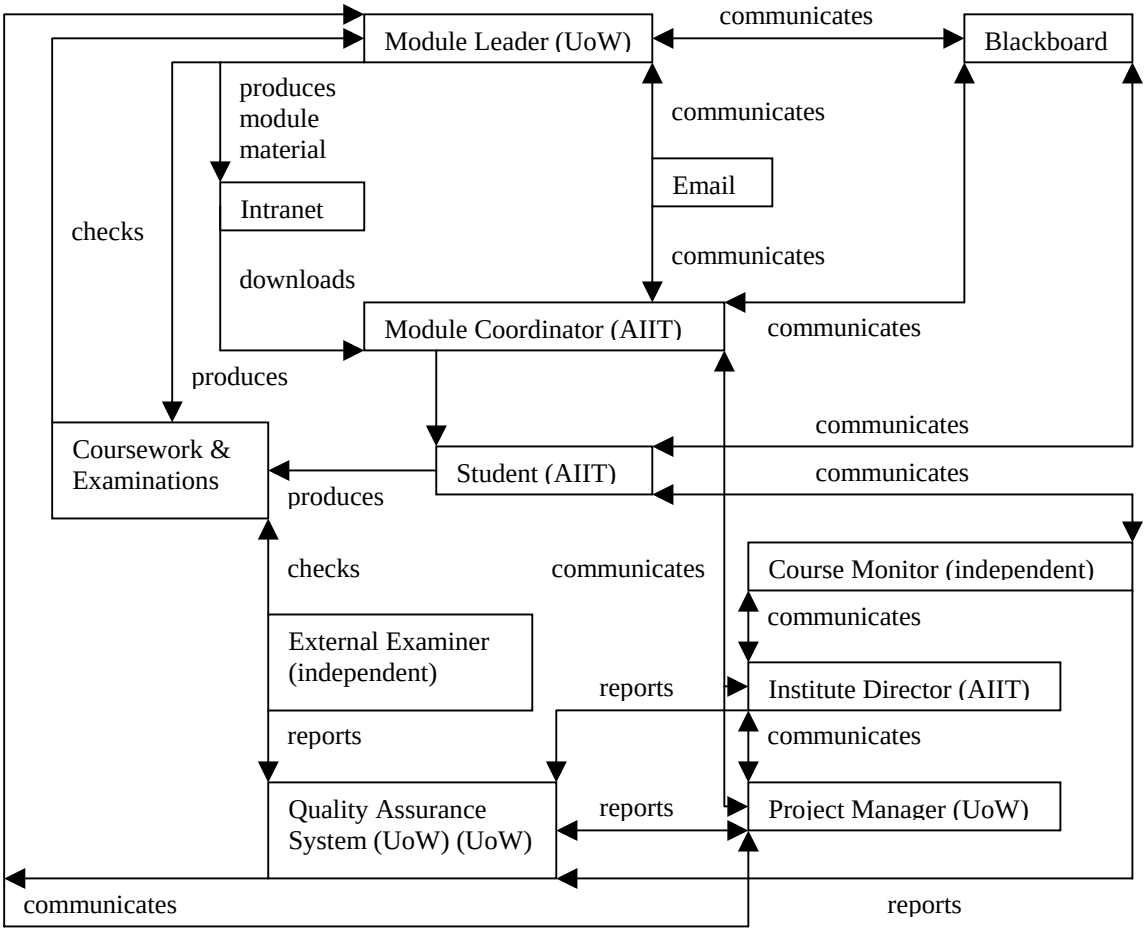


Figure 1: Communication within the Project

The discipline of Software Engineering studies how best to analyse, design, build and maintain systems software. The subject makes use of many of the technical sub-disciplines of computer science, programming in particular, but it is primarily concerned with the application of theory in the process of system design and construction. In the internet era, special emphasis is made on information security and quality.

The purpose of an Information System, as defined by the British Computer Society, is to collect, process and store data, and distribute information for a defined purpose or application using computing technology. Over a period of forty years, Information Systems has been a continuously changing field that has moved from the mainframes maintained by large centrally organised data processing departments systematising the routine manipulation of simple data records with the weekly turn-around of basic reporting, to globally distributed systems that generate multimedia information, integrated with key business functions for the purpose of enhancing competitive advantage.

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The University of Westminster's Modular Degree Structure

All undergraduate degree courses at the UoW follow a two semesters per year programme which starts in September and runs through to June of the next year. Each semester is fifteen weeks long and consists of twelve teaching weeks, one consolidation week, with two weeks for examinations.

The standard undergraduate course pattern is designed around eight modules per year of fifteen credits each, four modules per semester. Every module is scheduled to last four hours, roughly two hours of lecture time plus two hours of tutorial time. In other words student contact time per week is geared towards sixteen hours. The pass mark to achieve the credits for a module is 40% overall. Some modules are assessed by coursework only, and some by examination and coursework. For the latter there is usually a threshold mark, such as 30%, that must also be obtained in each element, examination and coursework, for the module credits to be awarded.

The BSc Honours courses in Software Engineering and Information Systems Engineering adopt the standard University model and are offered in exactly the same way and time scale in India.

The Use of the Internet

Clearly the internet, or in reality internet integrated with the intranet of the UoW, is the most important medium for communication of the course material between London and New Delhi.

The UoW has appointed a Project Manager to oversee the successful implementation of the two degree courses in India. He corresponds with the Director of the AIIT by email on a regular basis, supported by occasional visits to New Delhi. He also assumes the role of the Academic Liaison Tutor for the project.

Each module is allocated a Module Leader in the UK. The person delivering the module in India is deemed a Module Coordinator. The Module Leader places onto the University's intranet site:

- All the teaching material for the module including the tutorials and solutions;
- The set courseworks;
- A teaching programme;
- A tutorial programme;
- A coursework programme.
- Past examination papers with suggested solutions

This is carried out well in advance of the module being delivered in the UK. The module coordinator therefore has time to absorb the module material before having to deliver it in India. Any queries can be dealt with by email conversations between the Module Leader and Module Coordinator. Each Module Coordinator is allotted an internet ID and password which enables him/her to gain access to the University's intranet at all times.

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The module material on the intranet is made available for download in a number of formats, such as:

- Power point slides;
- PDF;
- MS word.

The students at the AIIT are all registered with the UoW. This gives them a student id which can be utilised to access the University's intranet. The module material can be released to the students once they have fully registered for their course and have been allocated their personal student id. Of course permission to view the site may also be withdrawn if the need ever arises. All modules use the medium of Blackboard through the intranet for communication between students, Module Leader and Module Coordinator.

Each Module Leader assumes the responsibility of keeping their intranet site up to date. Therefore, for example, towards examination time, it might be appropriate to add some example questions and solutions for practise by the students. Or if the date for submission of a piece of coursework is changed, the information can be relayed to the students through the site and Blackboard.

Courseworks and Examinations

Clearly the implementation of each module's assessment regime through courseworks and/or examinations is the key to the success or not of the project. Fortunately by insisting that the AIIT adopt the same programme at all times for the delivery of the two degree courses in India as is followed in the UK, many potential pitfalls can be avoided.

Examinations, for example, are held at the same time in the UK and India. Given that New Delhi is four and a half hours ahead of London in the summer, and five and a half hours ahead in the winter, it is not difficult to schedule examinations at the UoW to be in the morning and so in the afternoon at the AIIT at convenient times for both sets of students. The examination papers follow the usual scrutiny process adopted by the UoW, including referral to the External Examiner, and are then sent to India by courier service a few days before the examination takes place, together with solutions and a marking scheme for the Module Coordinator.

In a computing course, many coursework assessments are given on line. The same procedure can be adopted as for examinations. Usually, though, on-line assessments at the University have to be carried out in computer terminal rooms and there are often not enough of these available at any one time for all the students on a given module at a given Level of a module at the UoW. This necessitates the Module Leader setting an assessment as coursework, which varies for the different time zones when computer terminals are available, and the AIIT merely represents another time zone.

Deadlines for the submission of coursework are an integral part of modern student life and the same submission time and date is specified for the students in India as in London, bearing in mind the time differential.

Marking of the examination papers completed by the students in India is carried out by the Module Coordinator at the AIIT, with double marking provided by a colleague at the Institute.

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Then a sample of the marked scripts is sent to London for confirmation of the marking by the Module Leader. Further all the examination papers are scrutinised by the External Examiner to the courses at the AIIT, supported by the Project Manager from the UoW, prior to the examination board.

Marking of the courseworks completed by the students in India is carried out by the Module Coordinator at the AIIT, with double marking provided by a colleague at the Institute, as for examinations. A sample of the marked coursework may or may not be sent to London for confirmation of the marking by the Module Leader as appropriate. Many coursework assessments are submitted by email or disk on a computing course so it is an easy matter to transfer the student work from one country to another. However the nature of some courseworks is such that it is not always possible for the Module Coordinator to inspect them, for example some may be done in industry. In this case the External Examiner to the courses at the AIIT, supported by the Project Manager from the UoW, can look at the work prior to the examination board. Another example would be student presentations, in which case the judgment of the student performance is generally left to the academic staff of the AIIT. Of course it is perfectly possible to record a student giving a presentation in India and for that record to be examined in London. If this is done simultaneously, it is expensive, so the preference would be for a delayed assessment from the UK.

Student –Staff interface.

In order to provide transparency to the delivery of a course and examination system , Students Staff Course Committee (SSCC) has been instituted which has members from teaching faculty , admintrative staff and student representative from each course. It is ensured that girl students are adequately represented in the committee. The committee must meet at least once in a semester. The committee meetings are chaired by the Director AIIT (Course Leader)and records of discussions/ suggestions are recorded by the Registrar. Points raised by the students and action taken on previous points is read out in the meetings. Record of such meetings is reviewed by the Project Manager during his visit to AIIT. This mechanism has proved a very effective method of seeking participation of students and staff to make course delivery better.

Projects

The final year major project is an integral and very important part of a UK undergraduate engineering degree programme and this is certainly the case for the two UoW courses operating at AIIT. In fact it is studied as a double 30 credit module, as opposed to taught modules which are single 15 credit modules. In general the topics chosen by the students for their major projects on the two courses are derived from industrial, business or commercial contacts, and the same applies to the students at AIIT, only the contacts are local, mostly from the New Delhi area. The Project Supervisors are allocated from the academic staff at the AIIT under the auspices of a Project Coordinator back in London. The major projects are assessed by the academic staff of the AIIT, and checked by the External Examiner, with sample reports being sent back to the UoW for additional scrutiny. As all the major projects are computer based, generally involving the writing of software programmes or the design and application of databases, the transfer of any students' work between interested parties is easy to achieve through the intranet. This is vital for quality control purposes, given that the assessment of projects can be somewhat subjective.

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Financial Considerations

The AES is a private establishment supported by the Industrial Apeejay group. As such it sets the fees for students to enter its educational premises, for example at the AIIT. The fees are pitched at an appropriate level for the local market, sufficient to maintain the Institute as a quality establishment of Higher Education. A given percentage of the fee charged to students is transferred to the UoW per year. In reality between seventy-five and one hundred students per year of a course are required for the programme to be viable to the AES and the UoW.

Clearly therefore both the AES and the UoW can benefit financially from the arrangement, depending upon the level of fees charged. But there are many other benefits too. Staff exchange for example is encouraged. It is important for a good working relationship to be established between a module leader and a module coordinator for the successful delivery of a module and that is helped if they can meet from time to time. Student exchange is another valuable part of the cooperation. As the courses are identical in London and New Delhi, it is very feasible. Students from India relish the opportunity to spend one semester or maybe one year of their course in London from the experience point of view. Of course, they, or their parents, will have already chosen to benefit from taking a degree course from a UK university, but coming to London is an additional bonus. Many of the students at the UoW have an ethnic background and welcome the possibility to spend some time in India. And technical exchange is another vibrant area. India is at the forefront of technical computing development and the courses in London can only benefit from an input from such a knowledgeable partner.

Student Progress To-Date

This can only be described as very successful. The first cohort of students entered the BSc Honours courses in Software Engineering and Information Systems Engineering at the Foundation Level in September 2000. Therefore the first graduates from the courses will be produced in July 2004. Whilst it is unrealistic to compare the performance of the students in India with their counterparts in London, because there are many more of the latter, it must be recorded that there are very few failures in modules from the students at the AIIT and no failures in terms of progression of students from one Level to another due to insufficient accumulation of credits.

Table 1 summarises the student performance to-date. It must be noted that the table encompasses all years of the two courses, in other words every student is doing eight modules each per year.

Academic Year	Percentage of Students who Pass all Modules at first attempt	Percentage of Students with one or more Module Referrals	Percentage of Students with one or more Module Retakes	Percentage of Students able to Progress to Next Level of Course
2000-2001	88%	12%	0%	100%
2001-2002	83%	12%	5%	100%
2002-2003	86%	13%	1%	100%
2003-2004*	89%	10%*	1%*	*

* Based Upon First Semester Results Only

Table1: AIIT Student Performance

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Problems and Successes

Despite the paragraph above, it should not be thought that there have been no problems in implementing the two UoW courses at the AIIT. There are always technical problems which can be overcome. And recently, The Indian government has issued a directive that all external degrees must be approved by the All India Council for Technical Education (www.aicte.ernet.in). But there are cultural differences which manifest themselves in interesting ways. Not simply just that there might be a public holiday on January 26th in India to celebrate Republic Day with no equivalent in the UK, and a test in module X has been set for that day. Rather for example, it is the Indian expectation that their students should be kept occupied for much of the day. This has necessitated the provision of extra modules, which do not count towards the degree award, but which give the students experience of languages or the arts for example. In the UK the provision is for sixteen hours per week student contact time. Many students in the UK work in part-time jobs in order to accumulate some money to support themselves through University. Obviously this affects their studies but there is not the equivalent approach amongst the Indian students, at least not those at the AIIT!

There are many success stories. The final year students from India are being accepted for postgraduate courses readily by Universities in the UK, the USA and Australia. And of more relevance many of them have already found positions for themselves in industry for when they graduate in July 2004. Local companies are keen to employ them because the degree they are going to get is different to the degree they would achieve from an equivalent University in India. Employers are discovering that the course involves far less spoon feeding of information, and that the students are being taught to think for themselves and are capable of providing accountable and cost-justified solutions to problems in the broadest context.

Conclusion

The implementation of two of the UoW's BSc Honours undergraduate degree courses in computing at the AIIT has been successful. The model adopted, whereby the University's course material, including lecture notes, tutorials, courseworks and examinations is delivered locally to students in India by Indian academics within the same time frame that operates in London, has ensured that the quality of the courses can be maintained at all times and that the output will be the same at both Higher Education Institutions. The use of the intranet, intranet and within it Blackboard, has played a large part in the success of the project, although this is to be expected of courses in computing. Further, student, staff and technical exchanges have been to the benefit of both the UoW and the AIIT.

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The activities and impacts of part-time employment on full-time undergraduate students in property and construction courses in Australia

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Abstract: *This paper examines the extent of part-time employment of undergraduate students enrolled in property and construction related courses in five universities across Australia. Forty five percent of the students responded to a questionnaire on their part-time work. Past research reveals that there is need for a more accurate understanding as to why students seek part-time work to the extent that they do and that working long hours has a negative effect on the study patterns of undergraduate students. Increased employer work demands results in less time available for study and an inability to attend lectures because of work. There is growing concern that students are increasingly disinterested in connecting with the broader and total university experience and are instead, seeking to adopt a minimalist approach to education.*

Analysis of current research for Property and construction students' results reveals that students are working on average 18 hours per week during semester time. The students therefore appear to be working beyond what is considered beneficial to their studies, although their contextual understanding and work ethic improves.

The paper concludes with some approaches that could re- engage students into the learning process. It may be helpful to develop a partnership between the University and the industry thereby providing work experience that complements the program of study. Otherwise students may not get the range of experience they need and may struggle to find the linkages between theory and practice.

Keywords: *Combining work and study, valuable work experience, negotiated engagement*

Introduction

Over the last two decades fewer younger people leave school and enter the workforce directly. According to Curtis and Lucas (2001) this has caused a fundamental shift in the youth employment market. Young workers of the 1960's and 1970's have been replaced by students, trainees and the underemployed. (Roberts, 1995). Young people are staying in education longer, and some have to fund their own education in the latter years. The study habits of undergraduate students as a result, have changed enormously from the patterns that

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existed in the past. Students combine work and study to a far greater extent than in any other previous time.

This paper examines the extent of employment of undergraduate students enrolled in property and construction related courses in five universities across Australia. The objective is to provide some degree of understanding of the advantages and disadvantages of part-time work in construction related courses.

Why students work part-time

Research by Curtis and Lucas (2001) suggested that students are today bearing a much larger educational cost than previous generations. In the UK, the results of a recent Nat West student finance poll (Nat West, 1999) reported that three quarters of undergraduate students who were working said that they could not afford to remain at university without a job. This has been caused mainly by the manner in which governments have changed the higher education funding arrangements to require the students to contribute to their own education.

In Australia this was done by the introduction the Higher Education Contribution Scheme (HECS) in 1989; the subsequent rises in contributions ever since cause the student to contribute over a third of the full cost of the tuition. This issue is widespread and occurs in many other developed countries. In the UK (Sorensen and Winn, 1993) stated that 31 per cent of students surveyed considered giving up their course for financial reasons.

Australian research by McInnis (2003) suggests that there is need for a more accurate understanding of why students seek part-time work to the extent that they do. According to his research, not all students are working to avoid starvation, or even pay the rent. Although one in three students is concerned with money issues, the remainder are working to maintain lifestyle with some financial independence from their families.

The positives and negatives of part-time work

Many studies have shown that excessive levels of part-time work can impact negatively on undergraduate students. In a study by Sorensen and Winn (1993), undergraduate students attributed the negative impact of work on study to having less time available for study, tiredness and the need to miss lectures to attend work. In an unpublished study at Oxford Brookes University in the UK, it is reported that every year, more than 200 students in part time work gain a degree at least one class lower than they would get were they not in paid work (Lindsay and Paton-Saltzberg, cited in (Curtis and Williams, 2002)).

On the other hand, other research suggests that semester-time work can provide positive benefits to students. For example, Watts and Pickering (2000) suggest that skills learned at work are transferable, and students who work are more employable due to the development of organizational and time management skills. Working students are also said to develop good inter-personal skills (Lucas and Lammont, 1998).

In addition, when part-time work is related to a students' vocational coursework, it may be beneficial as an aid to academic knowledge and career prospects. Part-time work experience is very valuable when students are seeking permanent jobs after graduation. (Davies, 2000)

According to Lucas and Lammont (1998) there is a perception that undergraduate students need to acquire work skills in addition to the financial necessity for paid work. This research

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cited that students are aware of the benefits of part-time work and are consequently reluctant to give it up. This trend has been recognised in Australia and overseas (McInnis, 2003).

The Dearing Report (Dearing, 1997) indicated that graduate applicants seeking their first career jobs do not possess the personal, transferable and employability skills which employers require. This supports past research by the authors (Lingard, et al., 2003) that has shown that students generally believe that part-time work is beneficial to their future careers. Modern students may have lower expectations of higher education and consequently there is a lower demand for full educational experiences (McInnis, 2003).

Research by McInnis (2003) states that the results of various studies over a number of years showed that undergraduate students are unclear about their obligations to the university, and tend to spend less time on tasks that improve their learning experience. Instead, students are more pragmatic about their study and view learning as a vehicle to obtain work. The results of the research suggest that the opportunity to learn is viewed as a less important outcome than the ability of the course to deliver a higher paid job. This according to McInnis (2003) reduces the student incentives to be engaged in the education process.

Extent of work on higher education

The results of past research show that the benefits of paid work only apply to students who work between 10 to 15 hours per week whilst engaged in full-time study. (Curtis and Lucas, 2001). Research by McInnis (2003) shows that Australian students work on average 15 hours per week. However, this national average actually disguises enormous variation across many fields of study as was found in this research paper.

Research by Lingard, et al. (2003) showed that construction-related students at the University of Melbourne were employed on average 20 hours per week in their final year of their course. The research suggested that at this level there can be a conflict between the demands of study and work.

Extent of part-time work at the University of Melbourne

The aim of the research was to determine the extent of part-time work during semester. Two prior surveys provided the initial data.

Prior study one (University of Melbourne only)

In 2001, students in their final year were surveyed, during semester one, to determine the average number of hours they worked. Students were also asked to report their course stream and the nature of their work. The minimum, maximum and mean number of hours worked were calculated together with standard deviations. The results showed that students in final year worked on average between 18 and 19 hours per week during semester time.

Prior study two (University of Melbourne only)

In 2002, a more comprehensive survey of all students in the Bachelor of Property and Construction program was undertaken. Students were asked to report on the type and number of hours worked. Students were also asked to indicate how many hours on average they spend at the University campus, including attendance at lectures, tutorials, participating in study groups and working on assignments or playing sport. One question asked students to rate on a five point Likert scale, the extent to which paid work interfered with study during semester. Another question asked the ease with which they could adjust their work schedule to meet

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their study needs. The results showed that students worked between 15 to 17 hours per week during semester and that students work longer hours in the last two years of their course.

This lead to a further study to examine the extent of the work and study in property and construction related courses in Australia. Three main research questions were posed:

- To what extent are property and construction students engaged in part-time work during semester time in different universities throughout Australia?
- To what extent does part-time work make it difficult to engage in University life?
- What type of part-time jobs are property and construction students actually doing?

Methodology

Results of earlier studies by the authors (Lingard, et al., 2003) showed that in general undergraduate students work longer in latter years of the course. This has been referred to as commencing their career before graduation. These results indicated that many students who worked part-time during study continue to work for the same employer following graduation. This outcome supports similar studies in the UK by Garavan and Murphy (2001) who concluded that part-time workers are socialized into the culture of the organization prior to completing their course.

The aim of this research was to determine the extent of part-time work in other similar courses around Australia. The role of the national survey was to verify the extent of part-time work that had been evident at the University of Melbourne in prior surveys and to benchmark / compare the participating universities' results.

Study three (National survey of five Australian Universities)

In 2003, a more extensive survey from five participating universities was carried out. Students responded to additional questions. Relevant to this paper, they included: Which university are you attending? The categories of the types of work were extended to include Property, Real Estate and Project Management to encompass all the various employment fields amongst Australian Universities' Property and Construction courses. Students were also asked to respond to questions related to why they work with the industry.

The survey forms were sent to each course coordinator. The completed surveys were returned anonymously via a stamped self addressed envelope to the University of Melbourne. The data was entered into an Excel spreadsheet and later converted in to SPSS for analysis.

Results

University	Year 1	Year 2	Year 3	Year 4 & Combined	Total
Curtin University	20	30	35	20	105
University of Melbourne	80	85	90	70	325
University of NSW	57	70	80	80	287
Deakin University	80	80	75	75	310
University of Newcastle	52	33	58	16	159
Total	289	298	338	261	1186

Table 1. Total number of students enrolled in property and construction related courses

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The results from Table 1 reveal that the overall response rate was 45% (536/1186) indicating that the survey represents a sufficiently large sample of students in property and construction related courses in Australia.

	Semester 1	Semester 2
Curtin University	20	22
University of Melbourne	15	16
University of NSW	19	20
Deakin University	18	19
University of Newcastle	17	18
Total	17	18

Table 2. Average number of hours worked per week by University

The results in table 2 show that students on average are working slightly fewer hours in Semester 1 (17 hours) compared to Semester 2 (18 Hours). Students at Curtin and University of NSW appear to be working above the mean, with both groups averaging over 19 hours per week. Curtin University in second year and Deakin University in third year have working hours in excess of 50% of the mean as compared with the other universities.

	Year 1	Year 2	Year 3	Year 4	Combined	Total
Curtin University	17	30	22	23		22
University of Melbourne	12	16	15	19	17	16
University of NSW	16	17	21	29		20
Deakin University	16	16	19	24	25	19
University of Newcastle	17	15	17	24		18
Total	15	17	18	23	19	18

Table 3. Average number of hours worked per week (Semester 2) by year level

The results in table 3 show that students work longer hours in the later years of their course. This outcome appears similar across the country in all universities. The students start working on average 15 hours in the first year of their course, rising to 23 hours in fourth year.

	Industry-based Work	Casual Work	Total
Curtin University	25	19	22
University of Melbourne	18	14	16
University of NSW	22	19	20
Deakin University	24	17	19
University of Newcastle	19	17	18
Total	20	16	18

Table 4. Average number of hours worked per week (Semester 2) in Industry or Casual

The results in Table 4 indicate that students spend more time working when employed in industry-based jobs, compared to those students undertaking casual only work. The average shows that students in industry-based work do 20 hours per week, compared to casual workers who only average 16 hours per week.

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	Contractor	Architect's office	Quantity Surveyor	Property/Real Estate	Project Management	Total
Curtin University	26		13		26	22
University of Melbourne	18	18	20	20	18	16
University of NSW	25		17		27	20
Deakin University	26	16	20	16	30	19
University of Newcastle	20	20	17	.	18	18
Total	23	18	17	18	21	18

Table 5. Average hours worked per week by employment type (Semester 2)

The results in Table 5 show that students working for contractors work longer hours than in other work types. This may be due to the fact that contractors require their staff to undertake site-based work (frequently a 6 day week). Other occupations seem to allow students to work fewer hours; *Quantity Surveyors* consume the least amount of student time during semester. This may be due to their more traditional "nine to five-5 day" style working arrangements. Students working with *Contractors* work a similar number of hours to those in *Project Management* across all participating universities with Deakin University well above the mean average.

	Year 1	Year 2	Year 3	Year 4	Combined	Total
Curtin University	1.8	3.1	2.3	2.7		2.3
University of Melbourne	1.5	3.4	2.3	3.2	2.0	2.3
University of NSW	2.9	3.1	2.9	2.9		2.9
Deakin University	1.1	3.1	3.0	2.6	2.6	2.5
University of Newcastle	1.2	2.0	1.9	1.9		1.8
Total	1.7	3.0	2.4	2.8	2.1	2.4

Table 6. How easy is it to adjust your work schedule to meet study requirements, Average Likert score 1 (Easy) to 5 (Difficult)

The survey sought the views of students to determine as to whether work interfered with their study. The results of the survey (Table 6), show that students do NOT perceive that work interferes with their study. The results of the five point Likert scale, Easy (1) to Difficult (5) showed that in general, students believe that they can easily combine work and study.

This may indicate that students already perceive that their work arrangements are flexible enough, and that employers are willing to support their study demands. Alternatively, it may indicate that students believe that there is sufficient opportunity to fit work arrangements around lectures. This may be occurring as a result of flexible timetabling by the universities that allows blocks of half or full day free time.

However the results show that the students in both second and final years believe that work interferes with their studies to a slightly greater extent than it does in other years.

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	Year 1	Year 2	Year 3	Year 4	Combined	Total
Curtin University	16	14	18	10		15
University of Melbourne	20	21	18	16	20	19
University of NSW	21	26	19	14		21
Deakin University	23	20	25	12	45	23
University of Newcastle	17	10	14	8		13
Total	20	20	18	13	26	18

Table 7. Average hours (Semester 2) spent on campus for study by year level

The results in Table 7 show the average number of hours spent on campus for study purposes. This is time that is required to attend lecture, and tutorials, and also includes time spent in study groups and access to the library. This data shows that students spend more time on campus in the early years of their course, compared to the latter years. Students undertaking combined degrees (with Architecture) spend considerably more time than the students undertaking solely construction-related courses.

The next section of the paper discusses the results in context with other known issues and makes some conclusions.

Discussion

The objective of the research was to investigate the extent of part-time work in universities across Australia. Each university has different entry standards and offers a slightly different course experience and yet the results are remarkably similar.

Extent of part-time work during semester time

The number of hours students work during semester-time is relatively high. Table 2 indicates that the number of hours at all universities is in excess of the 10-15 hours deemed to be beneficial to students (Curtis and Lucas, 2001). Australian construction students spend on average 17-18 hours per week engaged in part-time work during semester. This appears to be slightly higher than other Australian students who only average 10 to 15 hours per week (McInnis, 2003).

This survey of work time of students from five Universities in Australia verifies the results of previous studies at the University of Melbourne in 2001 and 2002. The first survey in final year students only showed that students averaged 16-19 hours of part-time work in 2001. The second survey of students in all years indicated that part-time work accounted for 15-17 hours per week. The results of the past two surveys are validated by the current study in 2003.The trend now appears to be very consistent over three consecutive surveys in successive years.

Difficulty in combining work and study

The results (Table 6) show that students do not seem to find it difficult to change their work schedule to accommodate study. This may suggest that students consider that they are reasonably successful at combining work and undergraduate study. However, past research by McInnis (2003) suggests that undergraduate students are unclear about their obligations to the university, and tend to spend less time on tasks that improve their learning experience.

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This is supported by the survey which compares the amount of time spent on campus for learning purposes with time spent working. Table 7 demonstrates that students spend the same amount of time on campus for lectures etc. (18 hours per week) as they do undertaking paid employment (18 hours per week-Table 2). It is also interesting to note that students tend to spend less time on campus during the later years of their course; first years average 20 hours per week compared to 13 hours for fourth year students.

It may be worth noting that this does not include time spent at home undertaking assignments, or study for exams. Therefore, unless students are working on average over 50 hours a week for work and study, it may be reasonable to suggest that many students do not undertake additional reading and other optional educational opportunities. This may suggest that some undergraduates are becoming disengaged from the university experience, particularly by the time they reach their final year.

Effect of location to construction demand

The range of average hours worked varies widely between courses, possibly due to the particular characteristics of the university. It would seem reasonable to expect that city-based universities which are located closer to the larger markets for construction services, encourages students to work longer hours. The hours worked by students at Curtin University (City-based) and University of NSW (City-based) are relatively high, compared to hours worked by regional students at Deakin University (Regional) and University of Newcastle (Regional). However, the exception to the trend is the University of Melbourne (City-based) which displays the lowest level of hours worked.

It is not clear from the survey what characteristics of the universities cause students to work to the extent that they do. However, the University of Melbourne has the largest cohort of students and also offers a combined degree with Architecture. Anecdotal evidence suggests that the pressure on the lecture timetable is such that students are not specially allocated large free blocks of time, except those that may occur by accident. On the other hand, of the five universities surveyed; Curtin University was city-based, and has the smallest student cohort (105). These characteristics may create a more flexible learning program which could encourage students to work longer than they do at other universities.

Effect of employer type on work

These construction and property programs are by their nature highly vocational and are structured to direct students into the construction and related industries. The results of the survey (Table 5) demonstrate that students working for Contractors and Project Managers work longer than for other employers. This verifies past studies by Lingard, et al. (2003).

Despite the reality of student employment, universities have not yet fully accepted the benefits of students' experiences in the workforce (Curtis and Lucas, 2001). Student work appears to change in its nature from casual-based to industry-based work. This may suggest that students perceive industry-based work to have educational or career-development value.

It seems likely that students experience a number of social and financial pressures that steers their energies away from university and towards work. This may be driven by two understandable pressures; firstly, job security from continued employment which assists students meets their short-term financial needs, and secondly they perceive there to be benefits for their long term job prospects.

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Conclusions

The overwhelming outcome of this nation-wide research is that students appear to be working to an extent beyond what is beneficial to their studies. Students appear to be increasingly disinterested in connecting with the broader university experience, and instead are seeking to adopt a minimalist approach to learning.

There is a large volume of literature on the subject of co-operative education, which is defined as a form of education and experiential learning which integrates classroom study with paid work experience (Anakwe and Greenhaus, 2000; Garavan and Murphy, 2001).

According to McInnis (2003) whether or not students SHOULD be able to negotiate their engagement at university in not the issue. It is simply inevitable that they will increasingly expect to do so. The new realities of the student experiences place additional demands on the policies of universities. He also believes that universities have a broader responsibility to assert their leadership through a process of “negotiated engagement” with their students.

The negotiation process involves a closer attention to the issues of student engagement by rewarding those practices that relate to the interactive exchange of knowledge. This can occur through a more focused assessment process that promotes students engagement, especially in study groups, called learning communities. In addition, (McInnis (2003) believes that the university should attempt to take control of timetabling to the benefit of students.

The development of a partnership between the University and the industry in providing work experience that complements the program of study may be helpful.

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Distance Cooperation in Mechanics

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Abstract*: We describe a co-operative project between Auckland University of Technology (AUT) in New Zealand and the Royal Institute of Technology Stockholm (KTH) to provide long range tutoring via the Internet in the subject of Mechanics. Many students enrolled in distance courses which are predominantly technical in nature, have learning difficulties which can be overcome with more personalized tuition.*

Keywords: *Distance learning, virtual classroom, on line tutoring*

Student and Instructor Roles

Modern society continuously requires more qualified and competent citizens. The economic and technological changes in society imply increasing need for a larger part of the young population to get direct access to higher education. But the changes also demand retraining of those already active in the labour market. At the same time education has been internationalized at the program level, and there is a need for integrating studies undertaken abroad for an extensive time. Consequently, there is a demand for distance education to give large student populations access to higher education, to keep contact with those studying temporarily abroad or at another place, and to assist those in the work-place. There is also an increasing globalization interest in the delivery of direct education in a competitive market to distant and foreign student populations again promoting the need for an effective distance education.

Distance education using the internet offers tremendous opportunities not only for continuing education but for education in general to break down the barriers of place and time that otherwise limit access to education. At the same time, schools and universities in most countries have to face problems with student pre-knowledge, work habits and concentration. As a consequence, we face great difficulties in both the teaching situation and the decline of exam results. This requires more individualized education which may be difficult to achieve with large student groups and with declining school and university economies. In both

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Sweden and New Zealand, declining Government funding and increasing costs have led to financial problems for departmental budgets. There is a need for change which will lead to better study results and to finding a new infrastructure meeting the need for less expensive teaching.

All this requires new student and teaching staff roles, as well as a new organizational education infrastructure using more peer-to-peer cooperation both at schools, at campuses, at the local area network, and on the Internet. Students must be trained to have responsibility for both their strategic educational planning and their tactical studying.

Constructivism and PBL

In pedagogy there is a strong tendency to require learners to take accountability for their own learning. Piaget *et al*. (1954) laid the foundation for constructivism and experience-based learning. Bringuier (1980) and Papert (1993, 1996) have described the process of constructive learning. The basic idea of constructivism is the own construction of knowledge by the learner. During the last decade constructivism has found a specific application with Problem Based Learning (PBL) where real world problems are used to support critical thinking and problem solving skills.

Mechanics as a Fostering Engineering Subject

Rationale

An introductory (basic) course in mechanics is essential for most engineering schools. One reason for this is the mechanics studies *per se* of motion, forces and the relations between them. Related to this is the basic vocabulary it gives which is needed for studies in many other engineering and science modules and courses.(Stonyer and Dodd, 2002) Another reason is that because of the subject's emphasis on problem solving, it develops the students feeling for mathematical modelling. A final reason is to promote a general insight into scientific thinking and reasoning.

However, it has long been internationally known that basic courses in mechanics are troublesome for many students in engineering sciences (*e*.g. Duit, 2003). Many difficulties appear in parallel: mathematical competence, the concept of models, insight into and analysis of the natural phenomena which one wants to describe, too shallow reflection leading to the lack of deep learning and understanding.

These more general difficulties manifest themselves in specific discipline oriented problems such as wrongly constructed free body diagrams with wrongly introduced contact forces, inability to time differentiate and integrate kinematics quantities (ie. position, velocity and acceleration) correctly, problems in using vector algebra, and problems in understanding the difference between a definition and a theorem, all of which lead to difficulties in handling formulas and derived quantities.

Further, the domains of differentiation and integration of vector functions, implicit differentiation, work and energy, and oscillations (using ordinary linear differential equations) have been identified as particularly difficult subject matter.

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Hypotheses

It is difficult to produce satisfactory technical education at a distance. Many universities have set up distance learning units taking on large student populations, and these courses are highly successful where the subject content may be taught on a descriptive basis. Analysis of the present situation can be made by looking at two distance courses which are being offered today via Internet, for example:

University of Phoenix Online	http://online.phoenix.edu/CampusProgramList.asp
Open University UK	http://www3.open.ac.uk?courses/bin/p12.dll?A01

Where more technical subjects are offered the course presents the subject in a more descriptive and shallower way leading to a less insightful understanding than is usual for students at traditional universities.

There has also been a belief that distance education can lead to a cheaper form of mass produced education, and many resources have been put into producing material on the Internet or on CD for mass distribution, for example:

Multimedia Engineering Statics	http://www.ecourses.ou.edu/statics/content_st/home.htm

However, technology is changing so rapidly that web or CD material is rapidly outdated (or unable to be accessed) and it seems a waste of valuable resources to try and compete with long established and successful publishers who already produce excellent texts backed up by on line resources for problem solving and testing, see for instance:

Wiley with Engineering Mechanics by Miriam and Kraige and EGrade.	http://he-cda.wiley.com/WileyCDA/Section/id-100303.html

Even with these resources, success for the distance student is not always guaranteed. Human contact between student and lecturer is essential (and highly desired by students), and this contact is seen by the authors to be a vital component for any distance course of a technical nature. Tutoring has long been a central part of the educational system at Oxford and Cambridge Universities, where the student visits his or her tutor once or twice a week during term times for an hour or more. One of the authors of this paper, who studied mathematics at Cambridge and subsequently worked as a supervisor there has first hand knowledge of this Socratic teaching method. Whilst this system would be highly desirable from a learning point of view, it is obvious that in today's financial environment, economics of numbers preclude it as a possibility for regular students studying full time, and it is obviously impossible for distance students.

The internet and the development of web based conferencing software however, open up distinct possibilities for long distance tutoring of individuals, or (more economically) small groups of students. Having access to extensive problem data bases (with problem solving hints), video illustrations, tutoring (individual and in groups), instructor and peer support with computer and video conferencing (asynchronous and synchronous) would improve learning and generate superior education for the same cost and human effort (for students and

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instructors). Also student international cooperation would be greatly facilitated. Student and group portfolios should amplify student accountability of learning.

Distance Tutoring in Mechanics – A Pilot Study

Both KTH and AUT run courses in Mechanics for 1st year students. Whilst the AUT course is a conventional full time one with large group lectures (100 students) accompanied by smaller group tutorials (up to 25 students with 2 tutorial staff), that of KTH caters for both this style as well as a distance course with around 20 students. For AUT, this project extends a group-based learning initiative presented at the AAEE. 12th Annual Conference (Stonyer et al, 2001)

The KTH course is structured with the Ping Pong Learning Management System from Ping Pong AB in Sweden (http://www.pingpong.se) and consists of a study guide for every week with individual homework assignments to be answered (via email, scanned solutions or faxed solutions). In total there are 25 weekly assignments and accepted solutions to at least 22 of these gives 3 credits. The course finishes with a traditional examination at KTH giving the last 3 credits. Ping Pong has an integrated asynchronous computer conferencing system allowing instructor-student and student-student interaction. It includes also a chat (text based) function.

The AUT course, although covering similar material is structured around 14 weekly assignments with acceptable solutions providing 2.5 credits also with a traditional exam giving the last 5 credits. AUT uses the learning management system Blackboard (http://www.blackboard.com/) for many of its courses, both in-university and for distance learning and this is similar to Ping Pong in many respects. The project has secured a 'Resources to Enhance Teaching and Learning' grant for ongoing development at AUT.

AUT and KTH have cooperated with each other for some time and both have expressed interest in creating integrated courses with a common student cohort at our universities. Following discussions earlier in 2003, we have set up a small trial of long distance tutoring for students in Mechanics from each others university. At this stage each of the authors is responsible for tutoring of two students at the partner's university. Meetings using the internet in real time occur on a weekly basis for up to 1 hour, and follow student submissions of pre set assignments either using the management system, or simply by fax or email attachment. Problems are discussed with the lecturer awarding credit for the assignment provided he believes the student to have a successful understanding of the content.

Initial contacts have been made using Microsoft MSN Messenger (http://msnmessenger-download.com) which at first glance looks suitable for this (audio, video if desired, whiteboard, file and picture sharing), but due to the need of opening TCP ports behind firewalls and its point-to-point paradigm, it is not well suited for more than two person contact. Its major advantage at this point in time is that it is free to download and use. Another possibility is Marratech® Work Environment (http://www.marratech.se) which only uses TCP port 8000 (this can be changed) and allows simultaneous video conferencing between many participants with high quality audio (also video if desired), as well as sharing of information, pictures, and MS Office documents. A further possible system is the American developed Centra**7™** (http://www.centra.com/). Whilst allowing all of the features found in Marratech including file and application sharing, it is more akin to a virtual classroom where the lecturer can control such things as speaking rights, etc. It is also possible to set up an agenda for the

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meeting which can be downloaded beforehand by the student to save waiting time during the meeting.

For successful operation, all participants require a modern computer with an operating speed of at least 1GHz as well as 128 Mb of RAM. The operating system must be Microsoft Windows XP and a fast or broadband internet connection is essential. Students are issued with a small graphics tablet (Wacom Graphire 3 with USB connection 4x5) on loan for the course duration to allow improved use of the software system whiteboard, and are expected to provide a headset with microphone for audio communication. A webcam for video communication is desirable, but not essential.

Future Development

It is hoped that a successful initial trial of the on line tutoring model will eventually lead to the creation of a truly universal technical content course, where students, whether local or distant can participate in tutoring sessions. Dependant on location, there are obviously some difficulties in scheduling of suitable times, although software such as Centra allows for recording and later playback of sessions when time is available. Extension into other course areas, such as mathematics and thermodynamics is a natural progression and the eventual aim is to investigate the creation of integrated courses with a common student cohort at both our universities.

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Coherent Design of Active Online Learning Environments

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***Abstract**: One of the eternal challenges for engineering educators is providing students with authentic design experiences equivalent to industry. To solve this problem many educators have developed and used multimedia and internet technologies intended to simulate real situations. This paper explores the application of existing usability heuristics and metrics to two online design resources for engineering students, an information portal ("Design Surfer") and a collaborative tool set for supporting engineering student projects ("Project Web"). The paper proposes a framework for the development of further heuristics for developing active online resources that recognises the inherent nature of the learning process and student motivations.*

***Keywords**: Engineering Design Projects, Active Learning, Online Learning*

Introduction

Creating authentic learning experiences of engineering for students at university is difficult and potentially very expensive, especially in design and management. This aspiration becomes even more problematic when additional degrees of flexibility are added to enable groups of learners or individuals to actively engage with these resources at different times and places. Many engineering educators have turned to multimedia and Internet technologies to create such things as virtual design projects and simulations in an attempt to expose students to more "real" situations. However developing online learning systems that really engage students in active learning are difficult to achieve in practice.

Schemas have been developed to evaluate the usability of web resources used in engineering education (Farkas and Farkas 2000; Spyridakis 2000; Williams 2000; Turns, Valeriano et al. 2003). These metrics focus on the authority, structure and accessibility of information but do not indicate how the resource is used or if it encourages active learning. Usage patterns can be obtained by recording hits on the web resource, they way students navigate through it and when they use it. However both usability metrics and usage patterns are lagging indicators. Essentially they tell you about the what, where, when and how of the resource once it exists, although usability heuristics can also guide the design. Focus groups or interviews may shed light on why students use a particular online resource in a given way at a particular time, but again this is a lagging indicator and it does not go to the intrinsic motivations of the learner.

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This paper proposes a coherent approach for considering all of these issues to guide the development and evaluation of more active, online learning environments.

Design Framework for Active Learning Environments

A framework is presented as a coherent basis for the design of online learning environments to achieve active learning. The framework is founded on a conceptual model of what drives people to learn (the "why") and the idea of "aliveness" in learning environments. This guides the conceptual design of any learning environment. Next the "when, where and how" of learning is considered in order to translate the inherent motivations into the design. This is the embodiment design aspect of the learning environment. Finally the detailed design phase considers more specific aspects of the "how" of the implementation.

Why we learn

Schein (2004) observes that learning, and more generally change, occurs when the "survival anxiety" of an individual or group exceeds their "learning anxiety". "Learning anxiety" refers to discomfort we feel when "disconforming data" challenges what we do or what we know or understand. "Survival anxiety" is the feeling that if we do not change we will "fail to meet our needs or fail to achieve some goals or ideals that we have set for ourselves".

In simple terms, a learning environment can increase the propensity for learning by either raising the "survival anxiety" by putting more pressure on the learner in some way or by reducing the "learning anxiety". A balance needs to be struck. For many engineering students, major sources of "disconforming data" in relation to authentic design experiences include the need to adopt an explicit approach or methodology and where necessary adapt it to the circumstances, the need to acquire information from diverse sources, the need to make judgements based on evidence, the subtle demands of communication of all types and the need to document and to monitor.

Aliveness

To make a learning environment "come alive" we can increase the "survival anxiety", for example by making its use mandatory or assessable for credit. Alternatively, and preferably, we can bring the environment alive by lowering the "learning anxiety" through increasing the student's desire to engage with it. This could be achieved by delivering some inherent value to the student, like making their work easier to accomplish through a more disciplined approach to their design or project work and the management of it.

Aliveness is closely linked to active learning. If learning is about a change of state in the knowledge of the learner, then active learning is about learners who are more in control of their learning, that is, they are in "charge of the change". The conceptual phase of developing an online learning environment needs to carefully consider what makes it active and what makes it alive.

Timing, Information and Interaction

Based on a social constructivist conception of learning, the conditions under which learning may or may not occur can be characterised by several key dimensions, each with two dichotomous states. These are the "when, where and how" of a learning environment.

The first dimension is time; whether the learning activity of the individual is intended to occur simultaneously with the rest of the group or at a different time. Thus it is either synchronous or asynchronous. The second dimension is the nature of the access to and acquisition of the

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relevant information. This can be passive or active. Passive acquisition implies a delivery mode that does not engage the learner. On the other hand, active acquisition involves the learner as part of the process. The third dimension is the type of interaction between the learner and the learning activity. This is uni-directional if the learner just receives and it is multi-directional if the learners interact with each other and with the teacher. For an online environment the "where" dimension is not an issue if it is assumed that the environment is available at any location at any time. While this assumption may not be true in all cases it is taken to be so in this paper.

The three dimensions are not wholly independent (orthogonal) as passive acquisition of information can only occur through unidirectional interaction. Nevertheless they identify six (6) different combinations that represent six types of learning environment. This is illustrated in figure 1 with representative examples of each.

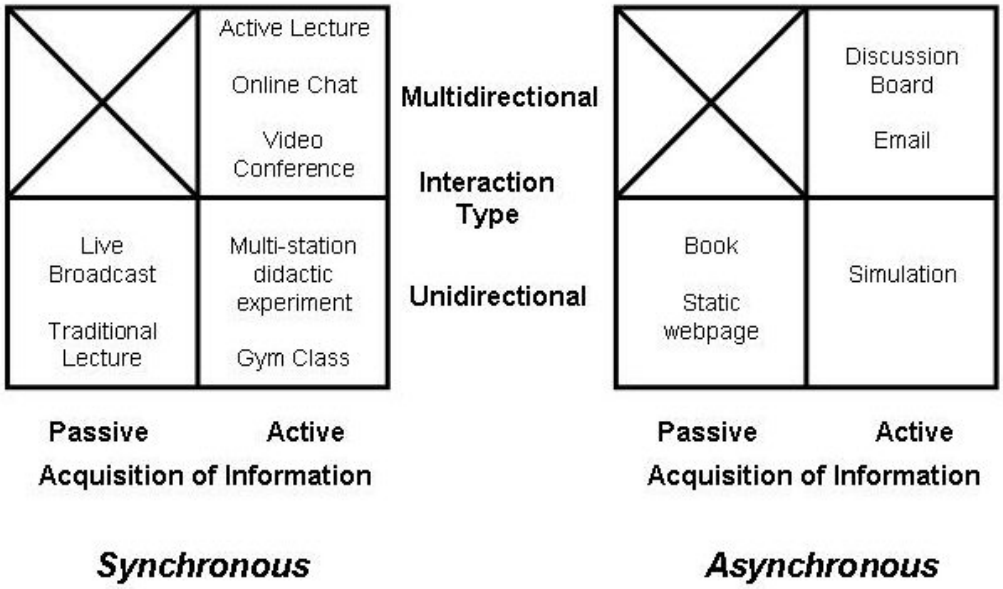


Figure 1 – Basic Active Learning Framework

Usability – direct and indirect

Useability is one facet of the embodiment and detailed design phases of a learning environment. Useability of an online learning environment can be assessed *indirectly* by evaluating it against a set of guidelines or heuristics. Turns et al (2003) drew on the work of Williams (2000), Farkas and Farkas (2000) and Spyridakis (2000) to develop the set of heuristics and a rating scheme to evaluate the usability of websites with particular application in engineering education.

In addition, the useability can be access *directly* by the users of the systems. This can be done by observing users engaged with the environment, by interviewing users or by holding focus groups with collections of users. Observation is time consuming and some instances of use are difficult to capture (e.g. when a student uses the system spontaneously at 2am). However counter balancing this effort is the knowledge that the data does represent what people actually do not what they think or say they do. Observation can be complemented by

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electronic monitoring of access and site navigation patterns to gain a rich qualitative and representative quantitative picture of usage.

Interviews and focus groups can be subject to various forms of bias mostly related to the gap between what people think and say they do and what they actually do in the moment. This can be controlled partially by having students give specific instances to illustrate their use of a system.

Application of the Framework to Evaluate Learning Environments

The application of the proposed framework is demonstrated through the critical analysis of two different online resources for student designers, the *Design Surfer* (a portal on engineering design) and *Project Web* (a collaborative web-based work space for student project groups).

Design Surfer

Created in 1995 the *Design Surfer*, is an information portal for design students focusing on the processes, methods and methodologies in engineering design. It has been developed over several years and has undergone many content and structural changes. Created in 2002 the present version of the *Design Surfer* has two levels of themed directory navigation. The site contains 51 flat html pages and 15 printable documents (in pdf format).

The site has a hierarchical structure with converging branches and secondary links (Farkas and Farkas 2000) as illustrated in Figure 2b. Figure 2a shows a traditional hierarchical structure. This is an intentional design feature to maximize the chance of the user navigating to a piece of information. However this chosen information structure is not always obvious to the user. Farkas et al point out that the underlying structure "should help users build a mental map of the node-link structure of the site (p348)"(Farkas and Farkas 2000).

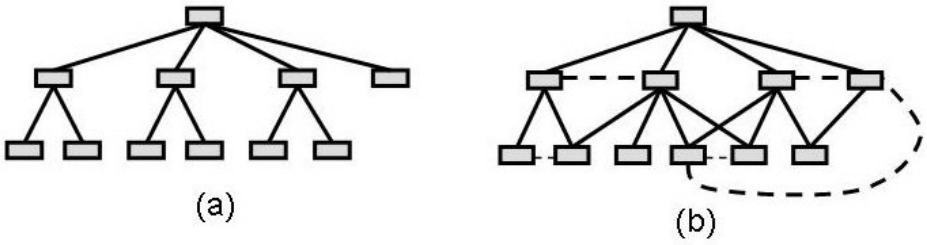


Figure 2: (a) Traditional hierarchy information structure. (b) Hierarchy structure with converging branches and secondary links as used in the *design surfer*.

The user of the *Design Surfer* has the choice of navigating step by step through the hierarchy by clicking on the major headings or by using the left menu, or accessing resources directly by clicking in the minor links in the centre of the page. The top level browsing themes for the *Design Surfer* include Design Engineering Basics, Working in Teams, Generating Ideas, Requirements, Concepts, Decisions, Embodiment and Communication. These themes are intentionally based on the general design process, such as those illustrated in Cross (Cross 1989) and Pahl and Beitz (Pahl, Beitz et al. 1996). Figure 3 shows a screen shot of the *Design Surfer* home page.

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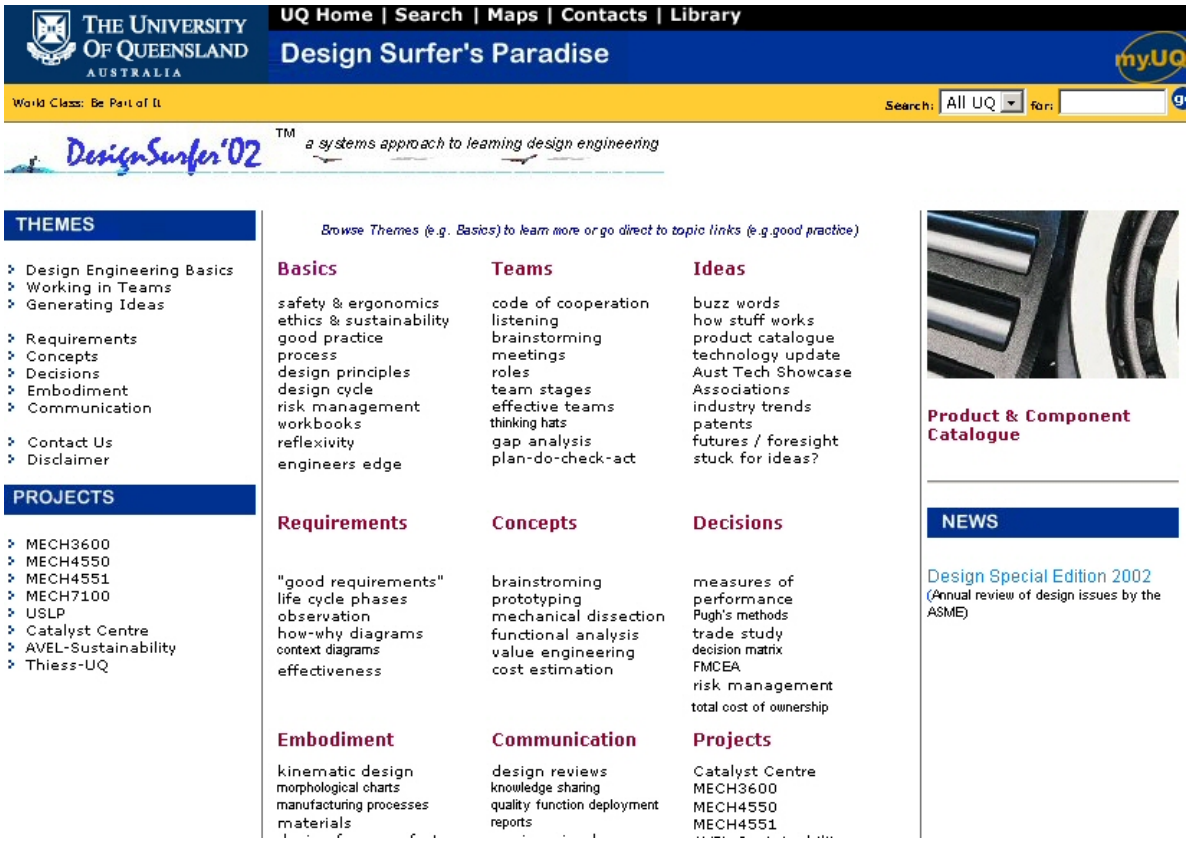


Figure 3: *Design Surfer* home page.

Project Web

While the *Design Surfer* offers students access to many useful resources, it does not offer them the opportunity to apply the information and concepts. *Project Web* is a prototype collaborative tool for supporting student engineering project teams and providing them with an active environment to engage with the concepts required to successfully "run" an engineering design team. It draws on the core ideas of commercial project management software but aims to deliver a much simpler, more accessible product that allows students to focus on and be actively guided through the fundamental concepts behind managing engineering projects. The prototype version of *Project Web* contains the following tools:

- A multi level access area for describing the project
- Client briefing (uploaded by course coordinator)
- A multi level access area for maintaining and developing the project scope
- A multi level access area for maintaining and developing the project requirements
- Contact details of project members
- A discussion area
- A facility for setting meeting agendas and posting meeting minutes
- A file sharing library
- A project scheduling facility that monitors actual and projected time.
- An individual task allocation and monitoring facility

The *Project Web* prototype was initially used in a project based engineering management and communication course on a voluntary basis. There were nineteen student groups in the class. Groups actively engaged in the use of the available tools at various levels. Figure 4 shows the number of groups that actively used the various tools.

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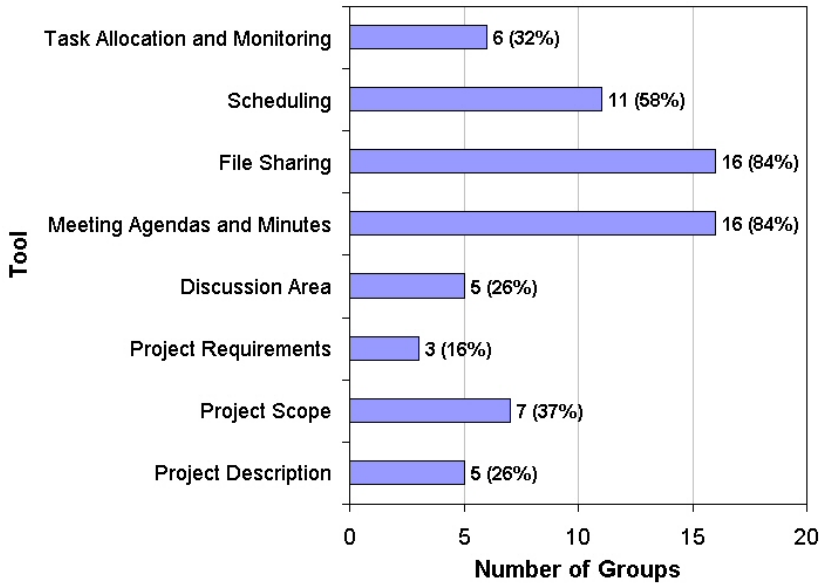


Figure 4: Usage of *Project Web* tools.

Overall the level and quality of engagement the students had with the system was disappointing. Students were asked to reflect on their management practices and methods including their use (or otherwise) of project management as part of the course assessment.

Analysis of this data has concluded that the major obstacle to the use of *Project Web* was the "barrier to aliveness", motivating students to log in and add and maintain information. In many cases students found it easier to email information because it did not require them to continuously check *Project Web* for new updates and postings. Students also viewed the systems as a communication tool for completed work rather than a place to "do" work.

Useability Heuristics – *design surfer* and *project web*

Design Surfer and *Project Web* have been critically examined by the same set of usability heuristics recommended and developed by Turns et al (2003) for accessing engineering education web sites.

Table 1 shows the results of the analysis of the *Design Surfer* and *Project Web* using these heuristics. Clearly, both of these learning support environments have strengths and weaknesses. Both could be improved according to this heuristic analysis. These heuristics, however, tend to focus on sites used for transmitting information in one direction, making them particularly applicable to a resource like the *Design Surfer*. *Project Web* rated particularly poorly against some of the heuristics. Some of these are not very good indicators of success for an active web resource like *Project Web*. It is arguable that even if *Project Web* had been designed to meet all of these heuristics that the level and quality of engagement would still have been low. A further set of principles and heuristics needs to be developed for guiding the development of active online learning environments for engineering students by focusing on the particular values of the engineering student culture.

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Heuristic	*Design Surfer*	*Project Web*
Indicate link destination	⊙	⊙
Create hierarchical breadth of information structure	◘	⊙
Reveal the information structure	⊙	⊙
Provide orientation information on the home page	⊙	○
Provide orientation information on lower level pages	◘	○
Provide search engine or index	⊙	○
Provide link to home page from every webpage	●	●
Minimise information	◘	◘
Orient readers	◘	○
Create hierarchical frameworks	◘	⊙
Create order in content	⊙	○
Include organisational cues	◘	⊙
Use understandable words	◘	◘
Demonstrate credibility	◘	○
Utilise appropriate size of visual elements	◘	◘
Avoid distracting background	●	●
Employ appropriate visual design to reveal information structure	◘	⊙
Group related elements	◘	⊙
Graphically reveal relative importance among elements of display	◘	⊙
Contain consistent and predictable graphical elements	●	●
Reveal sequence of information	◘	○
Ensure text is readable	◘	◘
Include supplementary text	○	○
Employ visuals to depict perceptual qualities	⊙	⊙
Label and use conventional icons	○	○

● Excellent – Consistent with principle; No useability problem will result
◘ Good – Minor deviation from principle; Slight confusion, impaired productivity, and reduced satisfaction
⊙ Fair – Major deviation from principle; Significant detriment to usability
○ Poor- Principle overlooked; User is expected to experience significant difficulty

Table 1: Usability heuristic evaluation of *Design Surfer* and *Project Web*

Project Web – "Staying Alive"

The following is a more detailed description of the functions included in *Project Web* and a performance analysis based on usage statistics and feedback from students. The functions are critically examined by considering the motivations and values of students as drivers for success.

Student Motivations and Values

Many of the functions supported in *Project Web* were developed based on emerging online tools used for cultivating and operating communities of practice. The distinct and fundamental difference between student groups and communities of practice is that communities of practice are voluntary (Wenger, McDermott et al. 2002). Despite enrolment and attendance at university being voluntary, most students would not identify as being volunteer members of their groups. Students' motivations differ significantly from those of practitioners who join communities of practice. Accordingly the incentives and barriers for keeping student project sites "alive" have to be approached differently. Accordingly we need additional heuristics that take into account the "barriers of aliveness" based on the different motivations and values that drive students compared to those of practitioners.

Project Description Function

The project description function contains three levels of open text fields for the project members to describe their project. The three levels correspond to public access, class access and group access. Group members can create project descriptions specific to these groups,

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tailoring the information for the appropriate audience. The initial concept for the three levels of access was to provide students with the opportunity to share ideas and progress with their cohort and the external community, while still having an area to place information only accessible to their group.

Initially the public access field was populated by the course coordinator. Six groups actually removed these descriptions from the public view and only two groups placed further information about their projects on the system for the rest of their cohort to view. Three groups placed further information on the system to be viewed by their group only. This area was intended to provide a workspace, not just a finalized description. Analysis of the information shows little development and updating after the initial stages of the project.

This feature had no inherent value for the students, it did not offer any support for how to develop a project description. This support would need to be more than instructional. The system would need to add value through active features. Students have little motivation for sharing their work with the class and the public. In fact, the competitive nature of engineering students would tend to actively discourage the use of the public and class fields in this feature.

Project Scope Function

A similar multi-level area was provided for defining the scope of the project. In addition to the public, cohort and group levels a field was set aside for the course coordinator and/or project client to place the initial brief for the project. The students could not edit this field. Seven groups used the public field, three groups used the cohort field and seven the group only field. Analysis of the information entered by groups who used two or three of the access levels shows little differentiation in the type of information entered for each access level. Again this feature had little inherent value for the students, it did not offer any support for how to develop a project scope.

Project Requirements Function

The project requirements tool was again set up using a similar three level approach. Only three groups used this tool, one placed the information on the projects requirements in the public area, while the other two groups placed the information in the group only area.

Feed back from in class presentations and group reports suggested that the requirements function could be vastly improved by providing a more powerful tool for categorising and tracking requirements throughout the duration of the project. For example, students have difficulty writing and understanding the difference between user requirements and systems requirements. A system that actively guides this process would be of benefit to students and would lower their “learning anxiety”.

Discussion Board

Each group has a discussion area only accessible to them. This function was actively used at various levels by five groups. Fifty two discussion threads were started with a total of 78 additional postings under these threads. The discussion board was only really embraced by one group. Threads started by individual groups ranged from two to thirty five. Most threads only contained one or two additional postings. The nature of the discussion almost exclusively referred to the progress of the project, arranging meetings and notifying group members of an individual’s progress on a particular task. There was little intellectual discussion on critical issues to do with the project content.

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The low level of engagement is not surprising since students had the opportunity to meet in person to discuss such issues, a much more appropriate medium for discussing difficult issues. This highlights the importance of selecting appropriate functionality and tools for students. Discussion boards are popular with parishioners and members of traditional communities of practice but offer little value in this context. However, engagement with such tools could be increased by offering an extensive email alerting facility. For example, alerting students of new postings.

Meeting Agendas and Minutes Function

There is an area in which groups could construct meeting agendas and then append actions to these agenda items during or after the meeting. Individual group members can add agenda items to be addressed at a meeting at any time before or during a meeting. An initial inspection of the use of the meeting agendas and minutes tools seems to reveal a high adoption and usage rate, 16 of the 19 groups. The 16 groups created a record of 155 meetings through out the semester. However, closer inspection reveals that this function was not used as intended. Most groups used the system as a repository for meeting notes. Groups did not create agenda items before the meetings. Preferring instead to store the notes from meetings in one agenda field, even though an inspection of the content revealed such items contained several distinct agenda items.

The primary cause of the lack of intended engagement with this function was the students' lack of preparation before meetings. It is obvious that students used this system to document meetings but not prepare for them. A much simpler mechanism for recording meetings would be appropriate given students' motivations. This function was of benefit, even if not in the intended way, because it added direct benefits to one of the activities students under took and were comfortable with.

File Sharing Function

Project Web allows students' to upload and share files in a common library for each group. Files could be checked out by a group member reloaded after changes had been made. Other group members could download the document while it was checked out but could not reload it. Students' comments and usage of this tool indicate this facility was particularly useful. Sixteen groups actively used this facility for sharing files, although the check in - check out facility was not frequently used.

This facility was widely used because it assisted with one of the core issues that these teams deal with, collaborating and sharing work with other students. It allowed them to share work that they prepared using software they were familiar with.

Scheduling Function

The scheduling function was in the form of a basic Gantt chart with a time increment of one week. The facility allowed students to compare predicted time for scheduled activities and actual time. The tool was used by just over half the groups (eleven of nineteen). Students found this function easy to use and the concepts contained within it familiar. The large time increment and the inability to group activities did create some resistance to the use of the tool.

This function was reasonably successful in engaging the students. This was because it added direct value to the early planning stages of the projects. Students however did not necessarily keep their schedules up to date over the semester because the value of doing so was not inherent. Students were also familiar with the concepts behind this tool prior to the course.

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Task Allocation and Monitoring Function

This function allowed the groups to monitor tasks within the project team. Each task is allocated to one or more of the group members. These members describe their input into the task and then enter the time that they spend on each activity.

This facility was seen by most students to be in competition with the scheduling function. Feedback indicated that the integrating of scheduling, task allocation and monitoring would greatly enhance the functionality of Project Web.

Design of e-Learning Design Environments using the Framework

The results of this analysis are informing the design of a new e-learning environment, called the *Collaborative Engineering Learning Environment (CELE)*. It incorporates elements of both the *Design Surfer* and *Project Web*. In terms of the conceptual design framework, the Design Surfer is located in the passive domain of information acquisition although it can be used at any time or place. Conversely, the Project Web is an active collaboration space that allows all types of interaction and any time or place. This is illustrated on the Time-Information-Interaction Cube in Figure 5.

While *Project Web* spans all four of the active "sub-cubes" (dark shading) it fits predominantly into the multidirectional asynchronous and synchronous active "sub-cubes". Functions like the discussion board are asynchronous tools, whereas meeting agendas and minutes, requirements management and file sharing can be synchronous or asynchronous depending on the context in which the group is using them. For instance groups could be collectively working at a single workstation on meeting minutes or requirements lists. Similarly the Design Surfer can be both an asynchronous or synchronous medium for accessing information. Students use the resource both as individuals at different times and as a collective around a single workstation.

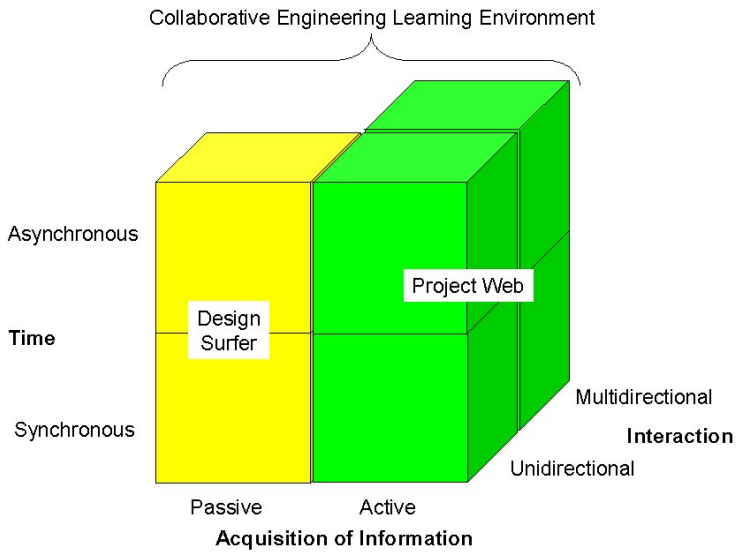


Figure 5 – Time-Information-Interaction Cube

Most of the heuristics developed by Turns et al (2003) are focused on web resources that fit into the passive, synchronous and unidirectional "sub-cube". While some of these principles can be extended as general good practice principles across all web resources, further heuristics and principles need to be developed and tailored for the various "sub-cubes" shown

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in figure 5. These heuristics and principles need to recognise the interactions and dependencies with other "sub-cubes" but also be specific enough to be valuable during development, not just as lagging indicators.

The *Collaborative Engineering Learning Environment* recognises the blurring of the boundaries between engineering design, project management, systems engineering and the development of professional engineers. The experience of *Project Web* has highlighted the importance of selecting functions and tools that are tailored to the particular subject area. For example, the development of collaborative functions and tools for design should focus on guiding and managing methodology, requirements, concept generation and evaluation, trade studies, design information management and group communication. This adds direct value to the student and enables the lowering of "learning anxiety".

Conclusions

If engineering educators are to fully utilise the information and communication technologies as valuable learning tools they must not only design them within the framework of accepted usability metrics but also understand the motivations of the students and the information seeking patterns of engineers. A coherent design framework is proposed that considers the conceptual, embodiment and detailed design of online learning environments in an engineering education context. Analysing two Internet based tools using this framework demonstrates the value of this framework.

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Java shells, animation and efficient collaboration

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Abstract*: The authors have in the past worked closely together. However, in recent years they have had little time to do so. This has meant that their collaboration has been similar to that which would exist between academics in different institutions. This paper describes how by using the skills of each author it has been possible for one to write software shells and the other to use the shells to produce many WWW application programs. It is expected that the sharing of teaching materials will inevitably become more common as the demands on academics become greater. The authors intend to make these shells freely available to academics in Australia and will be interested to see if any collaboration arises as a result. The paper describes the shells and gives examples of their use and where possible the effect on teaching.*

Keywords*: Collaboration, Software, Animation, Efficiency*

Introduction

The authors worked closely in the past (1993-98) on several CAUT and CUTSD grants. They have described [Scott 1999] the way in which their respective experiences and skills led to an ability to produce innovative software and a WWW based tutoring system. They started to use what we now call 'Java shells' in 1996 while developing the tutoring system. Scott wrote a Java shell for a typical tutorial problem and Stone used the shell to produce over 200 problems for a first year engineering dynamics course [Scott 1998]. This tutoring system (and the problems) have stood the test of time, being introduced in 1995 and still being used in 2004. We have noticed that the time required to master the Java programming language is not available to most academics. If a grant is obtained to employ a Java programmer then often the skills are lost at the end of the grant when the programmer leaves. Even worse, it is possible for the programmer and the academic not to appreciate what each is capable of and little of lasting value is achieved. It is the purpose of this paper to describe how the authors have interacted since their paper in 1999 and to show that it is possible to collaborate with minimal contact. Examples of the material produced will be given and the ease/difficulty of using shells will be discussed. Although this paper deals with the specific case of Java programs for the WWW the same degree of collaboration may be possible with other combinations of skills. We think that the AaeE could well be the 'broker' for enabling useful partnerships. This would require a list of skills and needs that could be exchanged. There would be the issue of intellectual property, as different universities have differing policies. However, the gains to be achieved should not be lost for this reason.

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Location of code examples

Code and "live" examples may be seen at

http://www.mech.uwa.edu.au/NWS/ae/java_shells/

You can view the shells with any modern web browser. However if you wish to modify them you will need a java compiler. We use and recommend "Metrowerks CodeWarrior" which is cheap and is available for both Mac and Windows computers. However many other good compilers are also available e.g. "Visual J++" from Microsoft, and the free package "Eclipse".

Previous Work: a shell for a numerical-answer problem

In 1993 the authors began their collaboration. The first shell was produced in 1994 for a simple single answer problem to be served via the WWW. The simplest example is shown in Figure 1.

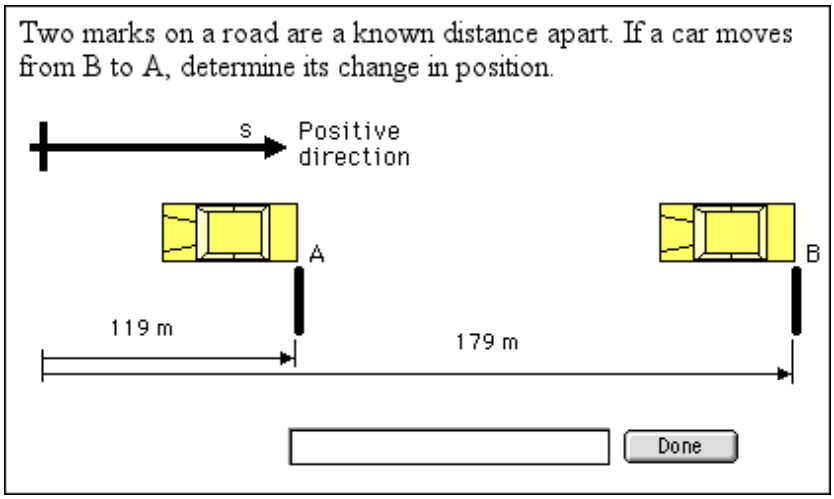


Figure 1: The first problem written using a Java shell

Each student received different numerical values that were specified as random numbers drawn from a specified range. The code for the problem is shown below.

```
import java.applet.*;
import java.util.*;
import java.awt.*;
import java.math.*;
import java.net.*;
import java.io.*;

import jellyfishclient.*; // base classes for all question types
public class Rect1010 extends Standalone
{
      int carDistA, carDistB;

public void ChooseVariables()
{
      carDistA = (int) RangeRandom(40, 120, 1);
      carDistB = carDistA + (int) RangeRandom(40, 120, 1);

      ClearErrorList();
      // remember that the first "error" is the correct answer.
      LoadError(1.0*(carDistA - carDistB), "m", "", "", 0, 1, 0, 0);
```

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```
      LoadError(1.0*(carDistB - carDistA), "", "sign.html", "You seem
to have forgotten about the sign convention; this is far more
important than you may realise.", 5, 1, 0, 0);
      LoadError(-85.0, "", "yourNumbers.html", "Remember you have
your own numbers for every problem.", 3, 2, 0, 0);
}

public void paint(Graphics g)
{
      super.paint(g);
      if (!done_loading_seed) return;
      // "numbers" have not arrived yet

      g.drawString(carDistA + " m", 45, 115);
      g.drawString(carDistB + " m", 220, 122);
}
}
```

In programming work there is often a need to strike a balance between advanced features and maintainability (which may be equated with extensibility). The type of simple problem illustrated has strictly limited capability: but as a result it is easy to see how to create new problems of the same type.

In addition to the code shown, each problem of the "single numerical answer" type required a few other files: an image file (a JPEG or GIF file with the problem picture); a solution HTML page; and perhaps some HTML pages to explain typical student errors in detail (as with the file sign.html in the example). The tutorial system was so designed that the picture and HTML files were kept together in a directory on the tutorial system server. This approach made it possible to develop each problem in a "stand alone" mode where the tutorial system server was not needed.

The heavily annotated code for the single answer problem type, and example directories with pictures and HTML, became our first shell.

We define a shell as a basic but functional example of a computer-based teaching resource, which may be duplicated as the first step in creating a new resource. The same concept appears in modern word processors such as Word™, where one may open a "stationery" document. Instead of the word "shell" we could also have used the phrase "simple, well commented example or template". "Shell" also has connotations of a husk or empty box, waiting to receive specific teaching content.

To understand why shells are an efficient way to collaborate, let us examine the process of changing the single-answer problem shell into a specific new problem. In schematic form:

1 A problem-specific picture called problem.gif is created and then replaces the file in the shell directory called problem.gif.

2 Variables which are exposed to the student are declared as global variables (for example carDistA). The problem author must decide at this point which numerical values are needed to solve the problem.

3 The ChooseVariables() applet method must be changed so that random values are assigned to all the important global variables, for example

carDistA = (int) RangeRandom(40, 120, 1);

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where 40 is the minimum value; 120 the maximum and 1 the step size from 40 to 120 for possible values.

4 Arithmetic must be performed to develop the expected correct answer, which is given to the problem shell as the first element of a list of possible answers:

```
LoadError(1.0*(carDistA - carDistB), "m", "", "", 0, 1, 0, 0);
```

The fields of LoadError are answer, units, title, message, severity, c0, c1, c2 [competence classes].
(The concept of competence classes was introduced in our tutorial system in 1996 but it never really caught on with the problem authors. It was an attempt to monitor students' understanding by recording achievement in atomic skill areas. Interestingly this concept seems now to be coming into fashion as part of "outcomes" based education.)

3 Possible wrong answers must also be calculated, based on known common student errors. Each of these has a short error message but may also have a more extensive web page (eg sign.html) explaining the error. Any number of such erroneous results could be loaded into the error list, but in this small example there were only two.

4 The applet method PaintVariables() must be amended to draw the global variable values on the screen for the student to see:

```
g.drawString(carDistA + " m", 45, 115);
```

places the value of the carDistA at coordinates (x=45, y=115) followed by the units "m".

5 The new problem can then be tested in "stand alone" form i.e. with no connection to the tutorial system. This is essential to allow debugging of the numerical code and fine placement of drawn strings.

6 The new problem files, which are kept together in a single directory, are uploaded to the tutorial system server.

A good shell protects the resource author from as much implementation detail as possible, exposing only the code and other files which really must be modified to create a new problem instance. For example at step (1) above, the problem author does not need to know why the file name has to be exactly "problem.gif", nor where in the code one would have to make changes to allow a different name. The code containing the file name "problem.gif" is hidden as a compiled java class file that the problem author does not normally modify. Flexibility – the choice of the file name – is deliberately sacrificed to make authoring easier. Figure 2 illustrates the division of labour in writing a shell and also something based on it.

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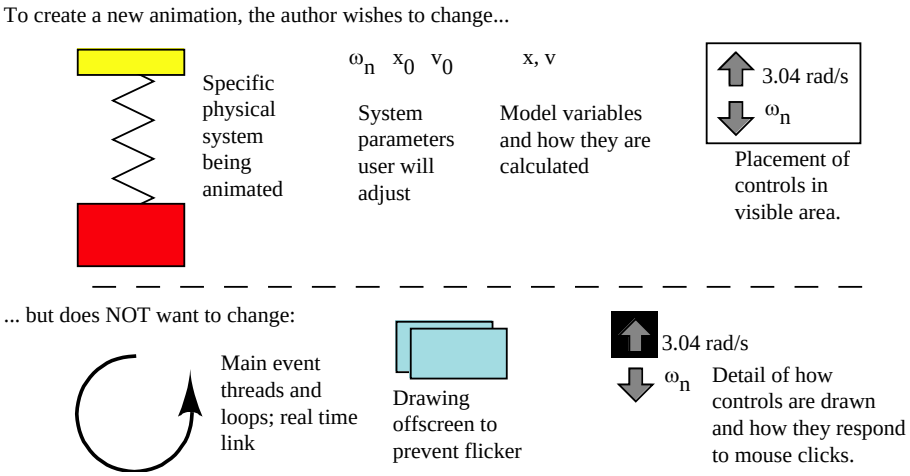


Figure 2 Division of labour: resource author vs. shell author.

The shell described above was copied and modified by Stone to create 200 problems in engineering dynamics. All 200 problems had the same general form: a picture, randomly chosen numbers, and a single required numerical answer. These problems, and the networked, monitored tutorial system they work within, have been described in [Scott 1999] It should be noted that the tutorial problems and tutorial system were developed during 1994, long before packages such as WebCT became available. Also the problems have not had to be changed as the serving package has remained stable and in the control of the authors.

Previous work: animation shell

In 1999, prior to a period of study leave by Stone, Scott wrote a shell to allow a simple vibrating system to be animated and the motion displayed on a "moving" trace. It was also possible to vary parameters and observe the effects produced. Stone used this shell to produce all the animations for a complete set of WWW notes with animations for one and two degree-of-freedom vibration. The same basic idea of a shell and modifications was employed. However, the code was far more extensive and complex. The first program that served as the shell is shown in Figure 2.

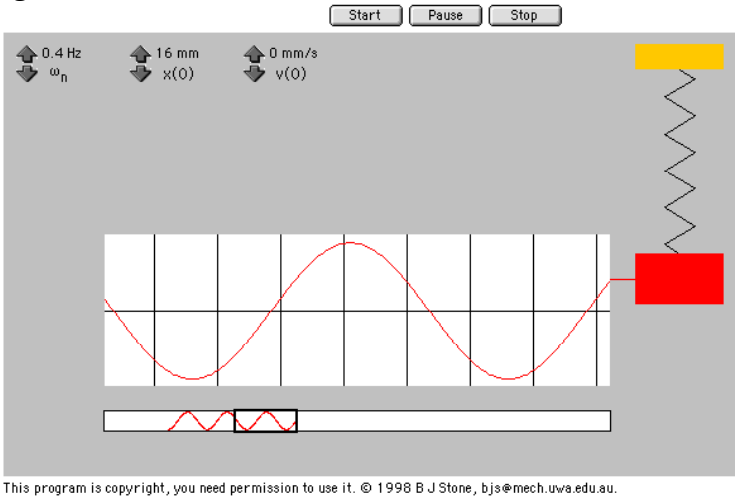


Figure 3: First Animation program "Undamped" (as seen in a web browser)

A software shell for animation, with parameter variation by graphical input, was developed. The important functional parts of the shell were concerned with:

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1 Storing state information about a physical system (global variables);
2 Modelling the progress of the physical system as a result of a change in time (or possibly of some other input) – which might be called the engineering science part;
3 Drawing the state of the physical system on the screen;
4 Drawing controls for adjusting system parameters;
5 Management of drawing order and timing to produce a smooth result.

The shell was designed to make it easy to customise (1), (2) and (3) – the detail relevant to animation of a specific physical system - while hiding (4) and (5).

For example the x(0) variation arrows, value and descriptor are drawn and governed by a java object that hides the detail. The animation author could request and position controls using high-level language:

```
// Second control is for the initial displacement Xo
CFrameSmallControl XoControl = new CFrameSmallControl(mFramePanel,
mAnimFrame, CFrameAnimation.kXoCode, 100, 10, kMinXo,
CFrameAnimation.kStartXo, kMaxXo, "mm");
XoControl.SetLabelOffset(20, 10);

// Now the x(0) label
Image XoImage = getImage(getCodeBase(), "xo.gif");
CFramePicture XoPicture = new CFramePicture(mFramePanel, 124,25, 0,
0, XoImage, false);
```

Java allows long variable names and this was found to be of great assistance. The animation author could infer a great deal about the meaning of any variable just from its name.

The program code specific to the physical system being modelled was all in one applet method “public void Response()” and so was easily changed (by a vibration “expert”) to allow the animation of a different system. This single shell allowed numerous programs to be written and some have been described by Scott 2001.

Current Work: “multiforced” vibration shell

In 1999 Stone asked Scott to produce a far more complex program that could be used as a shell. By this time Scott was an academic in his own right and with subject interests different to Stone. Stone wrote the code for the vibration aspects and then Scott wrote a significant program that has not previously been described or mounted on the WWW. A brief summary is given here and it will be mounted on the WWW at http://www.mech.uwa.edu.au/NWS/ae/java_shells/. Figure 4 shows a typical screen.

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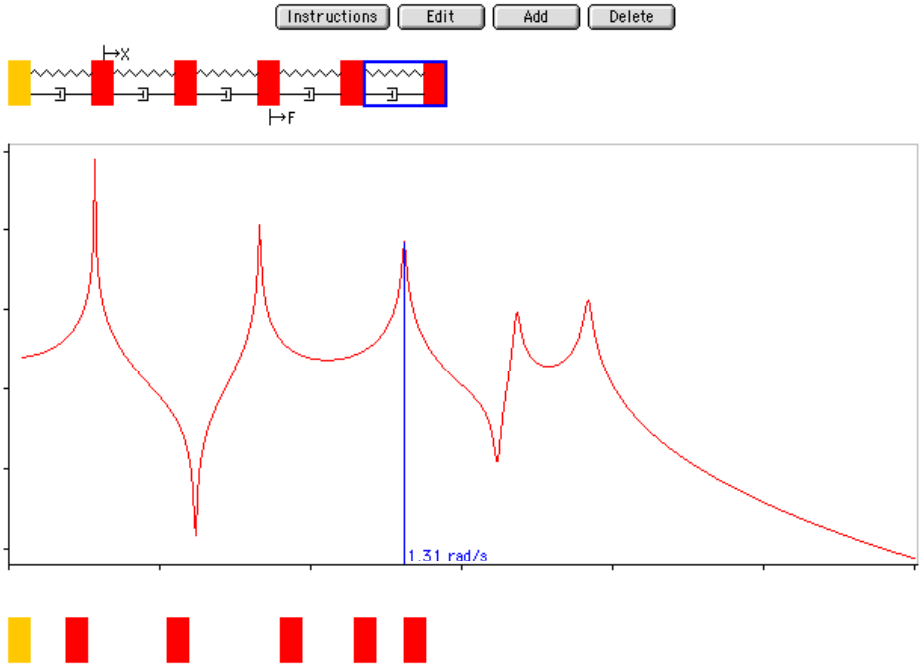


Figure 4: Multi degree-of-freedom vibration program

There are several main features of the program that represents the axial vibration of a series of masses and springs/dampers. The "Instructions" button produces the page shown in Figures 5 and 6. Thus the program has from the top: a layer of control buttons, a diagram of the vibrating system, a graph of the response (X/F) for the positions of X and F shown, and an animation of the motion at the frequency indicated on the graph. The animation is of course frozen and needs to be viewed to be appreciated. It is possible to add and remove spring/ mass/ damper elements, to change the position of X and F, and to change the animation frequency. The program has proved very useful in lectures as the response curve changes instantaneously when the X and/or F positions are changed. If students have a deep understanding of the subject then they can predict how many anti-resonances (major and pointed dips) will appear.

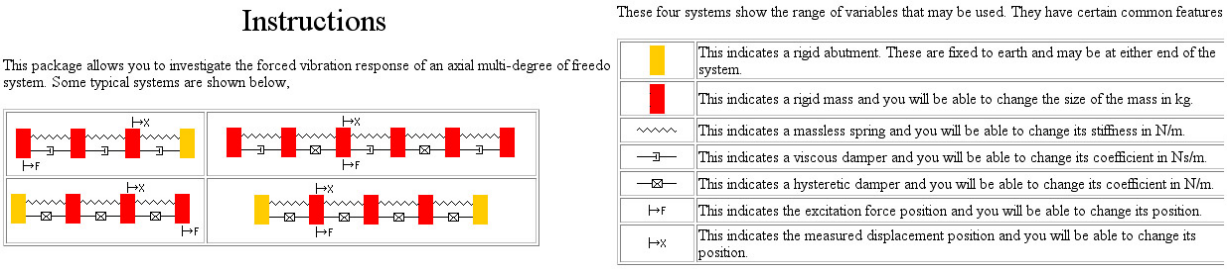


Figure 5: Instruction for multi degree-of-freedom package.

This program had several features that were new compared to the previous shells. There was a dialogue box (see Figure 6) that allowed the parameters of each spring/ mass/ damper element to be adjusted. The X and F positions could be changed simply by clicking just above or below the top diagram of the system. Finally the animation was linked to the frequency indicated on the response and showed how the system would vibrate at that frequency and for the force position shown. The code and instructions were written over a period of one day with the authors in close proximity. Subsequently the code was left with Stone and because of other priorities used in lectures but not used as a shell until 2004 when

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Stone commenced a period of study leave with the goal of extending the WWW sites on vibration to include multi degree-of-freedom vibration, continuous systems and complex systems. Scott was not available for any help because of increased teaching commitments. The code for the original multiforced program was very extensive and complex, and thus was the least shell-like of the three examples we are presenting. The complexity arose from the deeper connection between the animated physical system and the user interface. The animated system now consisted of a series of subsystems, each of which had both state variables and several visual interface representations.

The first derivative program, based on the multiforced shell, was of the axial vibration of a continuous bar (Figure 7). A vibrating system with a large number of discrete connected masses begins to behave very like a system with distributed mass. The similarity of the new modelled system to the original one made the conversion relatively straightforward. The continuous-system animation did not need the dialogue box code so it was deleted. Using only controls provided on the screen the dimensions of the bar may be changed and the animation reflects the changes in geometry in real time.

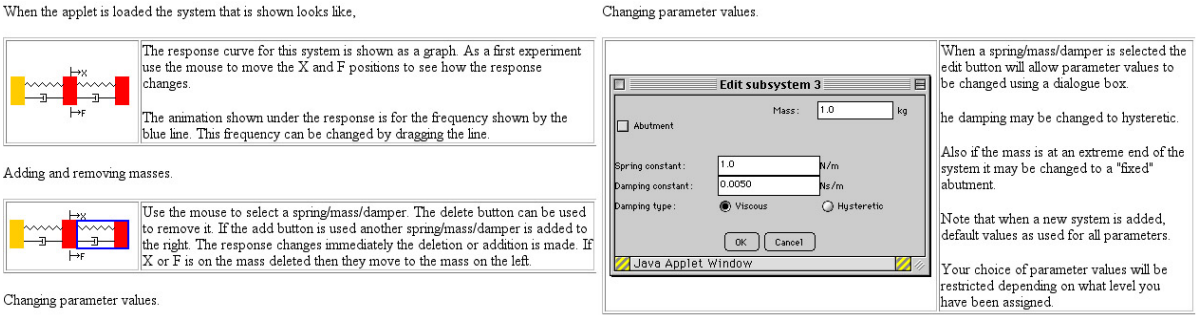


Figure 6: Instruction for multi degree-of-freedom package continued.

The resource author found that the multiforced shell could be modified by removing features not needed in a given new project. For example animations were written that did not use the new “dialog box” feature.

Discussion

The software expert – Scott in this case – spent a total of about two days writing the shells published on the web site. These were deliberately set up to be easy to extend. The academic content expert – Stone in this case – took those shells and over a period of weeks was able to write several valuable teaching animations.

Student surveys have indicated that the animation programs produced aid understanding. The WWW sites that utilise them have not been used as much as expected but the printable versions have been well used. The sites are in fact accessed extensively throughout the world. The copyright statement shown in Figure 2 has resulted in many requests from academics to use the programs and have links to the site. The one degree-of-freedom site is the top site recommended by the EEVL (Edinburgh Engineering Virtual Library). A Japanese version of this site was produced by Dr Senba, while on study leave at UWA and this has proved to be unexpectedly popular. The programs may therefore be agreed to be useful.

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A more telling question is *whether the approach of using shells is efficient*. The authors' experience is that neither of them would or could have found the time to produce the programs on their own. The expertise they have has been gained over many years and neither would have the time or inclination to attempt to gain the expertise of the other. The major attraction is that by collaborating for a short time it is possible to produce something that is immediately useful. At the same time the result of the collaboration allows one of the authors (an expert in vibration) to produce many more programs using the single shell. The larger the number of such derivative programs that are useful then the more efficient the process becomes.

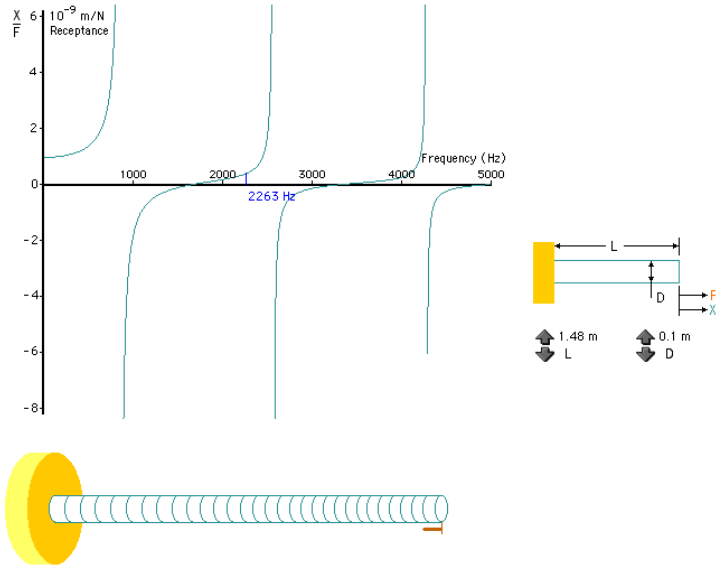


Figure 7: Vibration of a clamped/free bar.

Existing clearing-houses for educational resources concentrate on finished course materials: completed sets of lecture notes in multimedia form, for example. These tend not to be as portable as we desire and are rarely used outside the developing institutions. Teachers who wish to present concepts by animation need a different type of resource: libraries of shells like the ones we are presenting, along with detailed and platform-specific advice about how to make use of them.

Existing models for *research* collaboration tend to produce study tours of several months duration. Our experience suggests that, for *teaching* development work, a different approach may also be productive. If an expert in a certain type of shell were to visit an expert in a certain type of content, for a very short time, as little as a few days, this might mean that the content expert is enabled to work independently and productively – in other words, efficiently. Conference style workshops are a good way to educate a group about what is possible with a certain educational technology, but this is not quite the same as having a technology implemented, in detail, *in one's home environment*. Our educational institutions do not currently have mendicant shell experts – but perhaps they should.

Conclusions

We have drawn attention to a type of collaboration that we feel has been unusually effective and which could be introduced as a model of staff development or certain kinds of teaching resource development. Well constructed shells – detailed, open-source examples – can be

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used as templates for the creation of quite new teaching resources, without deep programming knowledge. Code for several of our most used shells has been published along with this paper.

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On-line support for students studying engineering management off-campus in summer semester

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***Abstract**: An on-line site was created to support students studying a time-shortened, off-campus unit in engineering management that was being offered over summer semester for the first time. An evaluation exercise was undertaken to assess the effectiveness of this arrangement, to identify what types of on-line resources students rated as important, and to identify those on-line resources that students actually used in their summer semester studies. Most students reported that they were successful in achieving their summer semester study goals, and that summer semester study was as good as or better than studying in a standard semester. The types of on-line resources ranked most highly by students were those that assisted in strategic study and exam preparation. The on-line resource ranked as least important and used least in practice was a discussion forum for all students. Other results and statistical analysis are presented.*

***Keywords**: Summer semester, off-campus, on-line support*

Introduction

An undergraduate engineering management unit was offered over summer semester in a time-shortened, off-campus mode only for the first time. To support students an on-line unit site was created. An evaluation exercise was undertaken to assess the effectiveness of this arrangement, to identify what types of on-line resources students rated as important, and to identify those on-line resources that students actually used in their summer semester studies. The exercise and results obtained are presented in this paper.

A summer semester unit in engineering management

The School of Engineering and Technology at Deakin University offers a three year Bachelor of Technology and a four year Bachelor of Engineering at the undergraduate level. The programs are delivered on-campus, full-time for conventional entry students who come directly from secondary school. Mature age students may study the programs off-campus and/or part-time. The use of computers is an integral part of all the engineering study programs. The programs are based on a model of flexible delivery systems that incorporates:

- a modular curriculum;
- a formal assessment system for recognition of prior learning (both academic and experiential) based on granting advanced standing in appropriate course modules;
- course modules developed in print form, supplemented by an array of learning resources, including audio and video presentations, home experimental kits, computer aided learning packages, remote (Internet-based) laboratory experiments and conventional laboratory work requirements; and

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- computer mediated communication systems, including e-mail, video conferencing, WWW-based bulletin boards and Internet-based conferencing.

The level three (nominally third year) unit SEB311 Methods of Managerial Decision Making covers project management, operations research, and accounting and financial management. Over the period November 2001 to February 2002 it was offered to students as an off-campus only summer semester unit for the first time. The student cohort included students who would normally study on-campus during standard semesters only, students who would normally study off-campus, and a group of students based in Singapore. The summer semester period is notionally only 10 weeks in duration, compared to the standard semester duration of 13 weeks. In practice, the summer semester period incorporates a two week Christmas/New Year period when the University is closed, as well as being a popular period for student holidays and/or vacation work, hence the actual time for students to study effectively is often considerably less than the standard semester duration.

Time-shortened course delivery formats were first developed for the delivery of standard courses during the shorter summer semester (Daniel, 2000). Research indicates that a wide range of discipline areas can be successfully delivered in a time-shortened format, including the liberal arts, education and courses involving computational skills, such as mathematics, science and economics (Daniel, 2000). It is suggested that intensive courses are best offered to upper year level students, since these students should already have the required foundation knowledge in the discipline area and maturity to effectively use the time-shortened study period (Brown, 1992). Though the identified sources don't specifically refer to off-campus delivery, they do suggest that chosen unit, SEB311, has the characteristics for successful delivery over summer semester.

To assist students to study the unit off-campus and in a compressed time-frame an on-line unit site was created using the TopClass (WBT Systems, 1999) online teaching and learning management system. The unit site included:

- general advice – getting organized, submitting assignments, preparing for the exam, etc;
- unit guide – containing administrative information, assignment details, etc;
- suggested answers to self-study review questions in the printed course material;
- suggested answers to semester assignments (posted after the final submission date);
- past exam papers and suggested solutions;
- class announcements area for latest class news and information; and
- a class discussion area open to postings from all class members.

This was the first time that this unit had been offered over summer semester, and the first time that the TopClass system had been used for the on-line support of a unit in the School of Engineering and technology. To evaluate the effectiveness of the TopClass system in assisting students to complete their SEB311 summer semester studies a pre-test/post-test survey was conducted.

Methodology

All enrolled students were mailed a questionnaire at the commencement of the semester that sought responses under the following categories:

- demographic information – age; gender; course of study; location of study;
- summer semester studies – previous experience; previous study mode; reason for taking;

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- on-line learning support – previous experience; was it beneficial?; what should be provided?; and
- on-line access – do you have Internet access?; where?

This was followed at the end of semester with another questionnaire that sought responses under the following categories:

- demographic information;
- summer semester studies – goals achieved?; how did it compare to normal studies?; and
- on-line learning support – compare TopClass to other on-line support; what on-line resources did you actually use?; in what way could on-line support be improved?

For both questionnaires, students were provided with a 'reply-paid' envelope so their completed questionnaire could be returned at no cost to the student. As required by University research ethics procedures, participation in the survey was anonymous and voluntary. For this research project a significance level (p) of 0.01 was used.

Results and Discussion

Response rate

For the start of semester survey 34 valid responses were obtained from a total class enrolment of 66, giving a response rate of 51.5 percent. For the end of semester survey 34 valid responses were obtained from a total class enrolment of 64, giving a response rate of 53.1 percent.

Demographic information

The following age statistics were collected from the start of semester survey: mean age 25.6 years; standard deviation 6.05 years; age range 19 to 38 years; and median age 25 years. The following gender statistics were collected: female 14.7 percent; and male 85.3 percent. The following course of study statistics were collected: Bachelor of Engineering 53.1 percent; Bachelor of Technology 37.5 percent; and Other 9.4 percent. The following study location statistics were collected: Australia 76.5 percent; and Singapore 23.5 percent. The following age statistics were collected from the end of semester survey: mean age 25.3 years; standard deviation 6.50 years; age range 19 to 42 years; and median age 23.5 years. The following gender statistics were collected: female 14.7 percent; and male 85.3 percent. The following course of study statistics were collected: Bachelor of Engineering 75.9 percent; Bachelor of Technology 20.7 percent; and Other 3.4 percent. The following study location statistics were collected: Australia 73.5 percent; and Singapore 26.5 percent.

The gender, course of study and study location characteristics of the entire commencing class group were known, permitting a comparison of the population and respondent groups. The proportion of females in the population was 9.1 percent. The proportion of BE students in the population was 68.2 percent and the proportion of BTech students in the population was 25.8 percent. The proportion of Australian-based students in the population was 80.3 percent. In all cases, the demographic statistics were not significantly different from the respondent group – see Table 1 for the statistical tests. The gender, course of study and study location characteristics of the entire end of semester class group were known, permitting a comparison of the population and respondent groups. The proportion of females in the population was 9.4 percent. The proportion of BE students in the population was 68.2 percent and the proportion of BTech students in the population was 25.8 percent. The proportion of Australian-based

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Table 1: Statistical demographic comparisons of commencing and completing student groups

Demographic characteristic	Chi-square test statistic	Significance
Commencing gender proportions	$\chi^2_1 = 0.723$	$p > 0.39$
Commencing course of study proportions	$\chi^2_2 = 2.108$	$p > 0.34$
Commencing study location proportions	$\chi^2_1 = 0.199$	$p > 0.65$
Completing gender proportions	$\chi^2_1 = 0.633$	$p > 0.42$
Completing course of study proportions	$\chi^2_2 = 0.313$	$p > 0.85$
Completing study location proportions	$\chi^2_1 = 0.484$	$p > 0.48$

students in the population was 80.3 percent. In all cases, the demographic statistics were not significantly different from the respondent group – see Table 1 for the statistical tests.

The gender proportions in both the commencing and final respondent groups compare closely to the reported overall female participation rate in Australian engineering undergraduate studies of approximately 16.05 percent (Department of Education Training and Youth Affairs, 2001). The good match between the demographic characteristics of both the commencing and final sample and population groups suggests that valid conclusions about the commencing and final population groups can be inferred from the respective respondent groups.

Summer semester studies

At the commencement of the semester only 8.8 percent of respondents reported that they had studied a summer semester unit previously, though 50.0 percent of respondents reported that they had studied in the off-campus mode previously. The vast majority of students (91.2 percent) indicated that their reason for undertaking summer semester studies was to accelerate the completion of their study program. Another 5.9 percent indicated that they were attempting to catch up a failed unit. A single respondent (2.9 percent) indicated that they were taking the offered unit over summer to make more room in their study program in the following semester so that they could enrol in 'night school' classes. For most students, summer semester provided the opportunity to accelerate their studies at a time that was convenient to them.

At the completion of the semester 94.1 percent of respondents indicated that they felt they had been successful in achieving their original goal for studying a summer semester unit. Respondents were asked to indicate if they thought studying in summer semester was better, worse or no different to studying in a standard semester. The responses received were: better 23.5 percent; worse 11.8 %; and no different 64.7 percent. Only a small proportion of students found summer semester to be inferior to studying in a standard semester.

On-line learning support

At the commencement of the semester 67.6 percent of respondents reported that they had studied a unit previously that provided some form of on-line support; 32.4 percent of respondents had not. Of those respondents that indicated that they had studied a unit previously that provided some form of on-line support all indicated that the on-line support had been beneficial for their study. Reasons cited included:

- access to study resources and information;
- access to model answers for problems;
- ability to get a feeling for how other students are progressing;
- receive latest/updated class information;
- communication with the academic staff member(s) and other students;

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- improved response time;
- universal access to resources – at home/at work/24 hours a day – 7 days a week; and
- on-line assignment submission.

At the commencement of the semester respondents were asked to indicate what resources should be provided by on-line learning support from a six item inventory, as well as listing any other resources they felt were important. The proportions of respondents indicating the inventory items were important were:

- e-mail communication with lecturer – 88.2 percent;
- study tips/advice – 85.3 percent;
- discussion forum for all students – 79.4 percent;
- assignment details – 91.2 percent;
- answers to exercises/review questions – 97.1 percent; and
- class announcements – 79.4 percent.

Two statistically significant correlations between survey responses were found in the start of semester responses. Australian-based students were more likely (92.3 percent) than Singapore-based students (37.5 percent) to indicate that class announcements were important ($\chi^2_1 = 11.240$, $p < 0.0009$). This is perhaps due to the fact that the Singapore-based cohort are accustomed to receiving a complete package of study materials, including study notes, textbooks and experimental kits, such that they can complete the study unit in a self-contained mode, without reference to additional external resources. Whereas, the Australian-based students have to purchase their own textbooks, download the assignment details from a unit web site, and generally seek out additional study resources beyond those that are delivered to them.

It was also found that, at the start of the semester, those students who had previously studied a unit with on-line support were more likely (95.7 percent) to indicate that an on-line discussion forum should be provided than those students who had not previously studied a unit with on-line support (45.5 percent) ($\chi^2_1 = 11.468$, $p < 0.0008$). This is perhaps because previous experience of studying units with on-line support is important in demonstrating the value of resources such as an on-line discussion forum.

Other on-line resources listed by commencing respondents as important included:

- past exam papers and solutions;
- feedback on assignments; and
- after-hours on-line tutorials.

Although not directly related to the TopClass system, one student said they wished to be able to make course enrolments and enrolment variations on-line. One area were the Internet has had a large impact on society in general is the provision of ‘e-services’, and e-commerce in particular. Compared to commercial enterprises, the education sector has been slower in offering e-services to students. Students are offered a wide array of on-line services and payment options from banks, phone companies and others; however, many students find that similar services are not yet available from their university or school. On-line access to payment of fees, purchase of textbooks, academic transcripts, course registration and other student services at the time of t he survey was highly variable (Green, 2001).

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At the completion of the semester respondents were asked to indicate what on-line support resources they actually used in their summer semester studies, again based on a six item inventory, as well as listing any other on-line resources they used. The proportions of respondents indicating the inventory items were important were:

- e-mail communication with lecturer – 38.2 percent;
- study tips/advice – 52.9 percent;
- discussion forum for all students – 32.4 percent;
- assignment details – 64.7 percent;
- answers to exercises/review questions – 76.5 percent; and
- class announcements – 44.1 percent.

A single statistically significant correlation between survey responses was found in the end of semester responses. Students who normally study in off-campus mode in a standard semester were more likely (61.1 percent) than students who normally study in on-campus mode (12.5 percent) to indicate that e-mail communication with the academic staff member was valuable ($\chi^2_1 = 8.476$, $p < 0.0036$). This is perhaps due to the fact that students with prior experience of off-campus study have already developed strategies for overcoming barriers to communication with academic staff, and have found e-mail to be an effective means of achieving this. Those students who would normally study in on-campus mode in a standard semester, by definition, live geographically close to the university and, even though technically enrolled in off-campus study mode for the summer semester, may have nevertheless taken advantage of their proximity to the university to visit academic staff in person to have their questions answered, rather than resorting to e-mail communication.

Other on-line resources listed by respondents as actually used in their summer semester studies included:

- past exam papers;
- past exam paper model solutions; and
- assignment model solutions.

Comparing the actual usage of on-line resources to those considered important at the commencement of the semester, it can be seen that all actual ratings are significantly lower. Though, the initial rankings of the resources correspond closely to the ranking of actual usage; with the first and second ranked resources (answers to exercises/review questions and assignment details) being the most used resources, and the lowest ranked resource (discussion forum for all students) being the resource indicated as used least. The on-line resources with the highest indicated actual use are those likely to assist students in strategic study activities to improve their ability to solve typical problems and maximize their exam mark. This is also reflected in the 'other' on-line resources indicated as actually used by respondents, particularly model solutions for semester assignments and past exam papers.

The on-line resource ranked as least important and used least in practice was a discussion forum for all students. While the discussion forum implemented for this exercise was not formally structured and student contributions were not compulsory, it was disappointing not to see the students make more use of the forum for student-to-student communication and collaboration. Research by the U.K. Open University into their 'tutorial support model', where computer conferencing was used to replace telephone, letter and face-to-face communication, showed that "...students value the interaction with other students, as much as interaction with the tutor. They find it valuable to compare notes with their peers, to chat about issues tangential to the course and to create the kind of community usually only found

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on campus." (Mason & Bacsich, 1998, p 250) The lack of use of the discussion forum in this instance suggests that students will not necessarily create an on-line collaborative group of their own accord, without guidance and a pre-existing structure for such communication and interaction, and that the conduct and benefits of such on-line collaboration need to be explained and demonstrated by the academic staff responsible for them.

The School of Engineering and Technology provides a standard set of on-line resources for most study units using a custom-built web system (Palmer & Tulloch, 2001). At the completion of semester 85.3 percent of respondents had indicated that they had previously accessed/used the standard unit web pages. Of those respondents that indicated they had accessed the standard unit web pages previously, they were asked to rate the summer semester TopClass system as better, worse or no different compared to the standard system. The responses received were: 31.0 percent better; 6.9 percent worse; and 62.1 percent no different. Only a small proportion of respondents ranked the summer semester TopClass on-line system as inferior to the standard School unit web page system.

At the completion of the semester respondents were asked to identify any ways in which the on-line support of their studies might be improved. The responses received included:

- more model solutions to past exam papers;
- provision of on-line tutorials; and
- one student noted frustration caused by two network outage periods during which the TopClass server was not accessible.

On-line access

Respondents were asked to indicate their source of on-line access. Only three sources were indicated; home 91.2 percent; work 5.9 percent; and university 2.9 percent. The vast majority of respondents had Internet access at home. Less than 10 percent were reliant on others for their source of on-line access.

Student academic performance

Daniel (2000) reports that research indicates that student academic results from time-shortened courses are comparable to results from traditional semester-long classes. The unit SEB311 is also offered during the year in a standard semester-long format, so student results are available for this unit in both the standard and summer semester modes of offer. The academic results from semester one 2001 were compared to the results from the summer semester 2001/2002. The semester one class contains both on- and off-campus students; as the summer semester class contained only off-campus students, only the off-campus student results from semester one were used in the comparison. The mean mark from the semester one class was 71.2 percent and for the summer semester class it was 73.3 percent. There was no significant difference between these results ($F_{157} = 0.790$, $p > 0.375$). A comparison was also made of the grade distributions (fail, pass, credit, distinction, high distinction) between the standard and summer semester groups, this is presented in Figure 1. Again, no significant difference was found ($\chi^2_4 = 5.102$, $p > 0.277$).

Conclusions

Most students were successful in achieving their summer semester study goals; their primary reported goal being to accelerate their study program; and only a small proportion felt that summer semester was inferior to studying in a standard semester. Prior to this exercise, all students who had used on-line support in their studies previously also reported that it had been beneficial for their study. The types of on-line resources ranked most highly by students

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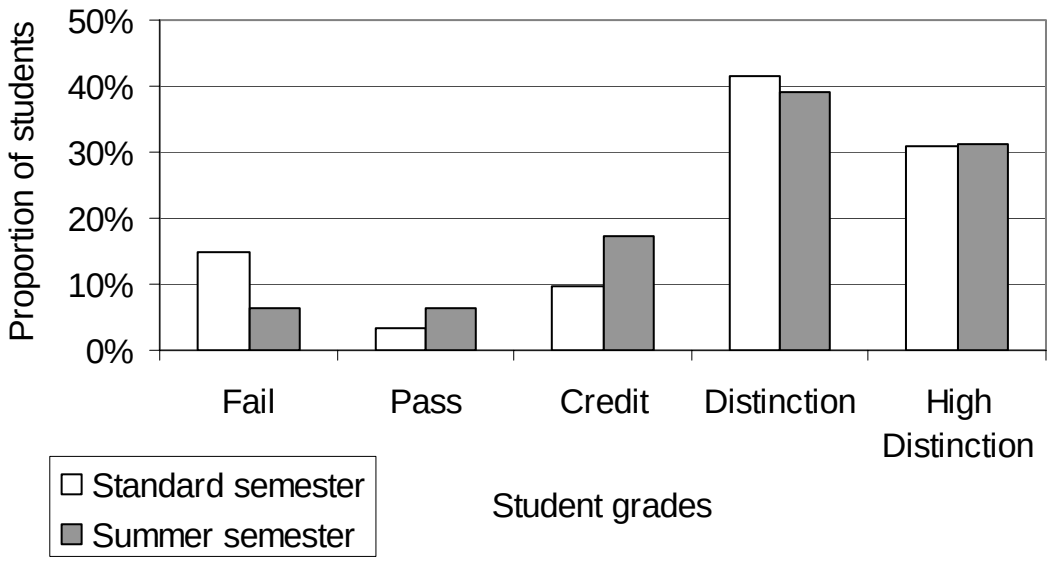


Figure 1: Grade distribution comparison between summer and standard semester classes

were those that assisted in strategic study and exam preparation, including answers to review questions and past exam papers.

The on-line resource ranked as least important and used least in practice was a discussion forum for all students. This suggests that on-line collaboration between students will not necessarily arise spontaneously, and that students need more exposure to the benefits and conduct of on-line discussion forums. A statistically significant correlation between respondents reporting prior exposure to on-line support for study and also reporting an on-line discussion forum as being important supports the proposition that exposure to on-line discussion forums improves students' perception of their value.

Overall, it is concluded that off-campus students value on-line learning support resources, and that these resources improve access to information, improve communication between academic staff and students, and assist off-campus students to achieve their study goals.

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Experience in Engineering Problem Solving for On-campus and Distance Education Students.

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Abstract: *The University of Southern Queensland (USQ) has embarked on a radical transformation of its engineering programs to modernise and equip students to meet new global expectations of the profession. A major element in this change has been the introduction of a strand of four courses to encourage teamwork, life-long learning and communication, as will as technical skills through a Problem Based Learning (PBL) approach. These courses were delivered to USQ students for the first time in 2001.*

The initial cohort of students included 163 studying at a distance. These students were dispersed throughout the world and were not able to meet face to face for this course. Teamwork was achieved by electronic means using email, chat groups and web pages. Student grades in the foundational course were at least as good as those obtained in other traditional didactically based courses with 85% of the cohort achieving a passing grade or better. Analysis of the individual student portfolios indicated that about 92% of the students viewed the course favourably while 5% had no definite opinion. External students were at least as successful as on-campus students in achieving higher grades.

We conclude that offering PBL courses to engineering and surveying students at a distance from the campus is not only possible but has been successfully achieved in the delivery of the foundational problem solving course in 2001.

Keywords: *Problem Based Learning, engineering, distance education*

Introduction

In response to a number of challenges at university, professional and faculty, level the Faculty of Engineering and Surveying at the University of Southern Queensland (USQ) implemented a radical curriculum change to its programs in 2001. This change introduced a strand of Problem Based Learning courses (subjects) as core to all degree programs.

The University of Southern Queensland has its main campus in Toowoomba, Queensland. It is one of Australia's leading regional universities and is noted for excellence in distance

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education. It has more that 23,000 enrolled students of whom over 17,000 study off campus, many of whom are located interstate or overseas. The faculty of Engineering and Surveying is one of five faculties at USQ. It offers two, three and four year programs in nine discipline majors (agricultural, civil, electrical and electronic, mechanical, environmental, mechatronic, computer systems, surveying and GIS). These programs are articulated and fully accredited by Engineers Australia, the national professional organisation. In 2002 our courses were the first in the world to be fully accredited in the distance education mode and are now designated as world's best practice by Washington accord countries. There are approximately 2,500 students enrolled in faculty programs of which about 1,700 are studying externally.

Engineering educators are becoming increasingly focused on graduate attributes, driven by the needs of employers and of professional registration bodies. University policy in Australia is also concentrating on generic attributes of graduates for quality control reasons. In Australia the professional accreditation body (Engineers Australia) has focused heavily on the development of graduate attributes required in Engineering professionals (ACED, 2002, IEAust, 1999). They now nominate a range of attributes and require detailed planning by universities on how these attributes are incorporated into the curriculum. In short, the main focus of higher education is now on outcomes and not the process. In 2001 the faculty prepared for their regular re-accreditation process by focusing the curriculum on these graduate attributes as well as on traditional discipline-specific knowledge.

A review committee examined the new requirements required for accreditation and concluded that they could best be met by an integrated strand of engineering problem solving courses, that employing a Problem Based Learning (PBL) approach. It also concluded that such a strand of courses would have the benefit of introducing first year students to "real" engineering and so reduce the early attrition rate from the programs (Dowling D, 2001 a & b). The only question was whether a PBL approach was practicable within the USQ engineering education environment. This question engendered much debate.

Course Design and Delivery

The new strand consisted of 4 courses to be delivered using PBL, plus our existing final year research project as a capstone course in the final year of our 4 year programs. The four courses were named Engineering Problem Solving 1, 2, 3 and 4 and were integrated into our suite of programs as shown in
Table **1**.

Course	Student cohort – all majors
Research Project (individual)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 4 (Teams of 4 students)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 3 (Teams of 4 students)	Bachelor of Engineering, Bachelor of Surveying
Engineering Problem Solving 2 (Teams of 6 students)	Bachelor of Engineering, Bachelor of Surveying, Bachelor of Technology, Associate Degree
Engineering Problem Solving 1 (Teams of 8 students)	Bachelor of Engineering, Bachelor of Surveying, Bachelor of Technology, Associate Degree

Table 1: Problem Based Learning Strand of Courses

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The curriculum and course objectives for these four courses were completed and formal specifications written (Porter & Brodie, 2001).
The foundational course has key learning objectives of developing teamwork skills, communication abilities using electronic media plus rapid learning and application of targeted technical skills. These objectives are assessed through four separate team reports on complex, real word engineering problems and an individual *reflective* portfolio (Brodie & Porter, 2001). In common with all other courses in the Faculty it is intended to require 155 hours of student effort.

Engineering Problem Solving 1 was offered for the first time in semester 1 of 2002. 176 on-campus and 163 distance students completed the course in this initial offering.

All students were assigned to a team, and all teams were structured to contain a mixture of different student backgrounds, degree levels and majors. Minority students (female and those with English as a second language) were not isolated in teams, but placed with at least two other similar students where possible. The teams had a maximum size of eight. This was larger than the size recommended by the literature, but did allow for changes in enrolment numbers, typical in a first semester, first year course.

An academic facilitator was assigned to each team. This person was responsible for monitoring the teams' activity and to provide guidance on the range of resources available through the university system. While on-campus student teams met face to face, external teams had to rely on virtual meetings using the Internet and World Wide Web.

The main resource provided to students was the Course Home Page. This website contained links to resources for organizing teams (codes of conduct and cooperation); team roles; communication tips; reflective and technical writing and conflict resolution. Details of the projects were released progressively during the semester. A 'FAQ' link was updated regularly in response to common questions as was the 'TIPS' link and noticeboard. Students had about four weeks to complete each project, and the projects became progressively more open ended through the semester. During the first week they had to elect team project leaders, decide on a "Code of Conduct and Cooperation", plan their approach to the project and assign work to team members. Two weeks were spent in researching the problem and developing individual contributions to the team solution. The final week was spent in assembling the team report. Regular meetings were scheduled throughout this process so that the team as a whole could debate the issues involved and reach a consensus on the solution. A progress report to the Facilitator was required on a weekly basis.

The four projects together were designed to force the students to learn and use required basic computing, physics and statistics content while discovering the value of their prior learning and life experience to the team's solution. Learning in the course is intended to occur within an engineering context.

Students used standard email for the bulk of their communications with the facilitator and their co-members, and common electronic chat-rooms for discussions. It was in this early phase where evidence of peer teaching/assistance was first seen. Most external teams used chat rooms (Yahoo, MSN etc) and the less computer literate members of the team were guided through the use of this technology. Some teams set up home pages, again guiding colleagues through the process after discussing problems e.g. Internet access and personal timelines.

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Evaluation of Student Performance

The students performed very well for this first offering, using an unfamiliar problem based learning approach. In fact the external student group presented less problems than we anticipated. The overall attitude seemed to be founded on a recognition that the teamwork requirements would not be easy so they must be made to work. The facilitators noted some team conflicts but these were largely resolved within the team structure.

Students were graded by the marks obtained in the four projects (85% of total) and the individual portfolio of reflections submitted at the end of the semester (15%). The team reports provided an overall mark for each project, and this mark was then moderated by the results of peer assessment forms submitted by each student and nominating the level of contribution provided by every member of that student team. The facilitator's observations were used as a quality check on the peer assessment forms.

The individual portfolios were developed throughout the semester as a record of the student's learning experience during the course. The course objectives were to be specifically addressed during this process, and a list of topics were provided on the website that the students had to cover in their portfolio. It became evident during the assessment stage that many students left the portfolio until the end of the semester and then tried to complete it in a couple of days. On reflection, this approach is no different to that adopted by these students to their assignments in all other traditionally taught subjects. It was more a result of a lack of experience than any lack of ability or motivation in writing portfolios. Individual student comments in their portfolio were very encouraging to the Course academic team. While indicating that Engineering Problem Solving 1 required a greater than average workload, the students reflected that they had enjoyed the process and found the course to be a very effective way to learn.

The students' grades for this course were at least as good as those obtained in other, traditional engineering courses. Of those external students who completed the course, 85% achieved a passing grade. Figure 1 shows a breakdown of the students achieving passing grades. The majority of the students who failed did so for not participating in the team process.

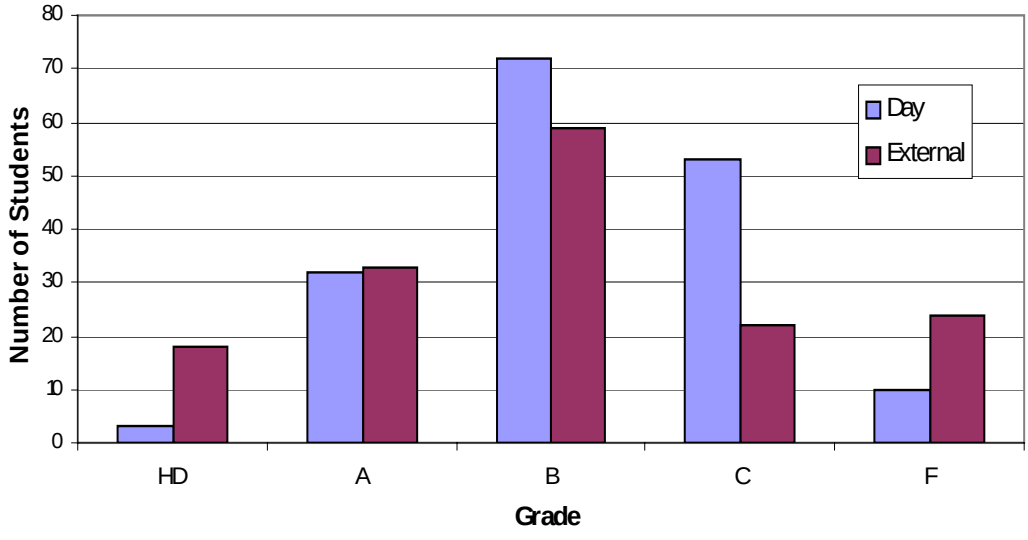


Figure 1: Results for Day and External Students in Semester 1 2002

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Student Perceptions

True student perceptions are difficult to gauge. Analysis of the portfolios submitted by the students in 2002 indicated that approximately 92% of the students viewed the course favourably and 5% offered no definite opinion. This positive response was not reflected in the standard teaching evaluation process carried out by the university. To some extent, this difference reflects the inappropriateness of the standard evaluation items used by the university for this type of course. The standard instrument assumes lecturing as the main vehicle for student learning. Students did raise some valid criticisms that need to be addressed in future offers: the high workload for the course, difficulty in communication, non-participating team members, poor support from facilitators and slow turnaround time on assignments were all mentioned. Steps under consideration to address these points include additional information on objectives, resources and expectations and additional facilitator training.

One unexpected advantage of the course was the social aspect. It provided the students with a mechanism for meeting people and establishing friendships, an important aspect of first year university life. This also occurred with external students.

Some students had difficulty in appreciating the value of this multidisciplinary course. Input from Industry will be sought to counter the belief of students that unless a course is specifically technically orientated it is of no use e.g. *"I am going to be a surveyor, none of the projects were about surveying…they were interesting, but of no use to me"*

Many students gave insightful comments on their learning experience. The following comments are taken from student portfolios.

"This course has challenged my ideas of learning, and through the application of problem-based learning [The course] has taught me what no other subject has before…. As such, I feel confident in my basic knowledge of all the areas covered in this course, and I am confident in my ability to learn what I don't already understand"

"one thing I did learn from this course is that team-based problem solving is a much more enjoyable method of learning and I also believe that I learned a great deal more than usual"

"Although there is a significant distance between most team members, friendships arose and I am looking forward to coming face to face with my team mates"

"in summary I have found this subject very challenging but as it has progressed I have found it also very enjoyable. I find this unusual to say an engineering subject has been enjoyable. … Problem Based Learning is a valuable learning technique."

Conclusions

The Faculty of Engineering and Surveying at USQ has successfully introduced an innovative curriculum to its engineering programs. This new curriculum meets the growing expectations from industry and the profession for the continued development of engineering graduates ready and able to positively contribute to the changing faces of the engineering profession. It provides a thoroughly practical and contextual grounding in problem solving, communication

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using a variety of media and working efficiently in multidisciplinary teams as well as nominated technical content.

Studying at a distance has, in the past left many engineering students missing many of the social aspects of the university experience. While this course cannot replace the on-campus experiences it has given many students early contact with a wide variety of students from different backgrounds and disciplines that they would not normally have made contact with. "*I'm looking forward to being part of the group. With all the other distance learning I've done, I've been on my own."* (Quote from student email)

The distance students can, with the correct planning, support and resources, successfully meet the academic objectives in a Problem Based Learning environment. 85% of enrolled distance students were able to demonstrate this through the assessment tasks. About one third of this student cohort were awarded a High Distinction or A grade, as a result of gaining more than 75% of the available marks for the course. This result was obtained with the students working in teams that were dispersed geographically and unable to meet face to face.

We conclude that the required teamwork, communication and problem solving skills can be successfully integrated into a 'virtual' PBL environment. The positive responses by the majority of students, studying in both day and distance modes, demonstrates that they are willing and able to take responsibility for and participate in their own learning. These skills of life long learning will stand them in good stead in the rapidly changing profession of engineering.

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Defining boundaries of PBL in the context of engineering education

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Abstract: *In engineering education, PBL is evident in different disguises. This paper investigates the feasible and favourable boundaries of PBL based teaching and learning in the context of delivering engineering degree programs. This is looked at in two aspects.*

The first of these is its ability to create and maintain a highly motivated proactive teaching and learning environment. With regards to this, the experiences gained in developing project based courseware at RMIT University are presented. The underpinning hypothesis and the course design model used in this development can be found elsewhere in a companion paper titled "Untutored mind and learning in engineering" by the same author.

The second aspect which will be discussed is the snowballing effect of the vertical integration of a number of complimenting courses to a study stream, to provide a favourable mindset. At this stage, it is difficult to ascertain what proportion of traditional teaching methods and PBL methods, in combination, would provide an optimum learning environment, both from a student's workload point of view and a demand on academic resources point of view. However, there is compelling evidence, gained through a project conducted at RMIT, that when students and academics work closely as a unit, and apply themselves to the task within a value structure comfortable to both, the outcome can change quite rapidly. There is a tendency that a PBL approach without proper resources, both academic and infrastructure needs, is more vulnerable to produce results which are more superficial than credible. However, the impact can be minimised to some extent through cross-fertilization between students.

Keywords: *PBL subjects, engineering education, PBL framework*

Background

The Institution of Engineers Australia Manual for the Accreditation of Professional Engineering Programs (1999), called for a major shift in the way the universities teach and train engineering graduates. This demanded the inclusion of generic graduate attributes in all programs which were tied to the re-accreditation in 2004. In response to this and also as a part of the general quality assurance process, the faculty of engineering at RMIT University issued, in 2002, a project plan titled: Renewal of the Bachelor of Engineering 2002-2004 (2002), encouraging project based learning methods in teaching practices at RMIT.

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I have been using PBL methods successfully in teaching individual subjects since 2000. However, this renewal of programs provided us a window of opportunity to revitalise some of the traditionally taught subjects in a more integrated manner. Encouraged by the changing landscape mentioned above, I have launched a project which I call 'self-discovery in teaching design subjects'. The idea was to explore and discover myself as a teacher in order to improve the way I teach civil and structural engineering design subjects. The underpinning hypothesis which has driven me and the course design model used in this ongoing development project from 2002 to 2004 is presented elsewhere in a companion paper titled 'Untutored mind and learning in engineering' by the same author. The self-discovery project is a progressive ongoing improvement, which commenced in 2002 with my 2nd year undergraduate students. I had the rare opportunity to work with the same group of 80-90 undergraduates, starting from second year through to the final year, vertically integrating their capabilities and learning in civil engineering design courses. My teaching capabilities grew hand in hand with the students' learning. Project based learning methods were used to create and maintain a highly motivated proactive student body during this period.

The Engineers Australia requirement, that all future programs to be designed to incorporate generic graduate attributes, means that PBL methods are destined to gain wider acceptance and popularity. This is a favourable policy innovation which, in my view, drives the quality and adds value to engineering programs. Engineers Australia should be congratulated for that vision. There is also a compelling worldwide trend to adopt PBL methods, both in schools and universities.

Most of our tertiary institutions are currently at a very early stage of transformation. Naturally, those academics who are interested in embracing this change have reasonable concerns which need attention. These include:

1. How stressful is it for students to manage their learning in a project based mode in the university, given that their learning habits, through schooling, are traditionally prescriptive?
2. What impacts does this have on existing staff capabilities, infrastructure and learning recourses?
3. How effective are PBL methods in the delivery of fundamental and theoretical content intensive subjects?
4. How do we know that PBL methods don't only offer a 'perceived-short term benefit' not a 'real-long term benefit' to the learner?

There is no doubt that PBL provides the best environment for student motivation and self-learning. However, in pragmatic terms, the above concerns must be thoroughly investigated over the next few years. For example, engineering is not something one can do by trial and error, as safety is a prime aspect in engineering education. There is a tendency for the PBL approach, without proper resources, both academic and infrastructure needs, to be more vulnerable to produce results which are more superficial than credible. The objective of this paper is to share my experience of developing and implementing a vertically integrated civil engineering design stream over three years, in the above context, rather than to propose solutions to those questions that I do not believe exist.

It is difficult to ascertain what proportion of traditional teaching methods and PBL methods, in combination, would provide an optimum learning environment, both from a student's work load point of view and a demand on resources point of view. A well accepted framework to maintain this balance within the institution is not apparent in existing literature. It is important

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to develop a framework where traditional and PBL methods complement each other to yield an optimum outcome, even if only as a short term strategy. It is envisaged that the use of such a framework would facilitate the process, especially during the transition from a traditional, teacher-focused learning environment to a fully fledged PBL environment.

Four dimensions of courseware design

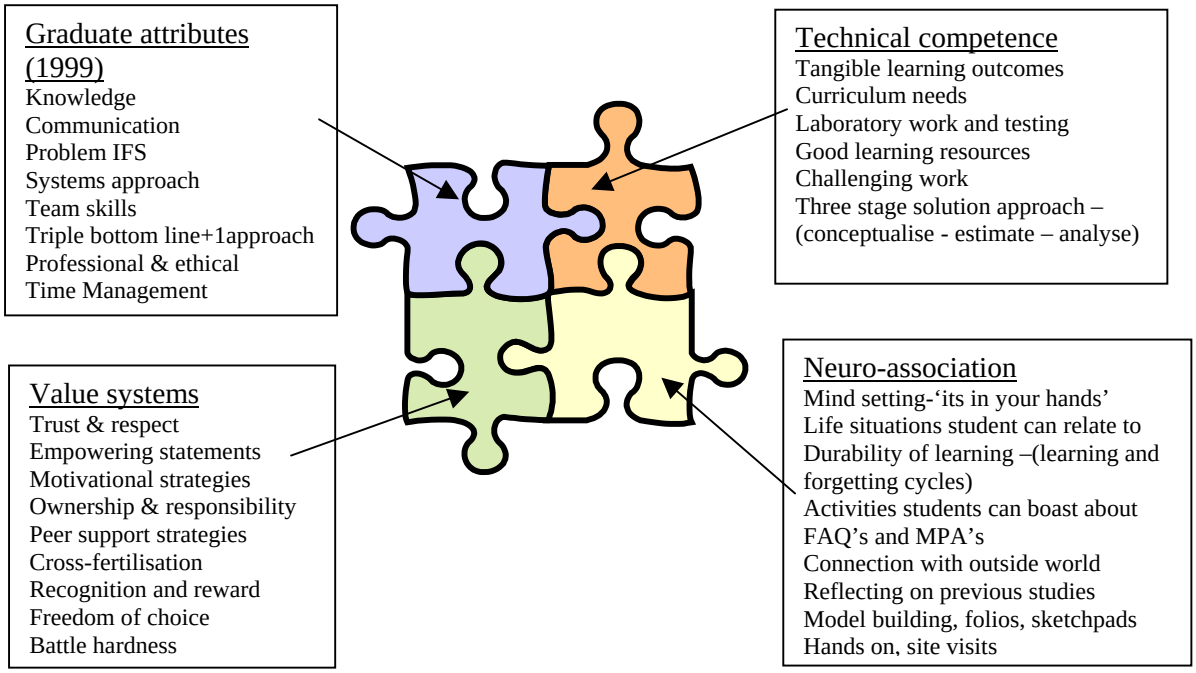


Figure 1: Four dimensions of course design

Figure 1, is reproduced here for the benefit of the reader, to facilitate a meaningful discussion. Refer companion paper titled - *'Untutored mind and learning in engineering'* by the same author for the hypothesis behind the development of this model in detail.

There are four dimensions, as shown in Figure 1, which compliment each other in creating and maintaining a motivated proactive learning environment. The difference in the proposed approach compared to other methods is the inclusion of the 'neuro-association' dimension, to enable students to become reflective life long learners and the 'value system' dimension for them to make a passionate attachment to the leaning environment. The model has been successfully implemented and tested in my courseware developments since 2002. The vertical integration of a subject stream - engineering design from second year through to fourth year is discussed in detail. The model can be adopted in designing a new course or adding value to an existing one. There is no reason why it cannot be adopted for the lateral integration of all subjects at a particular year level. The function and performance of the model is pivoted on the following compulsory rules.

1. At least two dimensions of the model must compliment each other in designing major teaching activities such as lectures, tutorials, discussion sessions and workshops. For example, lectures should not only be designed to capture 'technical competence' aspects but should include one other dimension such as 'neuro-association' or a 'value system'.

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2. Assessments must be regarded as major drivers which facilitate learning, self-assessment and feedback. In designing assessments the same complimenting rule must apply.
3. Designed courseware needs fine-tuning in practice. It may take at least three cycles to fully mature. Preferably feedback and follow-up should be managed by the same person.

Let us discuss an example of a single subject development in order to demonstrate this concept. Let us assume that I was assigned a new courseware design, which has six learning topic areas leading to six learning outcomes with a minimum of two assessment components. Let us create two scenarios for achieving the same objectives.

To simulate a setting within a traditional classroom format: I would have started by thinking about a good learning resource, such as a good textbook with well illustrated pictures, explanations and worked examples. I would prepare a good set of notes, preferably one per topic area, using the same textbook. I would arrange tutorial classes and provide a list of problems students have to try before they come to the class. I would carefully select problems in an ascending order of difficulty so that students can grasp the material thoroughly. I would have probably arranged an assignment or mid-semester test as a minor assessment and the end of the semester exam as the major assessment. I would use marks as their feedback. I would make sure students do not copy from each other. I would also make sure my major assessment, the exam, is compatible with past exams to ensure that students can be well prepared.

To simulate a setting to create a four dimensional project based environment, I would start by developing a project which needs in-depth knowledge of the course content. I would be looking for a project students could relate to, either by students' personal or professional neuro-association. I would take all practical steps to ensure students' minds roam outside the confines of the class room. I would encourage students to determine their own boundaries of learning. That is, problem identification, formulation and solution within the scope of the project. I would conduct workshops where students actively participate in discussions and respond to their questions. I would treat project tasks, milestones and commitment to quality as assessments and reward them for technical competence, battle-hardiness, leadership and citizenship. I would obviously be looking at realistic project outcomes within the area of study as a minimum requirement.

'Self-discovery in teaching design subjects' - an ongoing project at RMIT University

Largely due to engineered products and processes, civil engineering design is becoming an art more than a science. Arguably, ninety percent of a civil engineer's time in practice is spent in critical decision making in an interactive and dynamic environment. There is no argument that their technical training and professional experience forms the basis for decision outcomes. However, these decision outcomes are quite often conceived by common sense or intuition first, then supported by back-of-the-envelope type estimates and verified by detail analysis using applied sciences. This means that in practice, 'intuition' precedes 'intellect'. As such, I find it difficult to understand why we are practicing the exact opposite in teaching.

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Structural engineering design – 2nd year core subject

I have started developing the new course content, mode of delivery and assessment strategy of Structural Design 1, which is a second year subject, in this light. The fundamental changes made in re-designing the courseware and the delivery strategy were based on the hypothesis discussed before.

They were intended to achieve three outcomes:

1. To change students' mindset to believe that the skills needed in design and documentation of a structure are not only a mere deduction of structural calculations, but also a critical decision-making process within a multi-disciplinary environment.
2. To achieve technical competence in basic element design and verification of structural adequacy with the consultation of the current design standards AS1170, AS3600, AS4100. To achieve basic competence in using widely accepted software to analyse structures.
3. To achieve a significant shift in the value structure. A set of new trade-off concepts such as battle-hardiness versus exam marks, ownership versus responsibilities, frankness in failure versus the dilemma of perfectionism, overwhelming trust versus policing, etc.

In comparison to the way we used to teach structural design at the time, as a mere deduction of structural calculations, these changes have made a significant improvement in learning outcomes and graduate attributes. A major emphasis was put on commanding respect and motivation. We have also made bold changes to the rules of engagement to introduce a new value system as given above. At that time I was quite convinced that sincerity and trust were more powerful tools in human relations than policing. The bulk of traditional rules and energy was spent to police a few outlaws, than to recognise the battlers and reward the intellects. For example, cross-fertilisation through the sharing of ideas between students was almost a crime within the traditional value system of academia.

Eighty students have enrolled in this course. In an ideal world, I would have asked for additional resources and support to launch such an adventure, which, for obvious reasons, was not forthcoming. In reality, with the help of only one tutor who was one of my postgraduate research students, we were obviously thin on ground. However, my passion made me blind enough to dare. Neither my tutor colleague nor I knew what to expect. We did not fail. Students with a right mindset were proven to be an invaluable resource, which I had not accounted for in my initial planning.

Obviously, the vehicle we have used to accomplish the mission was PBL with a minimum focus on class based teaching and tutoring. It must be emphasised that it is the effort put in to teaching and tutoring that we have curtailed, not the course content or the intensity of learning. In fact, we have covered more material than we used to. In other words, freedom of learning was encouraged to facilitate the intensity of learning. The project was to design and document a 4-storey reinforced concrete building with a steel frame and steel roof system at the top level. Students were working in groups of three. Each group had a building with the same geometric shape but differences in internal configuration, dimensions and occupancy type, resulting in different projects for each group. The typical building envelope and the column layout were provided as constraints. The building was to be designed to comply with Australian standards, AS3600, AS4100 and AS1170. Students were working to a very tight

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time schedule with a number of milestones as drivers to complete the task within one semester. The formal assessment comprised a 60% project component and a 40% exam.

In my view, students took a lot of pride in and ownership of their work. Team dynamics were quite encouraging. Some groups established companies with names and logos, in which the team members acted as partners. One troubled group sat with me in confidence to discuss the "sacking" one of the members who was not pulling his/her weight. Most final reports, including structural drawings and computations were of a very high standard. They were good enough to put on display during the university's Open Day. I wanted their structural computations to be verified and signed off by a peer group. Ideally we should have had three academics to share the workload to better service the students. I was most impressed by their enthusiasm, the way they handled pressure and their commitment to quality. The new value system provided dividends. They were sincere and graceful in accepting errors. I marked them down only for negligence after one warning. It was very hard to manage and respond to 80 inquisitive minds. In the end we all became colleagues of a big team, proud and geared to move forward. About 15% of the class, in my judgement, struggled to manage time and work pressure.

Student experience was surveyed and reviewed independently by an experienced reviewer, in which 75% of the enrolled students participated. In her report, the reviewer commented that: "Overall, students responded extremely positively to this course. …while it is evident that the project requirements were demanding, most students responded positively because they clearly recognised how their learning was helped [not just this course] and because they found personal satisfaction from being meaningfully challenged. Graph 8 shows clearly the strength of the course; students overwhelmingly found that assessment tasks required them to develop an in-depth understanding of the content..."

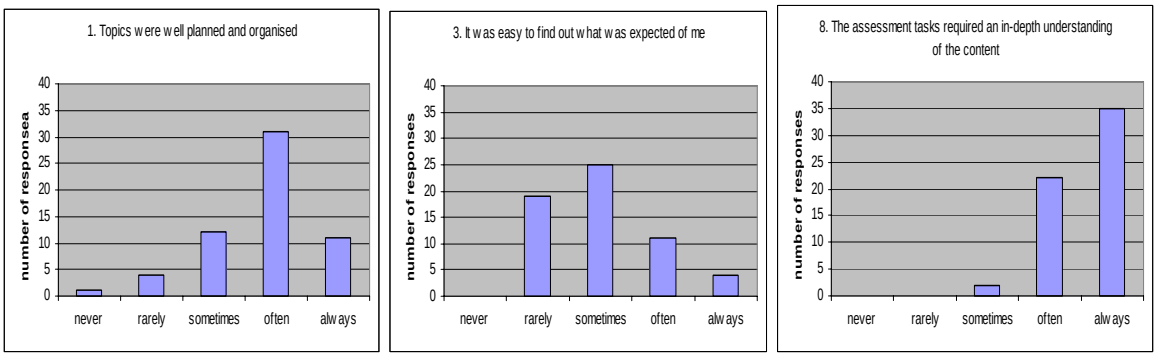


Figure 2: Student response survey results-2002

Figure 2 gives only a sample of three graphs including Graph 8, especially mentioned by the reviewer. They are students' responses to three conditions reviewer was attempting to capture. From left to right: Graph 1- Topics were well planned and organised, Graph 3 - It was easy to find out what was expected of me and Graph 8 - The assessment tasks required an in-depth understanding of the contents. The vertical axis is number of students and the horizontal axis represents rating from 'never to always'. It is interesting to note that, in my teaching practice, although students agree that my 'topics were well planed and organised' they disagree that 'it was easy to find out what was expected of them'. Yet, if you look at Graph 8, as the reviewer mentioned, students overwhelmingly agreed that the assessment tasks required an in-depth understanding of the content. When one combines these outcomes with the end of the semester results, which were quite outstanding, in my view, the courseware and the mode of

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delivery have achieved what it was designed to achieve. The reviewer went on to note that one student's comment summarises this section of the feedback succinctly: "I found everything useful and it was clear why we did the work. This is a great help when we can see why we are doing something"

My most cherished student comments, both positive and negative are listed below. They came in response to two questions. What did you particularly enjoy or find useful about this course? And, was there anything you found frustrating?

1. "The assignment (project) was useful because it related to what 'really' happens in industry" – 16 respondents.
2. "I became personally involved [enjoyed] in the assignment [gave me a good sense of achievement]" – 8 respondents
3. "The project helped me with my learning – the practical approach helped me understand the concepts" – 14 respondents.
4. "Not enough opportunity to ask questions during tutorials" – 11 respondents
5. "The project requirements disorganised/unclear" – 8 respondents
6. "Too rushed to learn all the content in one semester" – 11 respondents

Within the reviewer's main recommendation to, "identify why there is such an apparent huge demand on the need to ask questions of the lecturer and tutor …" is embodied the fundamental objective of my hypothesis. That is to trigger the inquisitive mind and condition of it to learn. Her suggestion also encompasses students' traditional mindset that causes them to habitually rush to the lecturer and tutor for answers. The second part of her suggestion to "…consider possible alternative strategies" is of great importance and the most challenging and sensitive aspect of all. It is most challenging because the response needs to be in real time. It is most sensitive because if it isn't handled well, the student may lose faith in you or you may have to spoon feed them. It is the skill of the teacher to develop strategies in response, but only to nurture their inquisitive mind to command respect and not to spoon-feed them so their learning is stopped. It is an art.

Third year civil engineering design

I had the opportunity to re-design the third year design subject in late 2002 for the same group of students, to be delivered in the second semester of 2003. Buoyant and confident by the experience presented above, I was keen to try out a unique approach, which to my knowledge, had not been attempted in civil engineering design before. I wanted to use this opportunity to motivate and teach civil engineering design to my students based on a "theme" (instead of a project) which is current and relevant. My initial motivation was only to provide a more flexible learning space, compared to their 2nd year experience, by softening the boundaries. As you may have noticed, the second year structural design project discussed above confined them to dealing with a structure with a defined configuration, and learning outcomes were limited to structural design and documentation aspects only.

At the time I was involved in two major research projects, both in the sustainable built assets area. This involvement educated me in the sustainability aspects and "green" built assets and concepts. I saw our new third year design course as a launching platform for "greening" our curriculum. I have selected the broad theme of "design of sustainable build assets" as the catalyst to achieve this goal. The next step was to narrow this down to select an appropriate project so that tangible learning outcomes could be achieved by the students within one semester.

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From a civil and structural engineering education point of view, RMIT University is located inside one of the largest and most sophisticated engineering laboratories and display centres on earth – the city of Melbourne. I noticed that we had hardly tapped into this resource in order to integrate it into our teaching. In project based learning it is very important to select a project idea, which is available for students to visit, inspect and collect information on, without relying on the teacher or tutor. Such engagement not only stimulates their inner learning but also provides great motivation for them to see "why they do" what they do. I was also mindful to find a project, which would be useful to our students after graduation, no matter which area of specialisation they may eventually choose to pursue as professionals. The other aspect I wanted to incorporate into the new course was to choose a project, which they can discuss and share with their parents, friends and relatives. All these ideas, and numerus discussions, compounded to enlighten us. We devised a project where each student would involve in designing and documenting their own 'dream home' with a sustainability focus.

The project is now passionately known, as the "Dream Home Project", which has become one of the most talked about courses in the school, among both colleagues and students alike. There were a number of blessings in disguise which surfaced as the subject evolved to its final status. Firstly, this project provided an insight into the whole-of-life performance of a development and the significance of critical decisions one has to make during the design phase to ensure the performance of the structure during its whole life span. In traditional civil and structural design we have only focused on the functionality and structural adequacy of the design. In this case students were looking at their design as a fully integrated system, where a multitude of trades and practices come into play. Students' learning horizons expanded immensely as they were made aware of the serviceability of the building, the significance of selecting proper materials to minimise embodied energy and operational energy consumption, potable water conservation and rain water re-cycling concepts, in addition to traditional timber design and the preparation of structural and civil drawings.

The project concept provided a superb motivation for students to learn. It was clearly evident that their involvement in second year has conditioned their mindset to not get overwhelmed but to look forward to the challenge with a positive attitude. It was further reinforced during this experience because the "Dream Home" sounded closer to them and they could tap in to the experiences of their parents. They had a number of display homes to visit around Melbourne. Students started collating information from the outset. They had to develop their dream home layout using passive design principles. A ninety lots subdivision was made available with lot numbers for them to select their land. They had their preferences, but land release was done on an agreed date on a first come first served basis. This has given students a lift, as they were looking for North facing blocks to get the optimum design orientation. North facing blocks were sold out quite quickly. Students lined up early. The corridor in front of my office was pretty packed by 12.30 for the 1.30pm land release activity. Even such a minor stimulant can lift their spirits to last a semester, which provides a highly motivated mindset.

We have maintained the same value structure we had already established during the second year experience. The management of the process became less daunting. It is needless to say, many students exceeded my expectations and few students even surprised me. I cannot emphasise enough the enormous satisfaction one can muster through a close working relationship with students.

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This course received an 'honorary mention' by the Engineers Australia program accreditation panel who visited us in May 2004. In a way I have made a small contribution to the strategic objective set out by the faculty outlined in 'Project plan titled: Renewal of the bachelor of engineering 2002-2004' (2002), by defying the odds, and not knowing it.

Final year civil engineering design

The same batch of students is currently working on their final year design project, managed by myself with all my colleagues in the civil engineering discipline. This is a year long course which is 100% project based. The project, which is a major infrastructure development project, is handled by a project team, which comprises of a group of three students and a supervisor. Work involves the feasibility stage of the development, site survey, geotechnical investigation, design and documentation of civil and structural works associated with the development. There are 28 such project groups working on a master plan development in a range of diverse projects covering all aspects of infrastructure design.

Eighty-four final year students, from civil engineering and civil/business double degree programs, have successfully concluded their design camp in Benalla. This one week off-campus residential camp is concluded in late March 2004. Numerous individuals and organisations, within and outside of RMIT University, contributed to make this event a rewarding experience. Camp organisation involved the setting up of a design office for 84 budding civil engineers, provision for surveying and geotechnical investigation of a 3.5sq km area of land, organising four site visits in the areas of water treatment, roads and building infrastructure and land care. The land owners Meridith Paez and Richard Saddler (Coranderck property) and Allan and Carrol Haslem (Innaminka property), Department of Geospatial Science, Delatite Shire, TXU, VicRoads, Benalla Land Care Group, North East Region Water Authority and G.E. Show & Associates Pty. Ltd have provided the logistic support.

Each project group has surveyed and developed their contour maps, carried out soil investigations, developed design concepts and prepared a folio of preliminary drawings for their designated projects. Work was supervised by seven academics from Civil Engineering and four academics from the Department of Geospacial Science. As mentioned, they have developed a total of 28 diverse civil engineering projects during this period. The participating academics have brought in a diverse range of expertise in the areas of water resources, structural, geotechnical, road infrastructure and surveying. Students are currently finalising their civil design package at the end of the first semester. This will work on the structural design package during second semester which will be submitted at the end of 2004.

I have been involving in this project since 1999, which is a long running tradition at RMIT. It is a general consensus, by all my civil engineering colleagues who take part in this project as supervisors, that we are witnessing something special. The only contributing factor I can think is their mindset which is now conditioned for learning to happen without someone dictating it.

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Future Engineering – Evolution or Revolution?

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Abstract: *This paper describes some of the key issues for the future of engineering and for engineering the future – from global, professional, organisational and educational perspectives. It calls for a revolution in engineering and engineering education to cope with globalisation and the need for sustainability in a rapidly changing world. We believe that we cannot prepare students for the multidisciplinary problems that we now face by using traditional teaching methods. Project- and resource-based learning must become the norm, built upon reflective practice. A new program being initiated within RMIT and its community – the Master of Sustainable Practice – is proposed to embody these principles.*

Keywords: *sustainable development, engineering education, future, problem-based learning.*

A future world

Although we cannot predict the future we can see key trends developing. For example, UNESCO, in its site for Sustainable Development, notes that it is necessary for students (read anyone) to "better understand the world in which they live, addressing the complexity and interconnectedness of problems such as poverty, wasteful consumption, environmental degradation, population, health, conflict and human rights that threaten our future" (UNESCO, 2004). If we collectively do nothing intentional, these trends are likely to continue and develop in a way that is profoundly unpalatable.

These problems have many dimensions but they are social in nature, but we cannot rely on a purely social solution to them to breakthrough. We have other means that are useful, for example – technologies, tools and techniques in science, engineering, economic and other domains. But technology can be a blunt instrument, and we have witnessed this over many decades; it can bring with it a range of unwanted and unforeseen consequences (eg pollution, land degradation, algal blooms and super-bugs).

The trend for increased complexity and interconnectedness of problems threatens to overwhelm traditional forms of "solutions" and decision making. We need to:

- change the paradigm from short-term *solutions* in a small number of dimensions to *managing* problems in the long-term in multiple dimensions,
- using a whole range of professionals to *get into action* using this new paradigm based on principles and priorities.

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Engineers have been dealing for centuries with many of these problems (poverty, wasteful consumption, environmental degradation, population, health, conflict and human rights). Now is the time for engineering to become even more principled than it has been, to focus on the shared concern of humanity that "development meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations General Assembly, 1987). From this principle we can develop priorities for action.

Engineering is evolving

Traditionally, engineers have been the providers of technical solutions – structures for shelter, water for drinking and crops, flood barriers, steam engines, computers, space shuttles, etc. Throughout earlier times, engineering was based firmly on heuristics and experience gained through practice. In the middle of the 20th Century, the scientific model of engineering became dominant and education became primarily university based, focussed on the underpinning physical and mathematical sciences. By the 70s, the importance of economic and management perspectives led to the compulsory inclusion of these topics in engineering curricula.

By 1990, the number of environmental engineering programs around Australia and the world was growing. Inserting environmental issues in mainstream engineering programs, however, seems to have mostly eluded us. Environmental engineering remains a distinct discipline, even though environmental issues and concomitant issues of sustainability appear in all areas of engineering.

In the 21st Century, it is clear that the social dimensions of technological development are emerging in society and in the profession. We (in Western societies) want a cleaner and quieter environment. We want engineering to satisfy our social needs – in an inclusive way. This trend was highlighted in the 1996 Review of Engineering Education (Engineers Australia, 1996) that called for a *change of culture* in engineering education.

One of the key developing issues for engineering is that we don't know the nature of the problems that we will need to solve, in the same way that we know about the problems of the past. We can see that the problems are more complex and interconnected than previously. Engineering has evolved in the past to meet new challenges, but …

Is evolution enough or is revolution required for future engineering?

In this section we will look at the environment and engineering from many different angles, with the intent of building a picture of our situation.

Firstly, Jim Watson, founder and chief executive of the successful New Zealand biotechnology company Genesis Research and Development states that 'the 'young' are the standard-bearers of our scientific revolution…they must be encouraged to discover the paths of the future, not trained in the ways of the past.' (Watson, 2001).

Secondly some engineers view the rapidly changing technology as the means of solving all our problems, for example Pearson (2003):
"We are changing the world faster than ever before, and the pace is accelerating says Ian Pearson, BT Exact's futurologist. Engineering is subject to a positive feedback loop, which is becoming more prominent as time goes on. The better we make the tools, the faster we can make new and even better tools. … Eventually, we won't even be limited by human intelli-

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gence, since computers will become smarter than us, and design even smarter computers still. … Some of us are already looking forward to the rapid advance of capability called the 'singularity', where technological development is so fast that it is like aliens landing and giving us all the gadgets out of their spaceship. Engineers disagree on when this is likely to happen but, with estimates varying from 2015 to 2040, that puts it within the working life of today's engineering students. … Engineers look forward to the new toys and capabilities, but most of us aren't looking forward to being cut out of the development cycle."

But, are gadgets the answer to the large complex, interconnected problems, in which humanity has to choose between potentially unpalatable options? Is there not danger in the above scenario that humans will be locked out of the decision making process in the same way that we suppress the needs of most other species on the planet.

Engineering knowledge and its impact on students

The focus on technical issues and the scientific model of the 20th Century has resulted in huge bodies of knowledge, which we are incrementally improving. In engineering, these specialisations include Civil, Mechanical, Electrical, Chemical and Environmental. In many universities it is these huge bodies of knowledge that have and are still being imparted to students, purportedly to enable them to act in the engineering profession.

There are two problems with this:
1. We are mostly preparing students for the problems of the past, eg to design a bridge, when they may need to design a transport system that minimises road based traffic and that is readily accessible by all people and goods.
2. The bottom-up approach to traditional teaching often fails to integrate the knowledge for the students.

The structured approach to imparting this knowledge is somewhat like a construction site where the students stand in the middle of the site with little or no briefing. The components of the structure are delivered to the site over the months and years of the project (bricks one moment, wall frames another, reinforcing steel, concrete and so on). It is expected that the students will be able to work out what to do with all of these components without any overall picture of what the project is about, until close to the end (final year) when they get smaller, similar sub-projects to work on. There is an assumption that putting this body of knowledge in front of them will enable them to be able to do their work, or that the employer will train them in how to engage in the workforce. The students also lack regular and varied practice in formulating strategy and plans to do or to have things done, as well as in the doing together in groups (especially with non-engineers).

Lloyd Peppard provides some insight into engineering employment in Canada (Peppard, 1994):
"Everyone knows that jobs are scarce these days, but most experts agree that there is currently a shortage of engineers in Canada and world wide. So where are the jobs? Because of the increasing specialization of engineering activities, some jobs are awaiting engineers with experience. But where will they get the experience? In the past, most engineers in Canada started their careers and gained experience with large firms--electric power utilities, machine manufacturers, resource and construction industries. With few exceptions, these companies are no longer looking for young engineers. Their business is shrinking and they are part of the "global restructuring" process. In contrast, small firms which have been in existence for only

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a few years cannot find enough engineers to fill their needs. Their requirements are often for graduating engineers with some experience and familiarity with a particular specialized field.
…
At the present time, graduates from Ontario find little if any opportunity to begin their careers with firms in the manufacturing sector centred in Toronto. However, if they are willing to travel to the Vancouver area, they may find new opportunities in engineering research and development within small start-up firms. These companies want new engineers with the broadest possible range of abilities and exposure to engineering tools and techniques.

If the future of engineering is not with the large old companies, whose business we could quite easily comprehend, how are we to describe the nature of the new engineering? The best we can say is that it will be diverse. In some cases, the skills required will be specialized but this isn't a rule. We know from comparing the present to the past that current products of engineering (look inside your video recorder, or telephone system) are not the simple machines they once were but rather complex systems. They are not the product of one or two engineers but of teams representing diverse skills and experience. Successful management of engineering projects of this degree of complexity is as vital as the design activities themselves."

These trends in the engineering workplace are being emulated globally.

Our experience of many engineers in business in Australia is that not only do they see themselves as servants of their organisations, but their primary motivations in the workforce are around technology and money. Further, for many, their primary motivations in life are outside of their work – in their family lives and other interests. These motivations are also reflected in many engineering student reflections, with the added motivation of wanting to do something visible, eg build a skyscraper, a dam, a (big) bridge or alternatively be the CEO of a company.

Reflecting on work further, a quote from Emery (1980) from his work on mainly technical organisations:
"At the heart of the traditional paradigm of work is the master/servant relation. Logically, this is a relationship of asymmetrical *dependence: the servant is dependent on the master for a job. As far as the master is concerned the servant is a redundant, replaceable part. From this relation the notions of managerial prerogatives and the right to hire and fire flow naturally. Over the past 15 to 20 years a new paradigm has emerged. It is a relation of* symmetrical *dependence, a relation of cooperation within work. It expresses a refusal to accept the role of servant in a master/servant relation. It accepts, however, that workers are often able to do their work better with good management and that management can do nothing without the workers."*

If we consider engineering education as described earlier in the construction site metaphor in the light of this shift in the workplace – on the one hand, the role of the educator in the construction site is the master (I know what you need to know to be able to work as an engineer) with the students as servants (willing recipients waiting to be filled up with knowledge). On the other hand, when graduates enter the workforce they are expected to form co-operative relationships and as new professional engineers to work on new and novel projects, the things companies can't solve for themselves – there is a huge cultural shift required of the graduate from viewing themselves as a servant of the system to a vital member of a co-operative exercise.

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Some trends in the nature of engineering problems

Even though we cannot predict the future or its problems directly, we can consider the trends in the nature of engineering problems. Some of these trends have already been alluded to in the introductory paragraphs, the extension of engineering beyond the technical into considerations of the environmental, economic, financial, governance (who makes the decisions and how) and other social issues making the nature of the issues to be dealt with more complex and interconnected.

As described by the Association of University Leaders for a Sustainable Future (1990), the Talloires Agreement, this increasing complexity is compounded by the nature of the environment/context within which the problem solving occurs; the world is becoming increasingly dynamic and turbulent; the nature of the workplace is changing together with what is being asked of engineers. Engineers (and other professions) must bring to bear knowledge from many disciplines, work in multi-disciplinary groups and ways, move beyond this to transdisciplinary thinking, assemble and create knowledge to define the nature of the system, how it is networked and what problem resolutions might be possible.

We have moved beyond the traditional engineering problem to complex puzzle solving – not like a jigsaw puzzle where you know you have the pieces (eg design a bridge) but like a puzzle where you have some of the pieces and you need to seek new pieces to fit (eg design a replacement for a city).

One of the most significant questions now is – what is the problem? What are its components? Who will be affected? What "solutions" are possible? What criteria will we use for choosing among them? How will we trade-off different types of criteria?

We have put "solutions" in quotes because we are increasingly faced with perennial problems that can only be managed, not solved. Each new "solution" has side effects that ripple through the system (eg the effect of building a segment of freeway within an existing road system).

A revolution

All of the earlier commentary suggests that we need a new form of engineering – a revolution in engineering, and a concomitant revolution in engineering education. This new form may in some ways be re-visiting the past before the maths and sciences became the "centre of the universe" of engineering and more heuristic methods were used. We are re-visiting the past in some senses but we are in quite a different position in relation to information than we were in the past: we have a huge amount of information available on-line and in libraries across a huge range of topics to inform the puzzle solving. What we need now are techniques to enable engineers to be able to effectively chose appropriately and use this material in innovative ways to manage the problems of the future. We will use an example of a new program to "show" something of the form of future engineering education and by implication future engineering.

Master of Sustainable Practice – a strawman design

Let's look at the issue of sustainability and education within RMIT University as an example of creating a new educational environment for the future. The Global Sustainability Institute was established to develop relationships with external organisations and to provide consultation and access to expertise in sustainability issues from within RMIT. RMIT has many pro-

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grams, many of which purport to consider some aspects of sustainability. RMIT has signed the Tailloires agreement with other universities to embed sustainability into the University, and it has policy statements in Teaching and Learning and other strategic documents to embed sustainability within its programs. RMIT is also undergoing extensive program renewal activities based on the need to build student capabilities, as well as undertaking a strategic approach to *Dissolving the Barriers* between the parts of RMIT as well as between RMIT and the community within which it resides (RMIT, 2002). However, many academics agreed at a recent Sustainability Forum (2003) that RMIT has no integrated approach to sustainability.

The proposal for a Master of Sustainable Practice recognises that professionals of all kinds (engineers, nurses, scientists, accountants, managers, educators) are coming across emerging significant issues of sustainability in their work, their professions and in their private lives. Organisations are also having to deal with issues of sustainability because the Triple Bottom Line is changing Quality Systems (eg ISO 9001) to Environmental Management Systems (ISO 14001), Occupational Health and Safety Regulations both nationally and internationally, and accounting and governance standards. Also, even if organisations are not taking up the challenges via these regulatory and standards routes, their customers and suppliers are asking for changes. A telecommunication product and service supplier recently stated that "one of our customers (another telecommunication service retailer) has product buyback in their standard global contract. We will have to deal with this issue in the coming years".

Some professions, companies, industries, governments and communities' issues of sustainability are clearer than others, but it is becoming evident that sustainability issues will be a dominant part of risk management strategies within organisations over the next decade. Organisations also want the development of their professionals to benefit them in the shorter term, so the focus on emerging issues of concern to the organisation within a Masters program is seen as highly beneficial and of increasing relevance.

In the Master of Sustainable Practice, participants form groups according to their interests and concerns. Inquiry-based learning or problem-based learning will be the dominant educational model. The objective of the first semester of the Masters program is to answer the question "What information, knowledge, skills or practice do I need to be able to develop possible solutions to or manage our concerns?" On this basis, the participants, together with their mentor, design a program drawing on the resources of the University and the wider community of practice. Each semester, they can tailor their experience of the program by choosing to continue project work and/or to do undergraduate or postgraduate courses from within the University or from elsewhere.

Not only will this program take a range of professionals from nursing, engineering, accounting, management, building, designing but it will also encourage practitioners with experience in sustainability to participate: to publish their work and add it to the broader knowledge base and also to mentor less experienced participants. Progress over the program is truly towards *mastery of sustainable practice*, not just acquisition of knowledge fragments.

We recognise that a key challenge is to engage busy practitioners in this type of group-based work. It is likely that we will concentrate contact time into intensive weekend short courses that can be experienced standalone if required (for those who want to sample the program or a particular problem). For this type of session, learning studios, equipped with group meeting spaces, internet access and refreshments, can simulate the type of highly productive environ-

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ment to which most practitioners are now accustomed. Such facilities are in contrast to many of our existing undergraduate teaching spaces.

This is a strawman design – it is intended to provoke discussion through the program development process steps of Intention to Develop, and Strategic Business Case within the University across the portfolios (super-faculties) and schools, and to take with us when we step out to engage potential stakeholders. We intend to use Search and Design Conferences (Emery, 1994) to bring together the stakeholders (from within the University and business, government and community organisations) to develop and design the 'real' program.

The Search Conference is a form of active adaptive planning, including scenario planning. The key questions asked are

1. What are the *emerging trends* in the broad macro environment?
2. What are the emerging trends in the arena of sustainability, practice, universities?
3. Given these emerging trends what is the likely future for organisations, for professionals?
4. Weaving together the trends and the likely future what is a desirable and feasible program?
5. What are the manoeuvres that will be required to make this program happen within the dynamic environment?

The Search will be followed closely by a one-day Design which will develop the meta-design for the program, based on the material from the Search. These Conferences will provide invaluable assistance to the program developers by developing the logic for the more detailed rationale for and design of the program.

Challenges

There are many challenges lying ahead of us. We may need to provide new teaching spaces (rather than lecture theatres we will need learning studios). But on the other hand, there are new ways of looking at learning and teaching that may provide some innovative models. For example, Leon Van Schaik (2003) describes early on-line education moves as being about 'massification' and says that

"*those providers who have begun after some decades of failure to succeed in online education have come to realise that their role is not to deal with individual learners, beaming curriculum at them in sophisticated and increasingly amenable ways, but to create* ***virtual learning communities*** *in which students interact with each other around a topic, within a discipline.*

*It is also evident that there is no such things as generic, one size fits all, learning community or community of practice in research or enterprise. Disciplines proceed by their own public behaviours and acculturation to modes of discourse is as much what the learning is about as it is about curriculum. The Boyer emphasis on 'scholarship' is about enhancing the learning experience of students by returning academics to their roles as scholars, and removing them from their roles as managers of curriculum. The focus on learning communities and their rituals is at the core of the production of knowledge…****The challenge of helping people to develop or find communities of practice appropriate to their goals in learning, research and enterprise drives the virtual concourse concept.****" This virtual concourse concept and finding communities of practice may allow us to develop new teaching 'spaces'.*

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We must also deal with more insidious, institutionalised problems. We will now return to the thorny problem of the existing University system within which these programs reside.

Students already experience our curricula as fragmented into individual courses (subjects) with little to connect them. We compound this problem by then fragmenting each course into two or more teaching periods each week. A timetable revolution will be required at the undergraduate level. This is possible for a small program like the Master of Sustainable Practice with its cohort of 25 participants per semester, but what about the thorny issue of the vast majority of programs going on within an existing university which have been 'designed' for the traditional "chalk and talk' technique (lectures plus tutorials)? For undergraduates, each course should be taught on one day, with formal classes in the morning and informal, group-based work in the afternoon. One or two courses at any one time should be the norm, rather than the four or more that are normally scheduled. This in turn will impact the learning spaces. Note the interconnectedness of the ideas and how changing one thing may impact on others.

An innovative example of a learning and teaching approach is the USA's National Engineer's Week, Engineering the Future (2003), where young people (Years 7 and 8) from across 34 regional sites participate in establishing visions and plans for a future city. Students use "Top Down" engineering – Research, Development and Design to develop a vision of their completed city using SimCity3000® and then build a section of the model using "Bottom Up" methods to practice Construction, Production, Operation and Management – thus working through the entire lifecycle of an engineering artefact. These may be valuable practice for all engineers to understand the nature of the whole cycle of development and its consequences and they could work with other disciplines to enhance their perspectives.

A big challenge is staff development. We hire academic staff on the basis of their research potential. This encourages staff to maintain an active interest in a small part of the body of knowledge in order to develop an international reputation and win competitive research grants. In this new teaching environment, however, we will ask them to lead and help students to unravel complex, multidisciplinary problems, for which their technical expertise will be just a small part.

On the positive side, such problem solving will require teams of academics to work together – across traditional disciplinary boundaries – bringing together students from different disciplines. What a revolution! From this, we should see a new focus on collaborative, multidisciplinary research.

This is *real* student centred learning. Assessment must be adapted to demonstrate that a student is capable of doing the range of tasks that engineers may be called on to do. It is no longer good enough that they can answer 30 minute questions on some technique that they have practised many times before the exam.

A huge advantage that we have is the ready accessibility of information via the Internet. This relieves the pressure that would normally build on libraries and lecturers in the past.

A big question is "do the students who are attracted to engineering" 'get' this type of learning environment? Will they stay away (or go elsewhere)? Do engineering students want to develop their own communities of practice? Have they been asked whether they want to develop

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such communities of practice? Will we really get a change of culture in engineering education (Engineers Australia, 1996)?

Conclusion – the vision

We face a world of accelerating complexity.

- To prepare our engineering students for this new world, we continue to emphasise the importance of mathematics and the physical sciences, at a time when the economic, ecological and social dimensions of problems seem much more challenging.
- We continue to rely on linear, bottom-up teaching processes when graduates must work top-down and bottom-up, in and out.
- We emphasise individual performance as the only true measure of what a student "knows", when a graduate's ability to network with others and contribute to teams of knowledge workers will be more important to them and to their organisation.

We have suggested the need for a revolution in engineering education. After the revolution:

- Project and problem-based programs will be the dominant paradigm allowing students to learn by *experience*.
- These projects will develop key theoretical understanding in *all disciplines* (not just the physical sciences and mathematics).
- Although a specialist lecture and a workshop in this skill or that idea may be useful, *resource-based learning* will be the norm, allowing students to move as quickly as they can through their projects, rather than following lock-step with the rest of the class.
- Staff will model *reflective practice* (Schön, 1983, 1987) for the students so that students become self-adaptive, lifelong learners.
- Students and staff must become explicitly aware of their own learning and working styles, developing learning communities and communities of practice.
- Students will develop their own view of what they want and need to learn to be able to practise engineering – with a regular performance review to guide their progress.

Through this process we will develop a revolution in engineering to meet the challenges of our rapidly changing future.

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Mathematics, Engineering and Education: Pathways for the future?

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Abstract: *Engineering education is undergoing positive change, embracing social and environmental issues, with Project (or problem) Based Learning (PBL) beginning to play an increasing role in replacing traditional lecture/tutorial passive learning. This application oriented emphasis in engineering education means that the mathematics component of engineering undergraduate programs will need to reflect this change as well. The increasing utilisation of appropriate software systems and hand held technology (with computer algebra systems (CAS) capability) to enhance learning in engineering education indicates that there is an urgent need to undertake a major review of the mathematics education of engineering undergraduates. It is argued that the content, delivery, assessment and the role of technology in the mathematics component of engineering education should be critically reassessed. This reassessment is necessary to ensure that the mathematics education provided for engineering students is compatible with the changes taking place in modern engineering practice. This paper will outline several possible pathways for cooperative effort to achieve a positive contribution to the desired learning outcomes in mathematics for modern engineering education.*

Keywords: *Engineering, mathematics, review*

Introduction

Changes taking place in engineering undergraduate education have been given impetus by the Institution of Engineers Review Report (1996). These changes have also been reported on by several sources, for example, Webster (2001) and Fuller (2000), with particular reference to the impact of the changes on the mathematical education of engineering students.

Three possible pathways for improving the contribution that mathematics can make to the enhancement of engineering education are outlined. The pathways listed are the result of a major review of the mathematics component of engineering undergraduate programs at a regional university. The review involved discussion with engineering educators, recent engineering graduates, students, engineering mathematics educators and a literature search.

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The Pathways

A review of the emphasis on content and delivery of mathematics courses in engineering programs

"In the past years there has not been a direct relationship between the mathematics courses provided for the engineering programs and other (engineering) courses taught where the mathematics content could be used". This statement was made by a project engineer in response to a survey of recent graduates of engineering where input was sought on the relevance of the mathematics courses in their degree programs to their current employment. This respondent referred to what he felt was the missed opportunity to link a mathematics course with an engineering course where the mathematics was particularly valid. Both courses were taught in isolation to each other and so the opportunity to set the mathematics within the context of engineering applications was missed. At a Forum on Mathematics in Project Based Learning in Engineering Education (Fuller and Hadgraft, 2002) it was agreed that more time in mathematics courses should be devoted to developing understanding of concepts and less on tedious manipulation which can be efficiently carried out by relevant technology. At the same Forum, joint teaching sessions involving both mathematics and engineering staff were perceived as a means of setting the mathematics in an engineering context and so contributing to positive learning outcomes.

It is vitally important to engineering students, especially first year students, that the mathematics courses are perceived to be an integrated part of the whole engineering program. (Clayton 1995). However whilst joint teaching projects can certainly set mathematics in an engineering context it is crucial that the underlying concepts in mathematics should be developed by dedicated mathematics educators. At the same time the development should avoid too much rigour if the motivation to learn is to be maintained. Ward, (2003), argues for a dramatic move from 'traditional' teaching of mathematics to engineers and scientists "Don't teach mathematics in the way we have for 50 and more years … In essence why learn a story by heart if at the press of a button, the complete story, with every comma, full stop, sentence and paragraph, can be heard again and again" (p.43). Ward proposes a greater role for user-friendly symbolic mathematics packages. What is required is more willingness to experiment with different teaching methodologies and presentation methods to address the different learning styles of the students. Experimentation as described by Eriksson and Gavel (2003) in setting up a reformed discrete mathematics course indicates that the main goal of the reformed course is to develop proficiency in computational skills, conceptual understanding, modelling, reasoning and communication techniques. This was achieved by innovative changes to the assessment process which included weekly group tasks, individual projects and group modelling projects coupled with oral presentation. These approaches have been tried before but a real effort was made to make the assessment procedures part of the learning outcomes of the course.

So we suggest, for the first pathway, that a new spirit in the content and delivery of mathematics for engineering programs is due. To achieve this spirit we need to:

- Address the background level of new entrants – it is vital that they have a thorough understanding of the basic concepts of mathematics. Foundation courses may be necessary for some new students based on a skills audit of their commencing levels of competence. If foundation courses are applications oriented and seen to be part of the total engineering program then, according to input from students, they will much more likely to succeed.
- Replace the tedious "hand" operations in mathematics by relevant technology and concentrate on developing in depth understanding of the concepts and their applications.

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Provide opportunities for greater integration of the process of mathematical modelling into engineering mathematics

Mathematical modelling in undergraduate mathematics has received increasing attention over the past 10 years. High school mathematics syllabuses in some states emphasise the motivational aspect of mathematical modelling. The Senior Mathematics B syllabus in Queensland (2001) is an example.

To expect students to formulate mathematical models when their competence in mathematics may well require strengthening can often lead to frustration and loss of motivation. It is therefore suggested that the development of the modelling process be gradual and guided but be a definite framework for engineering mathematics. In the final year of an undergraduate program it is envisaged that mathematical modelling would include team projects involving mathematics and engineering staff sharing the presentation.

Apart from being able to apply mathematics to real problems, modelling also provides an ideal opportunity to improve the communication and reporting skills of the students. Kent and Noss (2002) imply that there does not yet appear to be a generally accepted term for the kind of mathematical understanding that modelling represents. They maintain that the knowledge gained is not of mathematics but about mathematics, at a meta-level. Mathematical modelling in engineering mathematics provides opportunity for students to see mathematics in application.

The ability to formulate a mathematical model of a given physical situation, to solve the model, interpret the solution and refine the model, is stressed as being a key aspect of the mathematical development of the engineer in the document, Mathematics for the European Engineer (2002). However to enable students to make progress with the process of mathematical modelling it is vital that they have a thorough knowledge, not just a 50% pass rate, of the foundation concepts developed in the first year courses.

Setting the scene for mathematics to contribute to PBL in engineering education

The momentum for engineering education to embrace Project Based Learning (PBL) has increased since Don Woods (1994) first used the term, but there are universities which have included or project based learning in engineering education for some years. An example is Aalborg University in Denmark where PBL has been part of the engineering programs for over 25 years.

A special issue of the International Journal of Engineering Education (2003) is devoted to PBL in engineering education.. Questions raised in the Editorial to this special issue include: “How much PBL is expedient for a degree course, how does PBL fit into our established concepts of academic studies, and how does PBL affect the performance of brighter and more average students”. The second of these questions is pertinent to the challenge of integrating mathematics into PBL in engineering education. This is a challenge for both mathematicians who teach engineering mathematics and engineers who teach in the PBL mode. De Graaff and Kolmos (2003) discuss the curriculum structure in which the subject (course) disciplines are integrated through case studies, the learning process is facilitated by the lecturer and assessment is made compatible with the learning objectives. The emphasis is testing for competence in applying the course matter rather than testing for factual knowledge.

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In this special edition there is a serious omission! No paper addresses the challenge of integrating mathematics into PBL in engineering education. However Bowe, et al (2003) of the Dublin Institute of Technology describe how PBL can be used to teach physics to engineering students. These authors warn that the students do require a sound body of mathematical skills and that facilitation of the learning is a key feature of PBL. Tutors must be aware that students are only in the early stages of self directed learning. Using PBL processes to teach physics is, possibly, similar to teaching engineering disciplines by PBL. However in the case of mathematics, the main challenge is that the students need a deep understanding of the first year concepts. If an engineering problem requires knowledge of eigenvalues, for example, this topic cannot be fed into the PBL project without the student having a sound prior knowledge of matrix algebra. This is an example of one of the main challenges in having mathematics contribute to PBL in engineering education.

There is no doubt, for the development of a new spirit in engineering mathematics, a much closer cooperative effort between mathematicians and engineers will be required to make a positive overall contribution to engineering education.

A possible start to achieving this cooperative effort is the formation of engineering mathematics working groups consisting of staff from both engineering schools and mathematics schools and also student representatives. The review of mathematics in engineering then becomes an ongoing and mutually beneficial joint project for all stakeholders. Greater representation by engineers at engineering mathematics conferences and mathematicians at engineering education conferences could also contribute to generating the change of spirit in the mathematics education of engineers.

There are moves for mathematics to be taught to engineers as an integrated curriculum. An example of this is the Principia Program at the Institute of Advanced Studies in Technology in Mexico. This excellent example of an integrated teaching model is described in a joint paper (2003) by the Dean of the Engineering School (Delgado) and the Chair of the Mathematics Department (Santiago). An integrated curriculum of this type could make a positive step to addressing the challenge of providing a mathematics service for PBL engineering education. As Daniel Goleman (1998) points out in his latest book, “There is a crucial difference between *declarative* knowledge, knowing a concept and its technical details, and *procedural* knowledge, being able to put those concepts and details into action” (p242). It is the blend of declarative and procedural knowledge resulting from participation in engineering mathematics which can be achieved by cooperative and sustained effort by engineers and mathematicians which will determine the future blend of mathematics, engineering and general education in the development of the engineering curricula of the future.

A Summary

Currently the majority of engineering mathematics courses are taught as mathematics first, applications in engineering courses later. There is still considerable time spent on tedious, hand worked operations rather than utilising that time to reinforce in depth understanding of the basic concepts of mathematics. Researchers publishing in the literature, call for greater use of technology, and the integration of mathematical modelling into mathematics courses. Student feedback indicates that more positive learning outcomes are achieved if assessment truly reflects the learning outcomes and courses are presented within the context of engineering applications.

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We believe that the three pathways as outlined, are but some of the avenues to be explored for the engineering mathematics community to enter into greater cooperative dialogue and more joint projects so that the mathematics component of engineering degree program can be, even more, an integrated part of the education of engineering students. The authors do acknowledge that there is positive work being undertaken in some universities around Australia, so the challenge is to increase the momentum of this positive work by creating these pathways.

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Designing Flexible Entry Pathways to Mechatronics / Robotics Profession

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***Abstract**: This paper is a short review of an OTTE funded innovation project, called Mechatronics / Robotics Programs Design, conducted in 2003, by a project team from RMIT VET Engineering. While creating new programs, the team has followed MERSITAB's most recent proposals for different engineering professional levels. In addition to that, the team has specified requirements for the profession, based on the information gathered from a number of industry visits. An Industry Advisory Board was established to monitor and guide project development. The Board had representatives from the other RTOs and government institutions alongside with industry members.*

As a result, new programs, Diploma and Advanced Diploma were designed to deliver competencies from the National Metal and Engineering Competency Standards Training Package. First of all, sets of competencies were selected for each program. Program structures were designed and courses i.e. subjects specified. Mapping of the required competencies to the learning units, subjects, was done. Course teaching and learning material was developed. The pathway to a degree in Mechatronics / Robotics is open. There is more that should be done and any program is subject to constant evaluation, renewal and improvement. Currently, applicable standards are under construction, and are also subject to change and improvement.

Depending on prior knowledge and skills of prospective students, optimal educational pathways were specified by this project. Students with different trade qualifications, as well as high school graduates, could find their pathway to Diploma, Advanced Diploma and finally Degree in Mechatronics / Robotics. Employees and prospective students could upgrade skills and knowledge any time during their professional life. Graduates from any of these pathways are welcomed by different industries and/or government institutions, according to their needs.

***Keywords**: Mechatronics, Robotics, Program*

Introduction - Innovation Projects

Mechatronics / Robotics Project was an Innovation Project, funded by OTTE, in 2003. RMIT VET Engineering, now SIEBS (School of Infrastructure, Electrotechnology and Building Services, SET – Science, Engineering and Technology Portfolio), was granted a set of Innovation Projects for 2003 in the following areas:

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- Advanced Manufacturing,
- Building Services and
- Aerospace.

Mechatronics / Robotics project was a part of the Advanced Manufacturing projects group. That group also included CAD++, Photonics, and Process Control. School's staff members participated in different projects based on their expertise. Apart from the staff, other VET Engineering resources were used as well, like labs, offices, hardware and software. As a tool, MS Excel has saved the project team a valuable amount of time, while MS Project was used for project management.
Industry partners provide their support for programs' delivery by offering their equipment and labs.

Project Objectives

According to the initial project plan, and some revisions done in the later stages, the main objectives were to develop new programs, resources and/or innovative learning environments to deliver competencies from the National Metal and Engineering Competency Standards Training Package. Programs were intended to cover post trade, Diploma and Advanced Diploma in Mechatronics / Robotics.
In the process of design, the team planned to develop new comptencies, if necessary, and submit them to the appropriate bodies i.e. MERSITAB, for acceptance.
Consultations with industry leaders and appropriate Training Board(s) were conducted in order to facilitate development of the required competencies.
Competencies from similar training packages, electrotechnology, were also considered.
Development of learning resources, and employing enterprises in reskilling and upskilling the workforce for new technologies and business processes planned to be the next step.
As an intergral part of all these activities, the plan was to develop staff capabilities for program and curriculum design.
Finally, the aim was to deliver appropriate and suitable industry-focused training, when and if requested.

Design Phase

The team members have established contacts and have visited numerous industries. In addition to that, an Industry Advisory Bord (IAB) was set up with representatives from many companies and institutions, including: ABB, BOSCH, Box Hill Institute, Holden, MERSITAB, NMIT, RMIT, Silcraft, Simplot, Swinburne, Unidrive, Engineering Skills Training Board, etc.

Project activities were performed according to the MERSITAB Implementation Guide, which states that, in order to implement competency standards, one should follow a five-step process, as following: consultation, skills analysis and redesign, matching skill requirements to the competency standards, skills audit and implementation (MERSITAB, 1999).

Having done a number of visits and consultations, collecting information about industry needs, the team has performed the following tasks:

- Defined pathways from trade, or after finished high school, to the degree in Mechatronics / Robotics.
- Designed competencies for Diploma level according to National Metal and Engineering Competency Standards Training Package.

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- Designed a program structure for the Diploma in Robotics/Mechatronics, i.e. specified courses (subjects) and done mapping of learning units to the competencies.
- Designed a number of course guides, according to the project team expertise.
- Designed a number of course materials, according to the project team expertise.
- Designed a set of competencies for the program of Advanced Diploma in Robotics / Mechatronics, using the latest standard specifications announced in November 2003.
- In order to gain feedback, communicated the draft competencies set to the industry.
- Planned to use Internet, i.e. VET Senate web site for communication and used email instead, since web activities were behind schedule.

Industry view and flexible pathways

Currently, MERSITAB investigates the feasibility of two separate Diplomas in Engineering, according to the web site (April 2004). The board is focused on advanced trade and technical skills. These should articulate into a single Advanced Diploma in Engineering. In a multidisciplinary area such as Mechatronics / Robotics, we have found that the industry would be satisfied with three streams, instead of only two. According to the team's experience, the industry needs the following qualifications for their employees in the robotics field:

1. With electrician licence (4 years + 2 for Diploma / Advanced Dip.)
2. With mechanical licence (4 years + 2 for Diploma / Advanced Dip.)
3. With no licences (2 years for Diploma / Advanced Diploma)

Following that, there is a need for three streams of Diploma and Advanced Diploma courses. Companies using robots will accept type 1 and 2 graduates only, or mostly, while government institutions, robot making or selling companies, could accept the third-type qualified employees. The last option should be a strait forward pathway to the degree in Robotics and should be on the same engineering educational line as other engineering degrees, achievable in 3, 4, or 5 years of tertiary study, performed after high schooling.

Activities that a Robotics Diploma graduate should be able to perform in industry are Troubleshooting, Maintenance, Installation, and Upgrading… Matching those skill requirements to the competency standards was the most important task performed.

Competencies set selection

The Project team spent a large amount of time designing a **Competency Units Set for Diploma**. This task has taken a long time since the standard specified the exact number of points for each level of qualification, as well as prerequisites and excluding units of each of the competencies.

As mentioned above, team followed the Competency Standards Implementation Guide, and according to the standard Design of the Competency Units Set is in Step 3, which was: Matching skill requirements to the competency standards. The team has produced a draft list of competency units, which was circulated to the members of the Industry Advisory Bord. After collecting their comments and recommendations the final set is produced and it is shown in Table 1.

Award classification level was considered with the objective to achieve recommended points:

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- For Diploma level (C5) it is defined as 60 additional points above C10 level.
- C10 level is 96 points.
- Out of 96 points 76 must be Band A and 20 Core 1 points.
- Additional 60 points must be achieved with
    - 16 Core 2 points and no more than
    - 24 Band A points,
    - No less than 44 Band A points.

Selected set of competency units has to be a closed set. This means that all prerequisite units for any selected unit must be in the set as well. In addition to that, all excluded units for any selected unit should not be in the set. At the same time, and most important, the units set has to address all competencies relevant for that profession and the number of points has to be exactly as defined by the standard for engineering professions.

Foundation Competency Units

Unit Code	Points	Competency Unit Title	Prerequisites
1.1F	0	Undertake interactive communication	
1.2F	0	Apply principles of occupational health and safety in work environment	
1.3F	0	Apply quality procedures	
1.4F	0	Plan to undertake a routine task	
Points Σ	**0**		

Core 1 Competency Units

Unit Code	Points	Competency Unit Title	Prerequisites
2.1C12	2	Apply quality systems	
2.2C11	2	Organise and analyse information	
2.3C11	2	Operate in a work based environment	
2.4C11	2	Assist in the provision of on the job training	
2.5C11	2	Measure with graduated devices	
2.6C10	4	Plan a complete activity	
2.7C10	2	Perform computations (basic)	
2.8C10	2	Perform computations	2.7C10
2.9C10	2	Perform computer operations	
Points Σ	**20**		

Core 2 Competency Units

Unit Code	Points	Competency Unit Title	Prerequisites
2.10C5	2	Write reports	2.6C10
2.11C5	2	Research and prepare presentations and reports	2.2C11
2.13C5	4	Perform mathematical computations	2.7C10, 2.8C10
2.14C5	2	Use graphical techniques and perform simple statistical computations	2.7C10, 2.8C10
2.15C5	2	Operate in an autonomous team environment	2.3C11
2.16C5	4	Interpret quality specifications and manuals	
Points Σ	**16**		

Table 1: Foundation and core competency units set for diploma level engineering profession

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Band A competency units, given in Table 2, specify more specific activities for the profession and less complicated activities comparing to the Band B units, given in Table 3. As it could be seen from the table, some of them have no prerequisites.

Code	Points	Competency Unit Title	Prerequisites
7.24A	4	Operate and monitor machine/process	
7.28A	2	Operate NC/CNC machine/process (basic)	7.24A
9.1A	2	Draw and interpret sketch	
9.2A	4	Interpret technical drawing	
10.4A	2	Enter and change programmable controller operational parameters	2.9C10, 9.2A
10.5A	4	Commission programmable controller programs	2.9C10, 9.2A, 10.4A
10.6A	4	Install machine/plant	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.9A, 18.55A
12.2A	2	Electrical/Electronic Measurement	
12.3A	2	Precision mechanical measurement	
12.4A	4	Precision electrical/electronic measurement	
13.2A	3	Undertaking occupational health & safety activities in the workplace	
18.1A	2	Use hand tools	
18.2A	2	Use power tool / hand held operation	
18.3A	4	Use tool for precision work	18.1A, 18.2A
18.6A	6	Dismantle / repair / replace / assemble and fit engineering components	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.55A
18.9A	4	Levelling and alignment of machines and engineering components	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.55A
18.10A	4	Equipment condition monitoring and recording	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.55A
18.18A	4	Maintain pneumatic system components	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.55A
18.19A	4	Maintain and repair pneumatic system	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.18A, 18.55A
18.20A	4	Maintain hydraulic system components	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.55A
18.21A	4	Maintain and repair hydraulic systems	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.20A, 18.55A
18.22A	8	Maintain / repair / replace fluid power controls	2.5C11, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.18A, 18.19A, 18.55A
18.55A	3	Dismantle / replace and assemble engineering components	2.5C11, 9.2A, 18.1A, 18.2A
18.65A	10	Diagnose and repair digital equipment and components	5.1A, 9.2A, 12.4A, 18.1A, 18.57A
Points Σ	**92**		

Table 2: Band A competency units

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Feedback and redesign

There were a number of meetings that the project team attended and / or conducted in order to gain constant feedback and exchange ideas: Vet Senate meetings, IAB meetings, VET Engineering management meetings, project team meetings and work-sessions, and many informal meetings and discussions within the department and outside, with people from other RMIT departments.

Tables presented here are finalised after feedback was received and adjustments being done. As mentioned, Table 3 shows more complex, band B units, with more prerequisites.

Unit Code	Points	Competency Unit Title	Prerequisites
10.7B	6	Modification of control systems	2.2C11, 2.5C11, 2.6C10, 2.7C10, 2.8C10, 2.10C5, 2.14C5, 9.2A, 12.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.10A, 18.16B, 18.19A, 18.20A, 18.21A, 18.22A, 18.23B, 18.53B, 18.55A
15.12B	4	Maintain / supervise application of quality procedures	
18.16B	4	Analyse plant and equipment condition monitoring results	2.5C11, 2.7C10, 2.8C10, 2.14C5, 9.1A, 9.2A, 12.3A, 18.1A, 18.2A, 18.3A, 18.6A, 18.10A, 18.55A
18.23B	8	Modify fluid power system operation	2.5C11, 2.7C10, 2.8C10, 2.14C5, 9.1A, 9.2A, 18.1A, 18.2A, 18.3A, 18.6A, 18.10A, 18.16B, 19.19A, 18.20A, 18.21A, 18.22A, 18.55A
18.53B	6	Modify fluid power control systems	2.5C11, 2.6C10, 2.7C10, 2.8C10, 2.10C5, 2.14C5, 9.1A, 9.2A, 12.3A, 18.1A, 18.2A, 18.3A, 18.6A, 18.10A, 18.16B, 18.18A, 18.19A, 18.20A, 18.21A, 18.22A, 18.23B, 18.55A
Points Σ	**28**		

Table 3: Band B competency units

A unit description and selection process

As an example, one unit selected for the band B set, **MEM 10.7B**, ***A Modification of control systems***, is given here, while others can be found in the MEM98, MERSITAB, or on the MERSITAB web site:

"This unit covers the competencies required to plan the commissioning procedure, assess the control system performance, adjust the control system, and undertake commissioning modifications. Control loop/system components incorporate all instruments and devices that make up or control a loop/system including sensing devices, control devices, actuator and transducers. Control systems can mean closed or open loop or continuous or step processes. Loops/systems can incorporate the use of pneumatics, hydraulics, electrical/electronics or a combination of these."

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This unit describes with great accuracy what the project team has found in industry, as one of the crucial competencies for the profession. Apart from more obvious units that should be included in the basic set, such as MEM 10.7B, the team has experienced some difficulties in the selection for the Diploma level profession. Other training packages, UTE99 (1999) Electrotechnology and ICA99 (1999) Information Technology, were considered as well. Competencies from the Electrotechnology package are more appropriate to be used. More on Training Packages could be found at. New MERSITAB introduced competencies, in November 2003, have opened wide options and simplified units' selection and accordingly program design. It was a pleasure to design the set and the program for the Advanced Diploma level. In addition to that, agreement is made to enable articulation, i.e. open pathway from Advanced Diploma to the Degree in Mechatronics / Robotics.

Diploma level courses or learning units

The next step was to specify learning units or courses (subjects). Course selection and competency units' allocations are as presented here:

1. Engineering Mathematics, Competencies: 2.7C10, 2.8C10, 2.14C5, Points: 6
2. Applied Electricity 1, Competencies: 2.5C11, 2.13C5, 12.2A, Points: 6
3. Applied Electricity 2, Competencies: 2.5C11, 12.2A, 12.4A, Points: 6
4. Mechanics 1, Competencies: 7.24A, 10.6A, Points: 8
5. Mechanics 2, Competencies: 2.6C10, 12.3A, 18.6A, Points: 7
6. Mechanics 3, Competencies: 18.3A, 18.6A, 18.55A, Points: 9
7. Mechanics 4, Competencies: 18.6A, 18.9A, 18.10A, Points: 9
8. Digital Electronics, Competencies: 18.65A, Points: 4
9. Mechatronics 1, Competencies: 10.4A, 18.18A, 18.22A, 10.7B, Points: 11
10. Mechatronics 2, Competencies: 10.5A, 18.19A, 18.22A, 10.7B, Points: 11
11. Mechatronics 3, Competencies: 18.20A, 18.21A, 18.22A, 10.7B, Points: 11
12. Mechatronics 4, Competencies: 10.7B, 18.23B, 18.53B, Points: 11
13. Robotics 1, Competencies: 18.16B, 18.23B, Points: 3
14. Robotics 2, Competencies: 2.16C5, 18.23B, Points: 5
15. Robotics 3, Competencies: 2.15C5, 18.16B, 18.23B, Points: 5
16. Robotics 4, Competencies: 2.11C5, 7.28A, 18.23B, Points: 5
17. CAD, Competencies, 9.1A, 9.2A, Points: 6
18. Engineering Computing 1, Competencies: 2.3C11, 2.9C10, Points: 4
19. Engineering Computing 2, Competencies: 18.65A, Points: 4
20. Digital Control Systems, Competencies: 18.65A, 10.7B, 15.12B, Points: 6
21. Introduction to Programming, Unit of Competency from Electrotechnology Training Package
22. OHS and Workshops, Competencies: 1.2F, 13.2A, 18.1A, 18.2A, Points: 7
23. Engineering Communications, Competencies: 1.1F, 1.4F, 2.2C11, 2.4C11, 2.6C10, 2.10C5, Points: 8
24. Quality Control, Competencies: 1.3F, 2.1C12, 15.12B, Points: 4

The Number of points collected through this program is 156, which is equal to the total amount recommended by the standard for Diploma in Engineering.

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Advanced Diploma Level

As defined at the MERSITAB site, the Advanced Diploma in Engineering is at the Australian Qualifications Framework level VI, AQF VI, and meets the training and classification requirements for Engineering Associates – Level II in the Federal Metal, Engineering and Associated Industries Award, 1998, C3 wage group level.
Using MERSITAB specification, latest available at the time of project completion, in December 2003 (MERSITAB, 2003), team has designed a set of competencies, communicated it to the members of the IAB and the final revised version of the units set is given in Table 4.

Mandatory Units

Unit Code	Competency Unit Title
14.82B	Apply mechatronics fundamentals to support design & development of engineering projects
23.1B	Apply mathematics in engineering situations
23.3B	Operate and program computers and/or controllers in engineering situations
23.41B	Apply basic scientific principles and techniques in mechanical engineering situations
23.52B	Select and test mechatronics engineering materials
23.62B	Select and apply mechatronic engineering methods, processes and construction techniques
14.42D	Plan and design mechatronic engineering projects
22.1D	Perform engineering activities
22.2D	Manage self in an engineering environment
23.72D	Apply advanced scientific principles and techniques in mechatronic engineering situations

Drafting Units

Unit Code	Competency Unit Title
9.142D	Represent mechatronic engineering designs using manual drafting methods
9.152D	Represent mechatronic engineering designs using Computer aided design

Elective Units

Unit Code	Competency Unit Title
23.2B	Apply calculus in engineering situations
22.3D	Manage engineering resources
22.4D	Manage engineering projects
22.6D	Source and estimate materials
22.7D	Manage environmental effects of engineering activities

Table 4: Advanced Diploma competency units

The team has used draft competencies recommendations available form MERSITAB site. Deadline for comments on draft competency standards units was February 28th 2004.

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Project Outcomes

The project has achieved the following outcomes:

- Industry Network: Industry Advisory Board established and growing. Positive industry support received from ABB, Simplot, Amtil, Silcraft, Unidrive, Bosch, GM Holden …
- Constant communication and feedback from the industry.
- Team members have become members of the VET Senate Committee and volunteered to be members of the Senate Committee's team to develop, and maintain its Web site.
- Cross RTO support is received from NMIT, Box Hill TAFE, and Swinborne.
- Diploma program in Robotics/Mechatronics was designed.
- Competency unit set was designed.
- Courses / Subjects set was designed.
- Mapping of the set of competency units to the set of courses / subjects.
- A number of course / subject guides were designed for Diploma level.
- Teaching and learning material was designed for Diploma level.
- SIEBS already had valuable resources for Mechatronics / Robotics teaching and hopes to obtain more diverse and more relevant VET training resources as a result of this initiative in 2004-2005.
- Advanced Diploma competency set was designed.
- Industry is prepared to participate in the courses delivery.
- Staff capabilities were developed. The project was a great work, learning and management experience for the staff involved.
- The project has produced required outcomes and more.
- Apart from participating in the program design, staff had the opportunity to contribute in the National Metal and Engineering Competency Standards development.

Evaluation

Evaluation was a process that took place at all times during the project process running. In the Gantt chart for this project, **Evaluation of the Project Activities** was a summary task integrating the following subtasks:

- Weekly reporting,
- Attend Metals VET TP Senate Meetings,
- Evaluate Units Set, Internally and Externally,
- Prepare reports for all Innovation projects' meetings,
- All Innovation Project Meetings and Reports,
- Prepare a Project Report for OTTE.

Weekly report was an internal evaluation. For the external evaluation an Evaluation form is produced and sent to IAB members and HE RMIT from time to time, together with Competency Units Set and Units Descriptor documentation.

Recommendations

Instead of conclusions here are some recommendations given to SIEBS and OTTE:

- Continue with Innovation Project activities in 2004.
- Conduct market research in order to predict the number of students interested for the study of Mechatronics / Robotics.

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  - Complete the Program for Advanced Diploma in Mechatronics / Robotics, once MERSITAB endorses the standard in 2004 according to the reviewed timeline.
  - Finalise articulation of Advanced Diploma program into Degree program.
  - Further develop resources for Diploma and Advanced Diploma programs.
  - Engage enterprises in re-skilling and up-skilling the workforce for new technologies and business processes.
  - Introduce new members to the Industry Advisory Board.
  - Continue to participate in the VET Senate Committee activities.
  - Specify and purchase hardware and software resources for the pilot program delivery in 2005.
  - Conduct AQTF approval process for all programs.
- Perform activities to put programs into the VTAC guide for 2005.
  - Perform staff development / training for the new programs delivery.
  - Start with pilot delivery in 2005.
  - Evaluate and upgrade programs after the first year of delivery.

Pathways from Advanced Diplomas in Engineering to Degree in Engineering in current practice involve negotiated agreements between RTOs and universities, which are easier in the case of dual sector Universities, such as RMIT. This is exactly what the project team has initiated. In the future, MERSITAB will try to find ways of facilitating a standardised approach to credit transfer towards university courses (MERSITAB web site).

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Project-based Teaching of Mechanical Design

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***Abstract**: In this paper results of years of experimenting in project-based teaching of mechanical design at QUT are discussed. Group and continuing design project, as well as specifically developed teaching approaches, teaching and learning resources expose students to real-life design problems, shorten the learning curve, and help to develop the whole range of generic skills while studying mechanical design.*

Keywords: mechanical design, group projects, continuing projects

Introduction

Mechanical design is regarded by many as a backbone of Mechanical Engineering. Study of mechanical design requires a solid foundation in the basic sciences and fundamental engineering units such as Mathematics, Dynamics, Mechanics of Solids, Applied Mechanics and Materials. Students are also exposed to some specific engineering areas such as Fluid Mechanics, Thermodynamics, Industrial Automation, and Manufacturing processes. Mechanical design brings together all these units and this makes it one of the most difficult and interesting subjects to teach.

The structure of Mechanical Design units varies from country to country and from university to university. However, the following base prescription seems to be common - Design procedures, Concept development in design, Materials Selection in Design, Design of mechanical components, Machinery Design, and the Design project(s). At some universities these units are supplemented with elective units on Computer-aided Design, Design for manufacture, Tribology, Machine Condition Monitoring and Design Optimisation.

There is a large number of publications, e.g. (Dyn, 1993), (Wales et all, 1974) and even books (Dyn, 2004) on project-based teaching, where individual and group projects are discussed. Authors reviewing available publication, visiting other universities and communicating with colleagues identified some common trends and problems with the use of design projects in delivery of mechanical design units and achieving of teaching outcomes. They are as follows:

- Design projects often have educational nature and do not expose students to real-life problems and operating conditions.
- Complexity of the design project forced some universities to run it as an individual unit.
- Design projects in many cases are individual and do not encourage teamwork, or team-projects do not have individual component and everybody gets the same mark.

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- Mechanical Design units, including Computer-aided Design, often are self-contained and students do not see direct relationship between them and design projects.
- Many universities participate in the Warman Design and Build Competition of the Institution of Engineers, Australia. This competition is arranged on an annual basis and targets second year mechanical students taking the first design unit. In recent years due to increasing complexity of the problem statement for the competition, several universities ran it as a design only competition with only a few selected teams building the device. This undermines the whole idea of the competition.
- In educational design projects students do no get clear understanding of a system approach to design and the life cycle of a product.
- Students lack hands-on experience – at some engineering schools, students completing two or three design units have not seen real gearboxes, only transparencies or illustrations in textbooks.

As a result of these shortcomings, development of generic skills of students studying mechanical design and working on design projects becomes hard to achieve. New approaches to teaching of mechanical design and structuring design projects are required. In the School of Mechanical, Manufacturing and Medical Engineering (SMMME) at QUT, a new structure of design projects has been developed and new teaching approaches have been introduced that overcomes most of shortcomings discussed above.

Structure of Mechanical Design Units and Design Projects at QUT

In the School of MMME at QUT mechanical design is taught in three core units with the following design projects that are an integral part of the unit:

- MMB281 – Fundamentals of Mechanical Design.
  Design project: Design and Build Competition
- MMB381 – Design of Mechanical Components.
  Design project: Gearbox design.
- MMB382 – Design and Maintenance of Machinery.
  Design project: Lubrication project (extension to gearbox design project).

Students that want to gain more in depth knowledge on friction, wear and lubrication can take an elective unit MMB353 – Tribology.

The content of these units is as follows:

MMB281 – Fundamentals of Mechanical Design:

Introduction to mechanical design; System and functional approach to design; Design for sustainability and universal design; Concept development in design; Best concept selection; Review of creative problem solving methodologies; The Theory of Inventive Problem Solving (Ideation / TRIZ methodology); Detail design, fits and limits, surface roughness; Load analysis in design, Free-body diagram (FBD); Computational scheme in design; Modelling and simulation in design; Design for strength (review of stress computations for different load combinations); Determination of forces in gear trains; Shaft design code AS1403; Rolling bearing selection; Sliding bearing design.

This unit is common for most degrees offered by the School, such as, Bachelor of Engineering Mechanical, Bachelor of Technology Mechanical, Bachelor of Engineering Medical, Bachelor of Engineering Management, and from year 2005 for Bachelor of Engineering – Infomechatronics. Students from other schools and faculties can take it as an elective.

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Problem statements for the Warman competition are developed for Mechanical Engineering students and do not reflect the nature of non-mechanical courses. The School is considering in year 2004 to run individual Design and Build competitions for different courses with individual problem statement.

In Warman Design and Build Competition students in teams of four design and construct a device to carry out a certain function. The winner is determined by the highest score calculated using a formula specified in the problem statement. The winning team from each campus goes to the national competition (Australia / New Zealand). Most departments and schools that offer Mechanical Engineering Degree participate in the competition and determine the winner using the score. At QUT the School of MMME introduced special assessment scheme to determine a part of the final mark for the unit, which represents the mark for the Design and Build Competition, and the competition score is a part of the assessment scheme. This assessment scheme encourages development of several generic skills (discussed later). The essence of the assessment scheme is as follows.

The mark for the Warman Competition is worth 20% of the final mark for the Design unit and corresponds to 100 points. To reflect the assessment criteria the following breakdown is used: up to 5 points is given for Scrutineering (one week prior to the competition. 5 points are given only if the device is compete and fully operational). 8 points for meeting specification requirements (zero if the device does not meet specification requirements). Up to 15 points for engineering design (originality of the concept, use of materials, minimum weight, manufacturability, combination of functions). Up to 15 points for construction quality and appearance of the device. Up to 35 points for the performance of the device. Top mark 35 is given to the winning team, other teams get the mark proportional to their score. Up to 14 points are given for written report that each team submits after the competition. The report includes problem definition, idea generating, concept development, design and calculations, modelling, tuning of the device. Up to 8 points are given for assembly drawing of the device according to Australian standards. The drawing has to show the machine assembled, complete with all parts and sub-assemblies identified.

This arrangement facilitates the development of different generic skills. First of all students put to practical use skills gained studying the first Design unit. They apply problem-solving skills to conceptual development of the device. At QUT in the School of MMME about 10 problem-solving methods are systematically taught in the first Design unit, including the Ideation / TRIZ methodology. Students also improve team-building and interpersonal skills. The necessity to write the report encourages them to develop information, communication and presentation skills, including oral, written and graphical. Students choose team members themselves. Often students from different countries and cultural background form a team. It is also common for students enrolled in different Degrees to form a team (e.g. Mechanical and Medical Engineering). This gives them an opportunity to work in a multicultural and multi-skilled team.

These new arrangements with teaching of the first Design unit and running the Warman Competition proved to be successful. QUT team regularly gets in the five best teams at the National Competition.

MMB381 – Design of Mechanical Components:

Materials selection for machine components; Fasteners; Shafts and associated parts; Gear trains design calculations; Drives with flexible elements; Cam design; Springs; Fundamentals

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of lubrication; Frames and housings, Machine components relationship; Clutches couplings and brakes; Design for manufacturability.

An essential part of this unit is a gearbox design project that students carry out in a team of three. Using Genius gearbox selection software from Bonfiglioli Reduttori (the Italian gearbox manufacturer), and from SEW Eurodrive, they select as a team the configuration of a drive for a given machine, and then for an individual operating conditions (individual for every student) they design a gearbox. Students carry out design calculations for gears, shafts bearings and also design a housing for the gearbox. They also systematically study solid modelling software as part of the Design unit (e.g. Solidworks or Solid Edge) and produce a solid model of the gearbox, which has to be attached to the project report.

The benefits of this new arrangement are as follows.
Early students'exposure to gearbox selection software used by industry shortens the learning curve, gives them an understanding of possible conceptual solutions for the drive train from industry leading gearbox manufacturers before they design a gearbox themselves. Necessity to carry out a part of the project work as a team and the rest individually encourages the development of teamwork skills, communication skills and information literacy, especially when they have to work with catalogues and select standard components such as bearings, seals and fixtures. Development of the solid model of the drive train encourages students to put to practical use their solid modelling skills. This could hardly be achievable when solid modelling is taught as a stand-alone unit. 'Real-life' project makes them better prepared for working in industry (see students' responses on the next page).

***MMB382 – Design and Maintenance of Machinery**:*
Design of equipment for specific application (mining, chemical, food processing equipment, materials handling, etc.); Fundamentals of friction and wear; Optimisation in design; Design for reliability; Risk assessment and failure prediction, the use of fracture mechanics for reliability analysis; Machine condition monitoring; Styling and ergonomics; Intellectual property; Quality assurance in design; Engineering ethics.

An essential part of this unit is a project on the development of lubricating system, which is an extension to the gearbox design project that students carry out in the second Design unit MMB381. Students have to identify points in the gearbox that require lubrication, discuss specified operating conditions and what impact they make on lubrication system, select lubricants and methods of their delivery. Students also have to recommend maintenance and condition monitoring system for the gearbox. To facilitate students' study several interactive software packages are used. They are as follows:

- SKF bearing selection software with recommendations on lubrication.
- SEW Eurodrive gearbox selection software with recommendations on lubrication.
- "i-Learn" software for interactive learning of vibration and machine condition monitoring (developed by Mobius Ltd). It has several modules including lectures, transmission modelling, signal processing, and case studies on machinery failure.
- Innovative WorkBench software based on TRIZ methodology for creative solving of engineering problems (developed by the Ideation International Inc., USA, http:\\www.ideationtriz.com).

These software packages are available for students in the Design Studio during design tutorials and in computer classes. Examples of application of the software packages will be given in the following section.

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The Design Studio has been developed to carry out tutorial and practical sessions. In the Design Studio numerous gearboxes are put on display (some of them are sectioned), demonstration and test rigs built through final year projects (see figures 1, 2, 3). Students have an opportunity to combine theoretical studies with practical exercises and gain hands-on experience working with modern real equipment, such as gearboxes. Some of the demonstration rigs and mechanical components have been donated to the School by private companies, e.g. BMW Australia, SEW Eurodrive Ltd., MEN Australia Ltd and ETA Ltd.

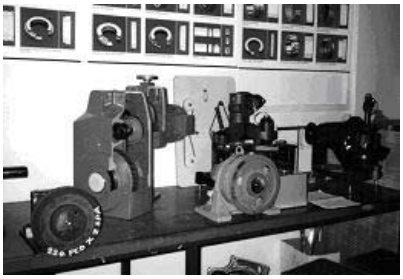


Figure 1: Sectioned gearboxes

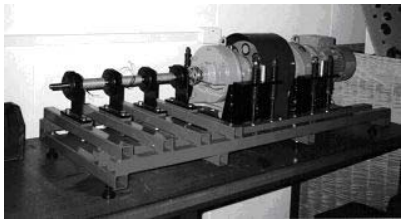


Figure 2: Cyclodrive test rig

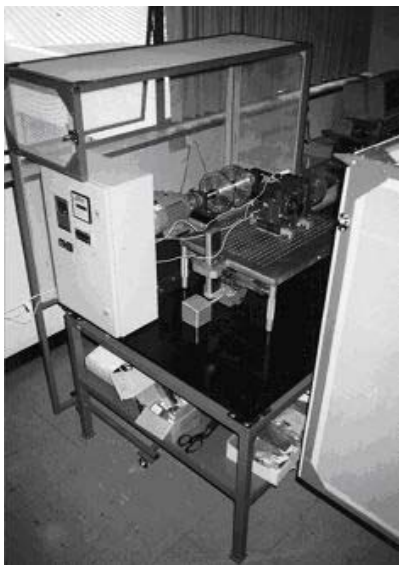


Figure 3: Machinery Fault Simulator for modelling of mechanical faults

MMB353 – Tribology:

Origin and magnitude of dry sliding friction; surface characterisation; Wear types; Lubricant types; Additives in lubricants; Lubricant selection; Types of lubrication; Design of sliding bearings (thrust and journal) using fluid film theory; Lubrication of gears, rolling element bearings using elastohydrodynamic lubrication principles; Application of lubricants; Use of rapidly biodegradable lubricants; Case studies of industrial component failures.

Tribology is an elective unit and is taken by about 1 / 3 of the third year cohort. It consists of a series of lectures, tutorial and laboratory sessions. The School of MMME has a wide range of tribology related equipment and students are encouraged to use it. Much of this equipment has been designed and built by students undertaking tribology projects either in groups or individually. Examples are journal bearing rig, seal testing rig, piston ring – cylinder liner lubrication test rig, wet clutch test rig, elastohydrodynamic lubrication rig (see Fig. 4 and 5).

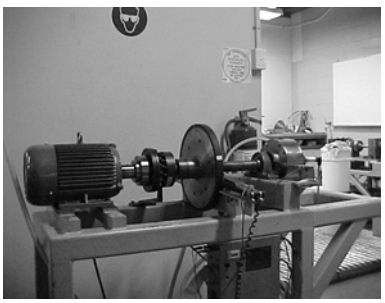


Figure 4: Wet clutch test rig

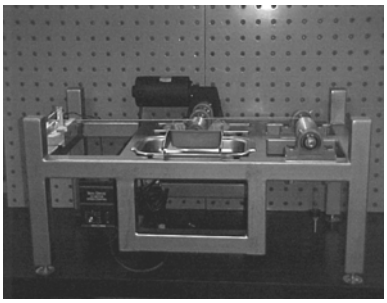


Figure 5: Lubrication test rig (Wire on drum test rig)

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The new arrangements in teaching of Mechanical Design and continuing projects have been highly welcomed by the students. Below some students' responses are placed.

> "I am writing to give you some feedback on design units.
>
> I have found the units mmb381/mmb382 to be the best learning experiences of the units I have covered at university.
>
> MMB381 was good as it incorporated the 3D modeling of Solidworks, which I have found to be a very useful tool. The gearbox design project, which involved 3d modeling, was very interesting and a 'real life' project. On work experience this year I received a similar project which required recommending a gearbox specification for a given power requirement of a coal conveyor.
>
> MMB382 was useful as we were able to continue on our gearbox design project from the previous unit and develop a lubricating system. Industry visits to the Safety department also gave us a very strong message on the necessity of workplace safety.
>
> I have enjoyed the integration of many fields and people in these units as we usually just cover one topic in other units. On top of these additional fields I have found the core topics covered to have given us a good understanding of mechanical components."

> "I have just completed a 12 month (paid) work experience contract with Holden Ltd in Melbourne as a student mechanical engineer. I was assigned to Powertrain Reliability section...
>
> I would like to say I found both design subjects 1 and 2 highly beneficial to the work I carried out during my time at Holden. I especially found the gearbox project for the 2nd design unit gave me a good grounding in both how the power is transmitted through the gearbox but also why and how certain design decisions are made. I have just begun design and maintenance of machinery and this is highly relevant to the work I was performing at Holden. I believe to produce good engineers the university needs to take a more practical focus as I found I relied more heavily on the practical - "real world" application, which your design courses address."

As is seen from students' E-mails, they appreciate 'real-life' design projects and highly practical focus in teaching of Mechanical Design and Tribology at QUT. Students' evaluation of design units has been very encouraging with average marks above 4.5 out of 5.

Teaching and Learning Resources

A variety of teaching and learning resources have been developed and made available for students to support project-based teaching of Mechanical Design at QUT. They include:

- Course notes for all three design units that are available from the Design Web-site and until 2002 were available in hard copy from QUT bookshop (Kosse, 2000).
- Course notes for the module on Fundamentals of Friction and Wear Hargreaves, 2001) that are available from the Design Web-site.
- A book on fundamentals of lubrication Hargreaves, 1995), is available from QUT bookshop.
- The Web site of the Department of Industrial Relations of Queensland Government with standards on OH&S and Risk Analysis (http://www.whs.qld.gov.au/advisory/index.htm).
- Design standards SAA HB6 – 1991 (Standards Australia, 1991) in hard copy that are available for students in the Design Studio.
- Standards on technical drawing (SAA HB6 – 1991) that are available for students in the Design Studio.
- Access to Australian Standards online from the Design Studio.
- Hard copies of catalogues from gearbox manufactures as well as on-line catalogues.
- Tutorials on different design topics with solved examples that are available for students from the Design Web-site.
- The Design Studio with numerous demonstration and test rigs, posters and networked computers that provide access to on-line teaching facilities.

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- Different textbooks on mechanical design are available from QUT library.
- Numerous specialised interactive software packages to assist students with group projects and individual study. In particular:
  - Innovative WorkBench for creative problem solving.
  - "i - Learn" for interactive learning of vibrations and machine condition monitoring.
  - Genius software from Bonfiblioli Reduttori on gearbox selection.
  - SEW Application from SEW Eurodrive on gearbox selection.
  - SKF software on bearing selection.
  - "Exact" software package on maintenance systems.

These teaching and learning resources provide excellent facilities for students' learning in groups and individually and for working on design projects. Some examples of the use of interactive software packages are given below. Students working on a gearbox design project using Genius software from Bonfiglioli Redutori (Italy) select a concept of the drive (from up to fife variants) and get a printout of general layout with overall dimensions (see Fig. 6).

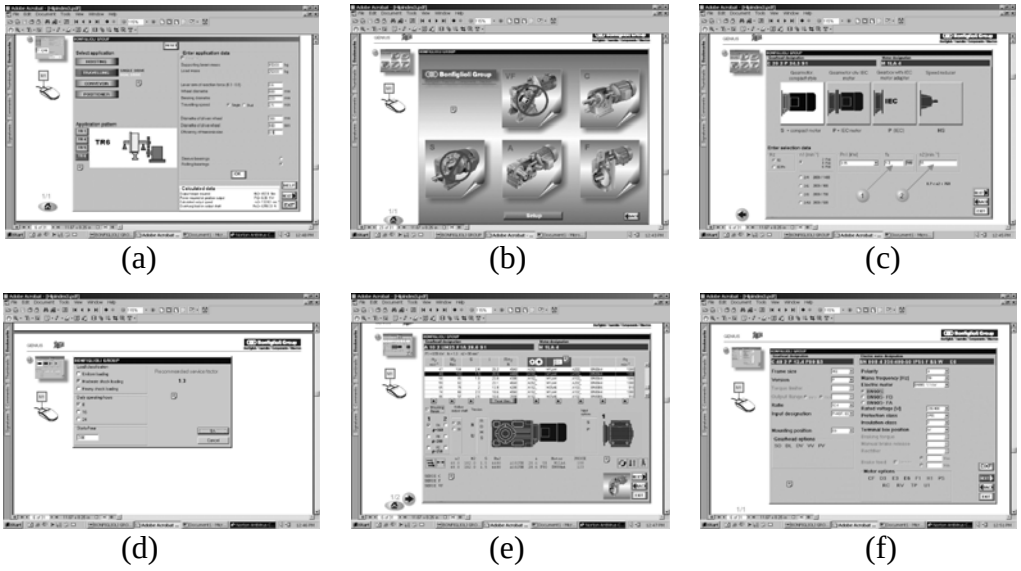


Figure 6: Selection of the drive concept using Genius software (Bonfiglioli Redutori)

(a) Data input; (b) Possible concepts; (c) Electric motor selection; (d) Service factor selection; (e) Comparison of drive concepts; (f) Detailed drive parameters with possibility of general layout and overall dimensions display.

Then, for individual operating condition (e.g. tropical, arctic, dusty coal mine with elevated temperature) each student individually carries out design calculation (gears, shafts, bearing selection, etc.) and has an opportunity to compare his design with a gearbox from one of the industry leaders selected with the use of Genius software. SEW Application software from SEW Eurodrive works in a similar way.

Then, each student develops a solid model of the drive and the gearbox and attaches it to the report. In the third design unit (MMB382) each students develops a lubricating system for the same gearbox and the same operating conditions.

Working on lubrication project students use different learning resources and software packages, such as SEW Application software, SKF bearing and lubricant selection software.

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For development of maintenance system students can use "Exact" software and "***i*** – Learn" software, as well as different sources available on-line.

Assessment and Evaluation of Outcomes

From year 2005 QUT will be introducing criteria-based assessment. Elements of this assessment have already been introduced in marking of the gearbox project. The following break down of the mark has been used: Gearbox concept: 20%; Materials selection: 15%; Design calculations: 30%; Bearing selection: 13%; Manufacturing process: 10%, and solid model: 12%. This puts additional pressure on teaching staff in term of time required for marking and there is no an obvious solution to this issue. To assess how learning outcomes are achieved in examination paper both theoretical questions and real-life problems are included. For example, for a given assembly drawing of a drive train students are asked to carry out analysis of loads acting on each threaded joint and suggest computational approaches; carry out analysis of points requiring lubrication and suggest methods of lubricant delivery. This enables evaluation of students' ability to understand loading and operating conditions and select proper design and computational approaches.

Conclusions

In this paper project-based teaching of Mechanical Design at QUT has been discussed. It has been demonstrated that:

- Project based teaching of Mechanical Design enhances practical focus, students' exposure to 'real-life' problems and makes them better prepared for work in industry.
- Continuing projects enable students to apply system approach to design and consider different stages of the life cycle of a product.
- Teaching and learning resources developed facilitate students' learning and their work on design projects.
- Means of flexible delivery of design units and the use of interactive software packages enable students' early exposure to the latest samples of mechanical equipment from leading manufacturers and shortens the learning curve.
- The use of laboratory facilities such as the Design Studio and Tribology laboratory fosters students' learning with hands on experience.
- The availability of Tribology unit as an elective gives students an opportunity to gain in depth knowledge on friction, wear and lubrication and get better prepared for career in design or maintenance.
- New teaching approaches introduced in teaching of mechanical design at QUT, and especially project-based teaching, have been highly welcomed by students. Responses from recent graduates indicate that they found themselves well prepared for work in industry.

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The SPQ in Monitoring Learning

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***Abstract**: A focus on student learning requires measures of that learning, and teaching practices that aim to influence the way students learn require that we examine learning practices. This paper examines one set of data collected using the Study Process Questionnaire (SPQ) and highlights difficulties that can be encountered in the interpretation of that data. Use of the SPQ in engineering-related studies of learning is not unknown, or even uncommon, but these studies are rarely explicit about the interpretation of the SPQ data and provide no examples of unusual outcomes. This paper suggests several reasons for the variety of problematic outcomes are found in the data set examined, and the implications for further research are discussed.*

***Keywords**: SPQ, approaches to learning, learning strategies*

Introduction

The learning outcomes of an undergraduate education should include not only good learning, but should also result in good learners. It is generally held that good learners beget good learning when they are driven by deep-achieving motives and employ an appropriate combination of deep & achieving strategies.

In order to judge the quality of learning that is occurring, and the capacity for improvement, it is important therefore to have some measure of the motives and strategies that undergraduate engineers bring to their studies. Determining the motive/strategy disposition of our students allows us to suggest support programs or curricular revisions (or other processes) that might aid in moving the student toward more profitable (scholastically speaking) motives and strategies. If the measurements are repeated they also provide a direct indication of any subsequent change in motive and/or strategy. This, of course, relies on the measuring instrument being reliably consistent.

The Study Process Questionnaire (SPQ)

Developed by Biggs (1987), the SPQ is a 42 item diagnostic questionnaire designed to identify the way tertiary students approach learning. Biggs describes the students *approach* as a composite of a *motive* for learning and the appropriate *strategy* they use. These characteristics of the students approach to learning are influenced by what Biggs describes as *presage* factors. The presage factors include *personal* factors (IQ, prior learning, personality, home environment and external workload) and *situational* factors (subject content, instructional methods, course structures, etc.). This is an alternative description of the contexts influencing education as described in several variations by Novak and others. Essentially these contexts are of the *student* (conceptions, practices, background), *instructor*

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(conceptions, beliefs, practices), *curriculum* (content and structure), *political* (nature of course university and society), and the *physical* (environment of instruction).

By examining the motive and strategy of the learner, the SPQ focuses on the student-centred consequence of these contexts. By using the SPQ an instructor should gain an insight into the type of learning process that is being undertaken, although not necessarily be cognizant of the reasons for that behaviour. Nevertheless, knowing the approach being utilised by the students and comparing that to an optimal approach provides insight regarding whether or not an intervention or revision of teaching strategy is required.

The use of the SPQ is not unknown, or even uncommon, in Engineering-related studies of learning (e.g.: Bates & Leary, 2001; Herbert, 1999; Quinn, 2002; Tang, Kwok, & Lau, 2003; Trigwell & Yasukawa, 1999). However, these studies are rarely explicit about the interpretation of the SPQ data and provide no examples of unusual outcomes. As the data set examined in this study reveals, counter-intuitive outcomes are certainly possible, and this paper argues that these instances need to be understood before any sensible decisions can be made about the type of teaching intervention required or the effect of any teaching that has already occurred.

Scoring the SPQ

The SPQ yields 6 numeric scores between 7 and 35 that indicate the strength to which the student ascribes to (in turn): *Surface motivation* (SM); *Surface strategies* (SS); *Deep motivation* (DM); *Deep strategies* (DS); *Achieving motivation* (AM); and *Achieving strategies* (AS).

The SPQ Manual (J. Biggs, 1987b) outlines the scoring process in detail, as well as describing a variety of profiles and the implications for teaching and counselling that might be drawn based on those profiles. Essentially, the higher the score on a subscale (such as *Deep Motivation*), the more strongly it features in the student's approach to learning. These subscale scores are typically grouped into decile bands (10% of students in each band) to allow comparison of individuals against the class in general, and the individual score converted to a symbol (+ , - , or 0) to indicate which group of decile bands they sit in for each subscale.

For example, a student's result from the SPQ might thus appear as ++ 00 +-, indicating that they fit a surface-achieving profile. This student's *Surface* scores (both *Motive* and *Strategy*) are in the high group of deciles and they also demonstrate a strong motive to achieve. But they tend to ignore or avoid strategies that support achievement outcomes, and they do not indicate any inclination toward wanting to understand the material for its own sake or to utilise any deep learning strategies.

Reliability of the SPQ

At the time the data discussed in this report was collected, test-retest data on the SPQ was not available. The closely related LPQ (Learning Process Questionnaire) had been tested in this manner however, and demonstrated reasonable stability over a four-month interval with year 11 students in two independent studies (J. Biggs, 1987b). This is marginally longer than a semester at JCU and indicates that profile changes between the beginning and end of a semester are likely to be a consequence of the education program rather than any other factors (such as learners simply maturing and changing their approaches).

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Alpha coefficients for the subscales indicate that they are reasonable consistent, focussing specifically on the object of the question and not being influenced by other factors. The weakest subscale is Surface Motive, and Biggs explains that this is because it arises from both positive and negative aspects of extrinsic motivation (getting a qualification and fear of failure). This double meaning reduces the alpha coefficient scores for this subscale (0.61 and 0.60 for university students) compared to the other scales. (Biggs' interpretation of the internal reliability of the questionnaire and the scales was supported by Herbert's analysis (Herbert, 1999, p5).)

Validity of the SPQ

LPQ and SPQ measurements have been compared to several different analyses of student performance, including student prediction of performance, HSC (Higher School Certificate) outcomes, and SOLO Taxonomy analysis of open-ended questions. All comparisons indicate the relationship between the SPQ measurements and student performance. Generally speaking, surface orientations result in poorer outcomes while deep-achieving (combined) orientations result in the best outcomes. Separate Achieving orientation or deep orientation can yield good outcomes but in various contexts this will not always be the case (for example: a student with a deep orientation in a subject that does not interest them may not have the experience or skills to focus on maintaining grades in the face of their disinterest).

SPQ Norms and their use

The SPQ has been normed for Australian University and TAFE students in Arts, Education and Science. The male university science students are the group that most closely resemble the group of undergraduate engineering students who generated the data considered in this report. The norms are provided as the scores defining the deciles for the reference group (N=139 for male university science). These decile boundaries provide the definition of the subscale indicators (+, 0, -) so that the profiles for each engineering student can be generated in comparison to a reference group of similar students.

If the profile "scores" are derived from the deciles of an appropriate Norm, a comparison of each student against that norming group is attained. This is useful in the prediction of learning outcomes for a conventional teaching program or activity that the norming group has also undertaken. For example, if you have normed SPQ data for first year engineering students and correlated examination results for those students, you can proceed to make examination predictions for other first year engineering students in the same subjects based on their norm-referenced SPQ profiles.

This prediction however is not useful in itself. The logical extension of making the prediction is to prescribe some intervention in order to improve the learning of the students. If an intervention improves examination outcomes (for example), and there is a reasonable correlation between examination outcomes and SPQ profiles, then it is reasonable to expect that the intervention also influenced the SPQ profile of the student. Apart from analysing examination results, this change should also be detectable in a retest with the SPQ, given the stability of the SPQ described earlier.

Collection of the Data in Question

The SPQ data used in this report was collected toward the end of the first semester as part of a study that required baseline data on engineering student profiles. The SPQ data was collected during a scheduled class session, with approximately half of the class volunteering (N=65).

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The SPQ was introduced to the students and a brief overview of the types of questions and how to answer them on the answer form was provided. Standard question and answer forms from ACER were used and collected as the students indicated that they had completed the questionnaire. The entire exercise took less than 20 minutes.

Data Analysis

The completed answer forms were duplicated in an Excel spreadsheet and the subscale scores and profile scores were generated automatically from the raw scores. The subscale scores and resultant approach scores for every participant were then automatically normed against several criteria in order to provide insight for the selection of teaching interventions to develop student learning skills.

Norm Referencing the Engineering Data

Table 1 provides the histogram of normed SPQ profiles for the engineering class (based on university science students of appropriate gender). These profiles are based on the second decile. That is, a student must score in the top 20% of the norm scores on a subscale to warrant a "+" (reflecting a preference for, or bias toward, that subscale) and in the bottom 20% to warrant a "-" (indicating a bias away from that subscale).

SMSS	DMDS	AMAS	#
--	00	00	1
-0	-0	++	1
-0	0-	00	1
0-	0-	+-	1
0-	00	00	6
0-	00	0+	1
0-	00	+0	1
0-	0+	-0	1
00	--	++	1
00	00	--	1
00	00	00	5
00	00	+0	3

SMSS	DMDS	AMAS	#
00	0+	00	2
00	+-	+0	1
00	+0	00	2
00	+0	++	1
0+	+0	00	2
0+	+0	++	1
+-	-0	00	1
+-	-+	0-	2
+-	0-	+0	1
+-	00	0-	1
+-	00	00	2
+-	0+	0-	1

SMSS	DMDS	AMAS	#
+-	+0	+0	1
+-	++	-+	1
+0	--	-0	1
+0	-0	00	1
+0	0-	+0	1
+0	00	-0	1
+0	00	00	2
+0	00	+0	2
+0	0+	00	1
+0	+0	+0	1
+0	+0	++	1
+0	++	00	1

SMSS	DMDS	AMAS	#
+0	++	0+	1
+0	++	++	1
++	0-	00	1
++	00	+0	1
++	00	++	1
++	0+	++	1
++	+0	+0	1
++	++	00	1
++	++	+-	1
++	++	+0	1
++	++	++	1
		Count	65

Table 1: Science-normed SPQ Profiles for 65 first year engineering students

Profiles that are internally conflicting (both strongly *surface* and strongly *deep*, for example), or that show no particular biases, are problematic. Such scores can result from a number of factors, particularly a total lack of interest in the subject material, or variability in the student's motive and strategy based on the case the student considered in response to each question. It is common to interpret both low scores in the achieving orientations (xx xx --) and high scores in the surface orientations (++ xx xx) as identifying students who are likely to achieve less well academically and therefore warranting intervention (there are several variations of these profiles). Intervention can also be recommended for students who exhibit a strong deep approach without reasonable achieving orientation (00 ++ -0), as this may lead to students pursuing learning goals that are inappropriate to the assessment, to the extent of risking their academic progress.

In order to identify these at-risk students, the test is normally administered once only. The students identified as at-risk are then offered guidance in modifying their orientations and approaches to learning in order to achieve better academic outcomes. In situations where improved learning strategies for all students is an objective of the teaching program, the SPQ could be used as a pre-test and post-test to determine if there has been significant change in student approach to learning. This would normally be done with random halves of the class

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taking the test as pre-test and post-test, in order that the data is not contaminated by students being overexposed to the questionnaire. In both test scenarios, the potential exists to obscure individual learning needs through the "averaging" process. In a student-centred context it is important that individual difference is considered in the design and evaluation of instructional design initiatives.

As this Norm is not based on engineering students it is possible that the profiles are not entirely accurate. Biggs, Kember and Leung have suggested, in a revision of the SPQ, that such norms are less appropriate now than when the instrument was developed, due to continued diversification of our student cohorts (Biggs, Kember, & Leung, 2001, p134). The range of profiles is very wide, and there are many that seem to indicate widely fluctuating motive and strategy. It may be more appropriate to develop an alternative distribution based on the class data alone.

Norming to class data

In situations such as this, where there is no specific norm data available, the subscale scores can also be based on the performance of the test participants as a group. This will ensure that the extremes of the SPQ profiles within the class are identified with respect to the class mean rather than an external reference and that the mos effective use of available resources can be made. Four variations of SPQ profile distributions based on the class results are presented in (c) **(d)**

Table 2. In these cases the "+" and "–" scores are assigned for subscale scores that
(a) fall more than one standard deviation away from the mean (Table 2a),
(b) fall in the top and bottom "20%" of the class scores (2nd Decile scoring),
(c) are more than 20% (of the mean score) above and below the mean (Table 2c), and
(d) are in the extreme top and bottom "10%" of the class scores (Table 2d).

"One Standard Deviation" Profiles

SM SS	DM DS	AM AS	#		SM SS	DM DS	AM AS	#
--	--	0-	1		00	00	00	9
--	00	-0	1		00	00	0+	1
-0	--	0-	1		00	00	+0	1
-0	-0	++	1		00	0+	00	1
-0	00	-0	1		00	+0	++	1
-0	00	00	4		00	++	0+	1
-0	00	+0	1		0+	0-	00	1
0-	-+	0-	1		0+	00	00	1
0-	0-	+0	1		0+	00	+-	1
0-	00	--	1		0+	00	++	1
0-	00	00	4		0+	+0	00	1
0-	0+	0-	1		0+	+0	0+	1
0-	+0	00	1		+-	00	00	1
00	--	-0	1		+-	++	-+	1
00	--	0+	1		+0	00	+0	1
00	-0	00	2		+0	++	00	1
00	-+	--	1		+0	++	0+	1
00	-+	00	1		++	00	00	1
00	0-	0-	1		++	0+	0-	1
00	0-	0+	1		++	0+	00	1
00	00	--	1		++	0+	++	1
00	00	-0	3		++	+0	+0	1
00	00	-+	1		++	+0	++	1
00	00	0-	2					

(a)

"2nd Decile" Profiles

SM SS	DM DS	AM AS	#		SM SS	DM DS	AM AS	#
--	--	0-	1		00	+0	0+	1
--	00	00	1		00	+0	++	1
-0	--	00	1		00	++	0+	1
-0	-0	++	1		0+	0-	00	1
-0	00	-+	1		0+	00	00	2
-0	00	00	4		0+	00	++	1
-0	00	+0	2		0+	+0	00	1
-0	0+	-0	1		0+	+0	0+	1
0-	-+	0-	1		0+	+0	+0	1
0-	0-	+0	1		0+	+0	++	1
0-	00	0-	1		+-	+0	00	1
0-	00	00	2		+0	0-	00	1
0-	0+	0-	1		+0	00	00	1
00	--	-0	1		+0	0+	00	1
00	--	++	1		+0	++	-+	1
00	-0	00	2		+0	++	00	1
00	-+	0-	1		+0	++	0+	1
00	-+	00	1		++	00	+0	2
00	00	--	1		++	0+	0-	1
00	00	-0	2		++	0+	++	1
00	00	00	10		++	++	00	1
00	00	+0	1		++	++	+0	1
00	0+	00	1		++	++	++	1
00	+-	0+	1					

(b)

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"Beyond 20% of mean" Profiles								
SMSS	DMDS	AMAS	#		SMSS	DMDS	AMAS	#
--	00	00	1		00	00	00	17
-0	--	0-	1		00	00	0+	1
-0	-0	++	1		00	+0	++	1
-0	00	00	2		00	++	-+	1
0-	--	0-	1		00	++	00	1
0-	-0	0-	1		00	++	0+	1
0-	0-	00	1		0+	0-	00	1
0-	00	0-	2		0+	00	00	1
0-	00	00	2		0+	00	+-	1
0-	+0	00	1		0+	00	++	1
00	--	-0	1		0+	0+	00	1
00	--	0+	1		0+	+0	00	1
00	-0	00	2		0+	+0	0+	1
00	-+	0-	1		0+	+0	++	1
00	-+	00	1		+0	00	00	2
00	0-	0-	1		+0	+0	0+	1
00	0-	0+	1		++	00	0-	1
00	00	--	1		++	00	00	1
00	00	-0	3		++	0+	++	1
00	00	-+	1		++	+0	+0	1
00	00	0-	2					

(c)

"Extreme 10%" Profiles (1st Decile)							
SMSS	DMDS	AMAS	#		SMSS	DMDS	AMAS	#
-0	-0	+0	1		00	++	0+	1
-0	0-	00	1		0+	00	00	2
-0	00	00	2		0+	00	+0	1
0-	0-	0-	1		0+	00	++	1
0-	00	00	1		0+	+0	00	1
00	-0	-0	1		0+	+0	0+	1
00	-0	00	2		+0	00	00	1
00	-+	0-	1		+0	00	+0	1
00	0-	00	1		+0	+0	0+	1
00	00	-0	3		+0	++	-0	1
00	00	0-	2		+0	++	00	1
00	00	00	22		++	00	0-	1
00	00	0+	3		++	00	00	1
00	00	+0	3		++	0+	00	1
00	0+	00	1		++	0+	+0	1
00	+0	00	1		++	+0	+0	2
00	+0	++	1					

(d)

Table 2: Four Alternative SPQ Profile distributions

The last two distributions are significantly more restrictive that those in (c) **(d)**

Table 2(a) and 2(b). That is, it is more difficult to score a "+" or "-" in these distributions. This is due to tight grouping of the subscale scores across the group that completed the questionnaire (in all except the achieving strategies (AS) scale, the standard deviation is less than 20% of the mean). This restrictive profile generation is warranted, and desired, for any "high cost" analysis, such as where intervention resources are limited or the analysis might result in a recommendation that a student withdraw from a program because their SPQ result indicates they will struggle academically. Decisions about which distribution is most appropriate can only be made with consideration for the purpose of conducting the SPQ, the range of subscale scores, the cost impact of interventions, and the ethics of making intervention judgements.

Aberrant Profiles

Reviewing the profiles generated from the SPQ data for this class, there are several that do not seem to be likely, and that are inconsistent with conventional results. The most obvious of these "outliers" are profiles that score strongly on all motives and/or all strategies (e.g. ++ 0+ ++). In the science normed engineering profiles (Table 1), there are no less than nine such aberrant profiles (14%), isolated in Table 3. (The *student* indicators are sequence codes and do not identify the student.)

The *Approach Scores* indicated in this table are sum of the original numeric scores (between 7 and 35) for each approach (*Surface*, *Deep*, and *Achieving*). A high score in one of these would indicate a dominant approach. The *DAA* score is the extent to which the student might be considered as using an ideal Deep-Achieving Approach (maximum 140).

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These profiles require follow-up investigations such as interviews to clarify if they indeed reflect an impressive diversity of skills or if they are a consequence of poor process. "Poor process" would include factors such as inconsistent interpretation of the questions from the student or recording answers to questions in the wrong locations. Removing these outliers for further analysis yields a more conventional spread of profiles, but that removal needs to be based on a clear understanding that the unusual results are not true reflections of that student's approach to learning.

Student	Approach Scores				Tertiary Science Norm Grouping (2nd Decile)		
	SA	**DA**	**AA**	**DAA**	**SMSS**	**DMDS**	**AMAS**
A	51	54	60	114	+0	+0	++
M	59	54	37	91	++	++	+-
X	45	50	45	95	+-	+0	+0
Y	58	60	56	116	++	++	++
AA	51	50	52	102	+0	+0	+0
AF	62	59	51	110	++	++	+0
AI	56	48	48	96	++	+0	+0
AU	55	57	56	113	+0	++	++
AV	58	56	56	112	++	0+	++
BH	47	59	52	111	+0	++	0+
Average	46.8	46.7	44.5	91.2			
St.Dev.	6.6	6.6	7.1	11.0			

Table 3: "Outlier" profiles with conflicting strong indications on multiple sub-scales

There should also be a question over profiles that evidence simultaneously strong *surface* and strong *deep* orientations. It is quite unlikely that students are simultaneously motivated in surface and deep fashions, and the strategies for these approaches do not normally coincide. It is possible that in answering the questions relative to these scales the students imagined situations where they alternated between these approaches based on interest in the subject material. If this were the case however, it is more commonly indicated as a deep-achieving profile – the deep-capable learner recognises their lack of interest in a subject and reverts to strategies that maintain their grade level. Examples of this problematic surface-deep profile are seen in the data for students K, AW, and BJ (Table 4, using the science-normed profiles).

Student	Approach Scores				Tertiary Science Norm Grouping (2nd Decile)		
	SA	**DA**	**AA**	**DAA**	**SMSS**	**DMDS**	**AMAS**
K	47	59	42	101	**+**-	**+**+	**-**+
AW	57	58	48	106	**+**+	**+**+	**0**0
BJ	53	58	42	100	**+**0	**+**+	**0**0

Table 4: Conflicting Surface-Deep profiles

Conclusions

The SPQ data for this engineering class provides a picture of diverse motivations and strategies, not entirely expected. It has been commonly believed that engineering students are predominantly surface or surface-achieving oriented and, whilst this is evident for a large proportion of the class, there is a significant number of students with strong deep orientations or a lack of clear preference for approaches to learning.

Whilst the reliability of the SPQ data might provide evidence of change in learning approaches through a test-retest format, the "aberrant" data collected would need to be investigated first in order to determine that it was an authentic reflection of student attitudes

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and skills. This determination can only be made through follow-up investigations, probably involving individual interview and/or testing. It might be that some of the "aberrant" profiles are the result of poor testing protocols or inconsistent interpretation of the test questions. This would imply that further care is needed in preparing students to take the test, either in helping them to focus on one question at a time, or ensuring that they answer the right question each time. This could be better facilitated with an on-line test where only one question, and answer space, was encountered at a time.

However, if it is indeed the case that these "aberrant" profiles reflect students with unusual motivations or a limited range of learning strategies, then it is likely that class-wide teaching interventions (such as alternative instructional designs) will not address the needs of each student. A student-centred approach would require that individual learning needs are recognised and that strategies are utilised to help each student adapt to an optimal motive/strategy profile. Perhaps this implies that individualised learning materials are required, or that individual students need to be directed to unique support by the university's learning support systems. At the very least, the presence of "aberrant" profiles calls into question any benefit that might accrue from changes to curriculum design and teaching strategies, and requires that the evidence of any benefit is analysed for individual students.

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Teaching Engineering to South-East Asian Students

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Abstract: *The pass rate in some electrical and electronic engineering courses at USQ fell dramatically when large numbers of students from South East Asia enrolled in 2001 and subsequent years. As the majority of these students enter their program with advanced standing a number of transitional factors may contribute to this phenomena. However, the main factor was poor performance in examinations because of the apparent inability of students to answer questions in a way which demonstrated understanding of the course content. Since that time a number of measures have been implemented, firstly to try to understand the reasons for this outcome, and then to improve the results. Staff are attempting to move beyond the simple theory of student deficiency being the cause, and are experimenting with ways to improve their teaching. This paper identifies and discusses the issues and then points towards some solutions.*

Keywords: *Cultural diversity, teaching, transition*

Introduction

USQ is a major provider of engineering education externally with significant groups of students in Singapore, Malaysia and Hong Kong. In 2004, USQ has about 25000 students of whom about 1550 on-campus students and 5240 external students are from South East Asia. External study involves students studying from home using print and electronic materials provided by the university plus attendance at USQ's Toowoomba campus for between three and eight one-week-long residential schools. USQ also attracts significant numbers of students from these areas to Toowoomba for full-time on-campus study. Some relevant statistics are given in Table 1.

Student category	Enrolment		Percentage	
	Faculty		Faculty	
	ONC	EXT	ONC	EXT
South East Asian	146	491	23%	27%
All other categories	490	1342	77%	73%
Total	636	1833	100%	100%
Total all modes	2469			

Table 1. 2004 Student statistics

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South East Asian students almost always enter their program with advanced standing, typically after having completed a two-year Diploma in their home country. They would normally receive between 8 and 12 exemptions in the 24 course Bachelor of Engineering Technology or between 12 and 16 in the 32 course Bachelor of Engineering, depending upon their existing qualifications and experience. They would then require at least one year of full-time study (two years of part time study) to complete a Bachelor of Engineering Technology or at least two years of full time study (four years of part-time study) to complete the Bachelor of Engineering. International students usually enrol through a local agent who may provide some services for external students such as delivery of study material and assignments, local tutorial classes and guidance about, and assistance with USQ administrative procedures and processes. The extent and quality of the services provided is variable and therefore requires continuous monitoring.

It also seems that, relative to some of the larger Australian Universities, the students in USQ's South East Asian cohort are not as successful in their studies. There are many factors that might explain this phenomena including: the first encounter with external study; a shortage of time due to work & other commitments and perhaps lower than required intellectual ability.

Symptoms of a teaching and learning problem

The experience of USQ academic staff with teaching South East Asian students has, until recently, been largely confined to small numbers, most of who were on-campus and any learning issues were able to be dealt with individually. However, in recent years the number of South East Asian students enrolling in Engineering programs has increased dramatically and staff have been trying to adapt their teaching and to cope with the cultural issues that have arisen.

There have been numerous experiences of high failure rates among these students, particularly when they reach the more senior courses in their programs and this paper discusses this problem in one course and the actions taken to resolve the problem. Parsons is responsible for teaching a course called "Electronic Measurement" which is a third year course requiring generally good understanding of concepts and the ability to discuss and apply these concepts in written English.

To illustrate the issues the student pass rates for the Electronic Measurement course are given in Figure 1. It should be noted that only students who completed all of the assessments in the course are included and that the relatively small number of students from other countries have been omitted.

The data shows that there was a dramatic drop in the overall success rate at the same time as the South East Asian enrolment increased. During this period the pass rate for Australian students remained much the same.

Examiners of other courses studied by the same students report similar but smaller drops in the pass rates. Similarly, the average passing grades achieved by South East Asian students in those other courses are much lower than those achieved by Australian students. There is evidence that suggests that the more structured or calculation-based courses have somewhat higher pass

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rates.

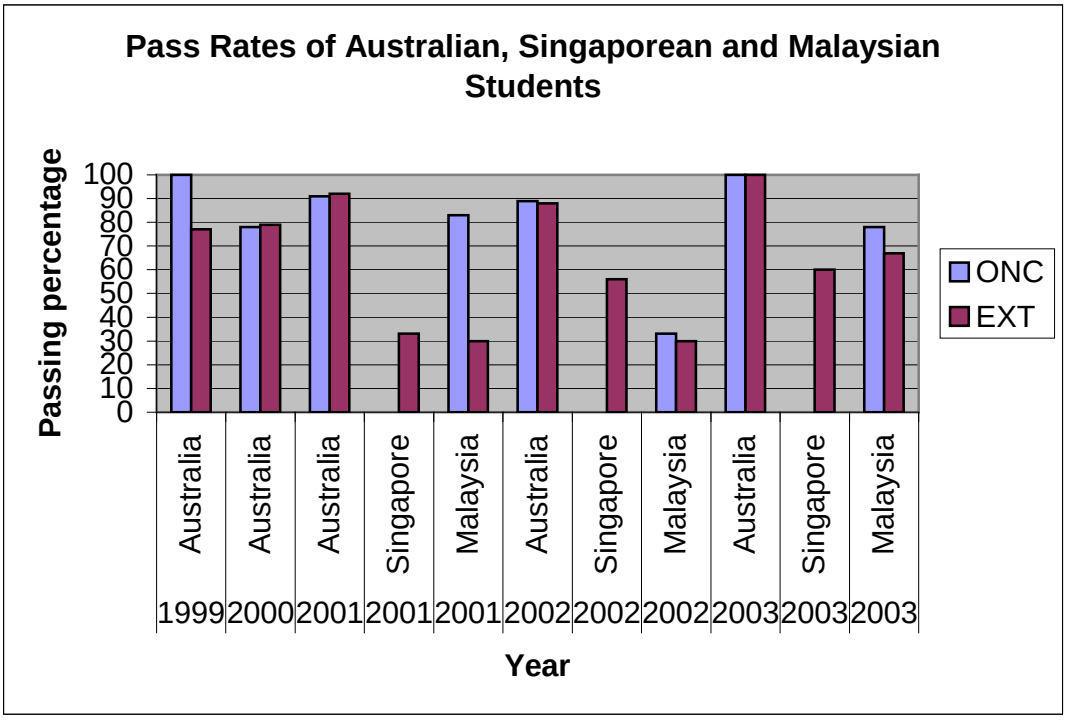


Figure 1. Student Results in Electronic Measurement

In the following sections the authors report their observations on student performance in examinations, assignments and practical work, as well as on their writing skills. This is followed by some anecdotal comments on the general study skills of the cohort. These observations are made from a perhaps incorrect stance of lecturers who expect students to perform according to traditional Australian standards, without considering the possibility that factors other than student deficiencies could contribute to failure. These factors are discussed in a later section of the paper.

Examinations

The main reason for the high failure rate in the course was student performance in the final exam – and it should be said that final exams have been retained in this course and in most others because of their value in enabling students to individually demonstrate their understanding of concepts and their ability to apply them. Generally the answers submitted by many South East Asian students showed they were unable to answer questions in a way that convinced the examiner that they had the required level of understanding of the material.

Typically students gave answers which:

- Were quotations, remembered word for word from the study material, that often did not address all aspects of the question;
- Were descriptions or explanations written in their own words, but paraphrased from a section of the study materials and which did not really answer the question asked;
- Showed little ability to relate material in the present course to basic material studied previously, either at USQ or at another institution; or
- Showed little ability to apply concepts.

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Assignments

The assignments involved students in designing, constructing and testing electronic circuits and were generally done much better than the exams. However, there is some evidence to suggest that although they satisfactorily completed the work, many students appeared to have received significant help because they were unable to adequately explain their work when asked about it in the examination.

Practical Work

A very noticeable difference between mature Australian students and the younger, less industry-experienced, South East Asian students was their lack of practical ability, or lack of translation of theory into physical reality. These characteristics were particularly evident when students were asked to construct and test circuits in a laboratory. Some characteristics seen in this situation were:

- A lack of ability to use electronic equipment. Inability for example, to connect a meter or oscilloscope to a circuit or to a signal generator, even after several weeks of exposure to the equipment.
- Lack of initiative. Unfamiliar with the idea of "having a go" or trying something to see what happens. Perhaps this was because they were unwilling to take risks? Some older Australian students also demonstrate this characteristic because of a fear they may damage the equipment.
- Little understanding of the meaning of the results of measurements. Many, for example, did not seem to be able to appreciate the meaning of a graph where one parameter is varied and the other is the result.
- Lack of critical thinking evidenced by the unquestioning acceptance of whatever results the equipment produced; and
- Lack of ability to link results to reality.

Language

One of the major factors is that many students have a limited command of the style of English used in Australia or in Australian engineering. Students admit that when they come to Australia, they spend perhaps the first semester "tuning-in" to the spoken English of lecturers. Others state that they reproduce passages from study material because they feel they do not have the skills to express the concepts in their own words.

Defining the problem

The experiences described above have led to attempts to define just what the components of the problem are and how they might be resolved.

Market related issues

Australian Government policies have "encouraged" Australian universities to compete on the world-wide market for educational services. Consequently, education is now Australia's fifth largest export industry (Dearn, et al, 2003). The globalisation of education, and the availability of new technologies has increased competition between Australian universities, both within Australia and overseas. USQ, like most other universities has entered the market and has had considerable success at establishing niche markets for its programs.

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Like all universities who have entered the global market, USQ has encountered a range of issues that have had to be addressed. Some of these issues do not surface for a year or two after the event, and it is often difficult to separate the causal factors without undertaking considerable research. For example, there is anecdotal evidence that some of the students enrolling at USQ may not be intellectually equipped to complete a degree. However, this is difficult to assess because of the other factors that could cause the same symptoms, such as low proficiency in written English.

University staff are under considerable pressure to maintain good pass rates in their courses and at the same time maintain academic standards. The maintenance of academic standards in this course has led to lower than acceptable pass rates.

Some staff feel that since the students are seeking an Australian degree, they must conform to Australian standards – in English, content, context etc. Other staff believe that the curriculum should be internationalised by removing reference to specific Australian examples, standards etc. This can be achieved by introducing case studies and examples from other countries.

Like all schools of engineering, the school at USQ is subject to market pressure to grant generous exemptions to international students in order to continue to attract students or to increase market share, but at the same time to maintain exit standards. USQ has also always had a relatively flexible entry policy to enable minority groups to enter. Recent experience has led the Faculty to slightly decrease the level of advanced standing granted to some groups of overseas students. Because it does take in students with significant advanced standing, many teaching staff believe that some students are not sufficiently prepared for the courses with which they begin their study with us. This has led to a proposal to create a special course for students who are granted advanced standing. This would help ensure that all students are treated equitably and have ample opportunity to achieve the exit standards.

Grading standards

There are, of course, debates about grading. Most staff feel that we should set a rigorous standard with respect to a passing grade, as was probably done in this course, but then, perhaps, be generous with higher grades. Another perspective, that does not have currency at USQ, is that examiners should be generous with the passing grade because of South East Asian student difficulties with English etc., but then only award higher grades if they are deserved according to traditional standards.

Language

Some language factors that impact on student learning are:

- Lack of English proficiency may be an important factor that leads students to resort to rote learning.
- The use of several words in English to describe the same thing. For example in the context of Electronic Measurement, “noise” and “interference”, or “mechanism” and “way” and “process”, or “mixer” and “modulator”.
- The use of one word to describe several different things. For example “distortion”.
- The use of a word with a general meaning and also a technical meaning. For example “sweep”, “flatness”, “integrate”, “handshake”, “trigger”.

(Mahalinger-Iyer 1995, p466):

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The un-written rules

It would appear there are quite a few un-written rules defining the Australian culture, and in particular, the way Australian engineering educators teach, and the expectations they place on students. Some of these cultural expectations are:

- A culture of individuality. Students are expected to look after themselves and for example, ask questions if necessary. Asian students generally have a much stronger culture of group support (Jarvis, Holford et al. 2003).
- An expectation that since engineering is a practical profession, students should at least be able to do some of the more basic things like take measurements. This is possibly rooted in Australian male experience of fixing things like cars and lawnmowers at home etc. which may not be the experience of Singaporean students who have lived in a housing unit all their lives.
- "Common sense" is expected. This is a form of emotional intelligence which has high value in Australian culture but which may not be so highly valued in other cultures. Australian common-sense includes traits such as ignoring things that don't seem important.
- Diversity of skill is expected. For example, most Australian tradespeople (and many of USQ's Australian students have a trade background) are used to doing many different tasks at work, and being the only person available to attend to those tasks. After speaking to numerous students, anecdotal evidence suggests that typical Malaysian and Singaporean tradespeople perform a very narrow range of tasks in their employment, an example being: ensuring that one machine in an integrated circuit manufacturing factory operates correctly.

Use of study materials

The bulk of the course content is provided to external students in printed Study Books. Students are guided through this material by a Study Schedule and supported by various other study materials such as software, video and web-based discussion groups. This approach is in line with advice given by Ayre & Nafalski (2000) to specifically plan for a diversity of learning styles when developing teaching strategies. However, many and perhaps the large majority of students seem to make little use of the extra, non-printed material, because of their perception that it would take too much time to study.

In the printed study books, theoretical material is supported by relevant examples of industrial products, illustrative material etc., in an attempt to provide students with the relevant industrial context. This contextual material is not normally examined in detail. However, it seems that some South East Asian students are not easily able to distinguish between examinable content and the supporting illustrative content in the printed material, and consequently waste time "learning" the latter. Australian students have traditionally been able to distinguish between these two.

Towards a solution for a teaching and learning problem

How we teach

Biggs (1999) suggested that the cause of the problems described lies in the way in which engineering is taught in western countries. As stated above, the first reaction of staff has often been to blame the students. In particular, they have reacted to the rote learning style used by South East Asian students. However this stereotypical explanation is condemned by both Biggs (1999) and Kennedy (2000).

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However Zobel & Hamilton (2002) contend that rote learning is what students may believe is expected of them, because it has been rewarded in their past. Some USQ students also say that they use rote learning in order to make efficient use of their time. Biggs points out that rote learning is necessary just as musicians must learn to play notes instinctively so they can then concentrate on larger issues. In other words, there are two relevant phases of learning, rote learning followed by a deeper understanding. Smith and Smith (1999) also point out that memorisation among Chinese learners is a part of the process of understanding and not normally the end point. As Biggs was specifically referring to the characteristics of a high-performing cohort of Asian students this may not be true for the USQ cohort. Consequently, students in the USQ cohort may need more time to get through the rote learning phase and onto the next level of deeper understanding. Because of their advanced standing and their desire to complete their program as quickly as possible, some students may not have this time.

There is some anecdotal evidence that on-campus South East Asian students who study full time and who have had regular contact with academic staff over more than a year, begin to adapt to local expectations and perform better in their studies. As Kennedy (2002), points out, this is probably because they began to understand the teaching and learning paradigm being used by lecturers.

USQ experience seems to contradict the findings reported by Smith & Smith (1999) that Chinese students are deeper learners than Australian students, and that they are good at relating material from different parts of their study program. This contradiction remains unexplained.

The second reaction of staff, according to Biggs (1999), and confirmed by USQ experience, is for them to try to adapt the teaching to suit the students. This process has begun and a number of the measures being trialled are outlined below. This approach also appears to be in line with the recommendations given by researchers such as Smith & Smith (1999) who suggested that, for example, learning materials should be structured to match the learning needs of Chinese students. However this is not the same thing as adopting particular cultural stereotypes (Kennedy 2002). It is not clear, however, just how this can be done nor how it can be done simultaneously to suit the learning needs of several cultures either pedagogically or economically.

Biggs'(1999) final argument is that any student will adapt to the teaching regime in which they find themselves, given enough understanding and time, and that Asian students learn the same way as Western students. Consequently, if we teach taught well, these students will learn well, given time. It seems however that, especially in the context of short duration enrolments, engineering lecturers need to define exactly what "teach well" means in their context. Some further clues about this may be taken from Badley (2000) who suggests that internationally competent teachers must, as well as being academically and pedagogically competent, be democratic and ethnographic in their approach. Being democratic, means for example, accepting that some of our deeply-held values such as a responsibility to share academic knowledge and use reasoned argument to reach a conclusion, may clash with the values of other cultures. Maybe it also means modifying or being more explicit about the un-written Australian cultural rules referred to above. By ethnographic, Badely means being

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willing to share in the lives and cultures of the students. There are clearly some major challenges for Australian academic staff in this message, for even if they do not entirely agree with Badely, it seems essential that more staff training in these matters is required (Leask 2000).

Assessment

As previously stated one of the major characteristics of the problem is that students do not perform as well in the examination as they do in the assignments. Examinations remain as major components of the assessment schemes for USQ engineering courses because currently, they are the only form of assessment where there is some guarantee that the work submitted is entirely the students' own work.

It is equally apparent that examinations are extremely stressful experiences for students. Yet Biggs (1996) contends that, for effective learning to occur, assessment should be conducted in a non-threatening atmosphere. It seems apparent then that part of the solution may be to find an alternative method of assessment. This maybe by preparing more individualised assignment questions, for example by asking questions that require students to answer with examples from their context, or by use of random numbers, etc.

It may also be that Australian lecturers should explicitly accept some degree of rote learning for part of the assessment. Examination questions could, for example, simply ask students to state what they know about a topic. Success in this type of question may give students more confidence to tackle more conceptual questions.

Course-specific responses

Since 2001, different aspects of the teaching materials and structures that support learning have been improved. In the course Electronic Measurement:

- Clear statements about how to study, how to think critically, and how to answer exam questions have been included in the study materials. These notes included advice that rote learning would not necessarily be rewarded in the Australian context. As recommended by Zobel & Hamilton (2002), clear statements about the meaning of plagiarism and the need to avoid it have been given, along with guidelines about how to work with others in a study group but still avoid collusion. However subsequent experience suggests that simply describing recommended approaches on how to study or sit exams did not achieve much. Students either did not read the statements or in some cases were able to repeat them back but were not able to apply them. This experience is supported by Ballard and Clanchy (1997).
- The lecturer has attempted to discuss these issues with students during teaching schools in Singapore. This seemed to annoy most students who, it seemed, preferred to spend the limited time available being told what to study for the exam. One interpretation of that experience is that just telling students they need to change their study and learning styles was rejected because they considered it to be an example of Western arrogance – with the lecturer seen as practising cultural imperialism (Badely 2000).
- An analysis of past exam questions in terms of, for example, key words and types of answers expected, as well as detailed model answers and detailed descriptions of what was expected for each question have been included in the

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study materials. Assignments have also been expanded to include typical exam questions related to the core content of the assignment. This also provided an opportunity to provide feed back about exam answer style and content. These two measures probably helped some students. Others, however, admitted that, whilst they understood the messages, under the pressure of the exam, they resorted to regurgitating from memory as their safest way of demonstrating that they knew something.

- Recent examinations have included more questions based directly on the assignment work that the students did during the course. The content of each exam question has also been narrowed so that it covers just one module of the study material. This was done because the skill of integrating knowledge from several modules, even though performed well by earlier students, was seen as being a relatively high order skill not required by the course learning objectives.
- A requirement for students to complete parts of an on-line course on how to study effectively has been added to assignments. This short course is called Communicating for Academic Purposes (CAP) (University of Southern Queensland, 2003). This initiative was included in the course materials in 2003, at the same time as some of the changes in exam style described above. These two initiatives together probably did achieve a slightly better standard of exam answer. However it was also apparent that many students did not do the CAP work as it was seen as non-essential, nor did they develop the ability to use the techniques described in CAP.
- Some general technical concepts, such as how a signal is swept over a range of frequencies in a spectrum analyser, which were previously expressed using written descriptions and moving graphical illustrations, have been illustrated with detailed numerical examples. It seems that many of the at-risk students can understand numbers much more easily than descriptions or even images – possibly evidence of a particular learning style

A new core course for articulating students

The Faculty is considering a proposal to create a course that will be the first course undertaken by all students who enter with advanced standing. This course will be designed to enable students to acquire, or enhance, many of the generic skills normally taught in first year courses such as: English and technical report writing; team skills; problem solving skills; study skills; learning and teaching styles and methodologies used in Australian universities (Biggs 1999 and Kennedy 2000). It is thought such a course would greatly assist articulating students in their transition into the USQ teaching and learning environment.

Conclusions

Finding long term solutions to the problems discussed in this paper is definitely a work in progress for staff at USQ, as it probably is for many others because this is a complex problem for which there are probably no simple or cheap solutions. However there are several conclusions which can be drawn from the discussions above:

- South East Asian (and other) students electing to study in a western university would enjoy greater success if they were forewarned about the difficulties of studying in another culture before starting. In particular they need to recognise that as a different teaching and learning paradigm will be used, they need to

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gain the skills to operate within it. Experience suggests that it should be the host university's responsibility to help them achieve this goal.

- Academic staff should be more explicit about what they require of students, both in study materials and in assessment items.
- Academic staff should fully understand the problems and the need for cross-cultural awareness if they are to become globally-competent teachers. This may also mean that they need to question their own teaching and learning values. Specific training in such matters should become a normal part of the preparation for teaching international students.
- There is a need to find alternative models of assessment that maintain standards but offer alternative routes for students to demonstrate their learning.

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The literature review as classroom genre for teaching ESL postgraduate engineers critical analysis and writing skills

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Abstract: *ESL postgraduate engineering students at the University of Melbourne enrol in a discipline specific EAP (English for Academic Purposes) program intended to develop their linguistic and academic skills for successful postgraduate study (Melles, 2002). While simultaneously attending to language issues in writing, a key concept of the curriculum is the development among students of critical analysis abilities (Melles, 2003). A series of writing and speaking tasks, including a three thousand word literature review, are used to progressively develop such skills and provide an appropriate assessment framework. The literature review, in the course is used as a 'classroom genre' (Johns, 1995) to initiate students into the academic culture and discourses. In this paper, I define the nature of critical analysis in the program, features of the literature review in the curriculum, and student responses to this framework. I conclude with a discussion on the relevance of applied linguistic contributions to academic literacy in engineering.*

Introduction

The Faculty of Engineering, University of Melbourne, enrolls a culturally and linguistically diverse group of ESL (English as a Second Language) students who arrive in Australia with heterogeneous levels of English proficiency, cultural backgrounds, and prior educational experiences. The University stipulates for some students that they must complete an EAP program during their first semester, and since 2002, a course has been offered to cohorts averaging twenty-five students per semester who have elected or been compelled to take the course as an induction into academic conventions and practice (Melles, 2002). Recently inclusion of students from non-engineering disciplines such as Chemistry, Land and Resource Management, and Information Systems have lead to a shift in the focus exclusively on engineering genres and content towards a format that foregrounds science and engineering as allied disciplines.

In teaching students, who are simultaneously pursuing discipline specific coursework and research programs, a conventional ESL curriculum limited to grammar and vocabulary is inadequate to preparing these students to succeed in their diverse projects. Students from Asia, who constitute the bulk of enrolments, come not only with limited English proficiency but also with academic practices that make their negotiation of critical thinking and writing difficult. Ballard and Clanchy (1984), for example, have referred to reproductive learning styles among these students. Also, as Jones and Freeman (2003) note, for many ESL students copying is 'a natural process, with cognitive roots in imitative learning'. Ward (2001) also notes that engineering students in Thailand learn strategies to avoid reading engineering texts in English in their undergraduate training, a practice which may be wide spread. Encouraging

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quality revision and writing work from students involves not only exploiting this initial drafting stage but also having very explicit writing formats (templates), and very clear criteria for assignments .

Limitations of conventional ESL Engineering approaches

A number of proposals have been made for collaboration between language specialists and Engineering faculty (Pattison, 1994), to negotiate better curriculum outcomes for students. There have also been calls for Engineers in particular to take more seriously the clarity of their communication through English (Oakley, 1998), to explicitly focus on cultural differences in rhetorical structuring of texts (McDaniel, 1994), and , in general, to take seriously the English and communication skills needs of engineers in a global industry (Riemer, 2002). In Australia, Pantelides (1999) proposes that integrated language across the curriculum programs are needed by undergraduate engineers. For the humanities/applied linguist lecturer, the process of attaining a form of literacy in the discipline, as Collins, Li and Cheung (2000) point out, takes time and effort. The recognition in texts within the field of engineering of the importance of coherence and the functionalist approach I take to this provides a point of contact across this applied linguistics and engineering 'gap'. My own experience has been that the language/content split is an artificial constraint used to bolster existing professional boundaries but practically irrelevant and one most language specialists ignore

Conventional ESL approaches to teaching engineering language places emphasis on the vocabulary and grammar acquisition of 'typical' structures such as the passive sentence (eg. Glendinning & Glendinning, 1995). A focus on a specific engineering vocabulary may not, however, be apposite since there 'may be no such thing as General Engineering English' (Johnson & Johnson, 1988), and, as Brown (1988) also seems to have shown, the difficulty second language students face in reading engineering texts can not be attributed the engineering vocabulary itself. Hyland (2002) has also noted that the so-called impersonal voice, ie. passive dominated, of academic writing is a misguided representation of actual use in engineering and other empirical disciplines where both active voice and personal pronoun usage, albeit less frequent, is found. Traditional ESL texts also reduce reading and writing to 'rhetorically simplified events' that 'teach forms of discourse they (teachers) themselves rarely or never use outside of the classroom' (Adam & Artemeva, 2002); they may also include source texts such as newspaper which do not expose students to research genres (Porcaro, 2001).

As Feak (1996) points out such texts take a very controlled and rather repetitive approach to language learning, and require substantial supplementation for students to engage with language and composition issues. More robust textbooks addressing the needs of ESL engineers (eg. Huckin & Olsen, 1983; Huckin & Olsen, 1991) and postgraduate students (eg. Swales & Feak, 1994) have appeared which attempt to balance a focus on language and discipline specific rhetorical choices. In their focus on specific academic and professional genres, eg. research reports, these texts provide a much needed complement to conventional EAP texts. They are not, however, sufficient in themselves to deal with the individually situated learning of students and their need to appreciate and practice critical analysis through writing. Such issues include but also extend beyond generic language and academic skills strategies deemed appropriate to all university students, and the *modus operandi* of learning skills centres (eg. Davis & McKay, 1996), which abstract academic literacy from social context (Hyland & Hamp-Lyons, 2002).

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As Hyland (2000) notes 'academic literacy is unlikely to be achieved through an orientation to some general set of trans-disciplinary academic conventions and practices' (p.145). Numerous guides to writing in the sciences and engineering offer advice on good style to native speaking students (Alley, 1996; Day, 1992; Kirkman, 1992; Silyn-Roberts, 2000). Such texts provide different levels of detail on the linguistic choices that determine engineering style. Although, as Alley (1996)claims no absolute consensus exists among engineers, style in engineering writing may be seen as a combination of rhetorical, imagistic, and language choices specific to writing purposes, audience, and circumstances. Second language students can be introduced to the norms and conventions of communities of engineering through discipline specific collaborations between applied linguistics and engineering faculties. In fact, as Tansely (1996) notes engineering schools seem to not include explicit teaching of the professional culture of engineering.

Genre-based pedagogies for teaching ESL engineering students

In textbooks directed at native speakers the socio-cultural characteristics of the discipline are not foregrounded but such a focus is essential for second language students. In response, practitioners and theorists of composition have adopted a social constructionist approach to the evolving genres of speaking and writing (eg. Gosden, 1995). As Hyland (2000) proposes, the basic idea is that 'academics work within communities in a particular time and place, and that the intellectual climate in which they live and work determine the problems they investigate, the methods they employ, the results they see, and the ways they write them up' (p.6). Social constructionism has implications for discipline specific genre-based teaching of academic literacies. Johns (1997) suggests that the 'socioliterate' approach to academic literacies incorporates traditional concerns with text form and schematic knowledge while emphasizing that 'all literacies are, in fact, social, intertextual, and historical' (p.16), and students need to be made aware of the social milieu or discourse community to which texts speak, the ways that texts 'call on' other texts through citation practices, and how current academic practices are bound to change.

A professional discourse community such as engineering may be seen as having a set of common public goals, mechanisms of intercommunication among its members, participatory mechanisms for information and feedback, a conventional set of genres for communication, a specific lexis, and a threshold level of accredited members (Swales, 1990, pp.25-27). Swales (1990, pp.45-58) identifies genres as a class of communicative events or activities with a shared set of communicative purposes for such events. There is variation in the proto-typicality of textual instances of genres, constraints on allowable contributions in terms of content, position, and form, and a nomenclature for genres, e.g memo. Linton, Madigan and Johnson (1994) note that in one sense (professional) disciplinary genres are 'unteachable' and must be learned through experience; Pogner (2003) has highlighted some of the complex social interactions that underpin workplace engineering genres. Arguing for the role of the general composition course and the use of 'transitional classroom genres', however, Linton et al. argue that writing faculty can play a role in raising awareness of the 'three categories of conventions which occur in all academic genres' in the natural and social sciences. These they list as conventions of (rhetorical) structure, referencing, and language use. Johns (1995) makes a similar distinction between authentic (AG) and classroom genres (CG) which is applicable here.

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Critical analysis through literature review

As Swales and Lindeman note the literature review 'is a part-genre or sub-genre of wide significance in the academic world and in graduate education' (p.107). However, although the literature review has a natural place in theses and dissertations as a genre it does not have a universal form or significance. Holtom and Fisher (1999), for example, suggest it may be necessary in certain 'particularly theoretical disciplines' (p.38); their only other comment on reviewing literature is to 'look through any literature that might be relevant to your project' (p.65). Evans (1995) also casts doubt on the general relevance of a literature review in thesis and report writing by referring to a critical review as 'one approach to thesis writing' (p.69), although he adds the caveat that it is impossible to 'critically review' until some experimental work has been done. Moore (1992), writing about biology, makes the important point that a comprehensive review of the literature is not required in the introduction to a research paper (p.242) since the review article now does this and science writers only need to provide 'enough' background to situate the research. Gustavii (2003) also notes that the introduction to a research article with an IMRD structure should contain 'specific findings by others that you are challenging or have developed in the study you are presenting' (p.54), adding, however, that in certain disciplines, eg. nursing, occupational science more space may be required (p.55).

Some engineering textbooks deal with the literature review in details outlining stages, purposes and processes (Silyn-Roberts, 2000, pp.78-91). A review may be incorporated in genres of engineering writing such as the lab report; the final year project in the engineering curriculum is an example where such an extensive review takes place. Shaw (1995) suggests that applied linguists have been reluctant to intervene in the literature review in engineering since they are too 'personal'; he suggests, however, that rhetorical analysis using schema can help. Swales and Lindemann (2002) note that while we have numerous publications on macro features of literature reviews or on micro linguistic features such as tense use etc., we have 'very little information on how writers get from the macro to the micro level' (p.108);

Silyn-Roberts (2000) and Reed (1998) suggest that finding sources and synthesizing information are two of the key tasks in performing a literature review in engineering. Learning how to use sources and evaluate their claims forms an essential part of reviewing the literature. Genre conventions provide necessary form and content boundaries to otherwise open writing criteria. Levis and Levis (2003) note that students have difficulties in managing multiple references, defining a research question, and discovering that articles may not overlap in obvious ways. The final year project is the context for a discussion of literature reviews in students project reports by Krishnan and Kathpalia (2002), who note how second language students in Singapore employ plagiphrasing and other compensatory strategies in writing their literature review due to language. They argue that 'these strategies need to be extended further to master the art of writing academically sound literature reviews'.

Generic definitions of critical analysis for university students abound (eg. Allen, 1997; Baker, 1989; Bean, 1996; Walters, 1994). In North American composition textbooks 'critical' may simply imply reading of humanities based fictional extracts, focus on rhetorical structures, eg. comparison and contrast, and personal response to reading questions (eg. Scull, 1987). Atkinson (1997, p.72) suggests critical thinking is a social practice that has its origins in culturally determined sets of behaviours that cannot be easily defined, and is, therefore

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'unteachable'. Benesch (1993) calls critical thinking both 'a democratic learning process examining power relations and social inequalities' and rejects, as others do (eg. Gieve, 1998) the idea that it cannot be taught. Belcher (1995) approaches the teaching of critical analysis by using book reviews as models noting rhetorical criteria, such as readability, credibility, and evaluative language which she brings to the attention of students. Braine (1995) identifies paraphrase and summary as key teaching issues for composition classes and, based on the frequencies given above, suggests discipline specific classes reduce their focus on the research paper.

Within the general academic community, citation practices within disciplines of engineering, e.g. electronic and mechanical, have been shown to be different (Hyland, 1999; Tribble & Thompson, 2001), and within disciplines different genres, e.g. theses and journal articles, frequency and type of citation differ (Thompson & Tribble, 2001). Hyland (2000, pp.41-62) has identified significant disciplinary differences in the amount of praise and criticism in such reviews with Engineering (Electrical and Mechanical) being significantly less critical than other disciplines in evaluating books. Other differences between science and engineering disciplines at the level of dissertation writing have also been documented, and remain under-investigated as a source of information about the needs of non-native speaking postgraduates (Dong, 1998). Bloch and Chi (1995) show that although Chinese and English speaking have different citation strategies these are not significantly different in the physical sciences, and Chinese writers are as 'critical' as their English speaking counterparts.

Given the heterogeneity of student backgrounds and the somewhat ambiguous relevance of the literature review to students, the initial drafts of some students reveal an inability to use the research literature as background to developing a writer position or claim. In addition, a substantial and initially unpredictable weakness among students in sourcing citations, let alone synthesizing previous work, became obvious. These processes and outcomes are embedded in the teaching syllabus outlined below.

Literature Review as a focus for developing coherent critical student writing

Reading resources for the course refer to the classroom genres used for assessment, for example the literature review, and oral presentation, and come from standard texts on engineering and science communication and writing, e.g. (Alley, 1996, 2003; Kschischang, 2000; Silyn-Roberts, 2000). During the first four weeks, which culminate in a critical review of an article from the student's field, we discuss cultural expectations about academic work (Bartlett, Holznkechy, & Thom, 1999), define critical text work (Facione, 1998) and review key aspects of grammar and writing, plus the characteristics of graduate text types, such as the summary (Swales & Feak, 1994). I also include a focus on the notion of text coherence as the underlying principle for adequate academic style (Gopen & Swan, 1990; Williams, 2000). Four assignments (three written and one spoken) incorporate 'critical engagement' as a key marking criteria.

Choice of article for written reviews needs to come from the sub-discipline of the students and meet my criteria, such as my stipulation that refereed journal articles from standard database sources, e.g. IEEE Xplore, are used. I take responsibility for reading the original texts for assignments 1 and 2 and such reading has familiarized me with a range of current topics in the sub-disciplines of engineering. Students are recommended to 'sustain' the same research topic through the assessment tasks so as to build cumulatively towards an extended understanding of an issue. Topic continuity also helps me identify an area with a student. In

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the case of the research students, the literature review takes on a different function and value compared with coursework students since it may be immediate preparation for thesis writing. The nature of acceptable critical text work is not fixed. Students are exposed through authentic genres and content in their discipline specific classes to different forms of critical text work. In addition, they come from cultural traditions where existing practices of critical analysis vary. Both sources of understanding then feed into a negotiated form of critical thinking and writing, which I propose through texts and teaching. The outcome in writing and speech, therefore, is necessarily particular, and I while assess on the basis of pre-established criteria, requires that I bear the above mentioned factors in mind.

Evaluating quality of teaching and critical engagement

Independent student evaluations of the course have been consistently high across four semesters (2002-2003) ranging between 4.2-4.6 out of 5.0 on quality of teaching. I also ask students to reflect on critical thinking as they have come to understand it, and most point to the fact that it was both relevant to their field, and that their other engineering courses included a focus on this. The following 'critical' themes are identified in their responses:

- Other engineering subjects do not require critical appraisal
- Poor language proficiency makes it difficult to critically appraise
- Grammar and vocabulary not critical appraisal should be the focus of the course
- Critical appraisal cross-culturally is not the same
- Critical appraisal is a Western (Australian) approach and not universal nor should be
- This is the first encounter with critical appraisal for many students
- Students recognize they must adapt to critical appraisal to survive in Australia
- Critical thinking helps independent problem solving
- Critical appraisal while familiar is represented in writing
- Critical thinking requires the writer make evident assumptions about shared knowledge

Students have also provided many other insights on the learning process and these observations have complemented the quantitative measures of quality teaching. In addition, the faculty of engineering has embraced the course as an essential component of its coursework programs, proposing that it become compulsory and accredited within the curriculum.

Conclusion

I view the teaching and assessment processes as an opportunity for 'legitimate peripheral participation' (Lave & Wenger, 1991, p.145) by students in academic discourses and practices My view of the critical analysis process encompasses the reading, synthesis, and evaluation of research-based texts sources, and the production of a coherent critique of such sources in writing which clearly positions the writer and her understanding of the topic in relation to the field. Belcher (1995) notes that unlike some discipline specific teachers she believes student writers 'whether native or non-native speakers, are not automatically made critical through subject-area reading' (p.136). She also acknowledges the debate about whether composition specialists can or should attempt to teach critical analysis, and that students themselves question the relevance and purpose of such teaching. In particular, students from science and engineering often claim that 'professionals in their field never argue' (p.137) but rather build cumulatively on each other.

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Student and faculty responses to the program suggest that an applied linguistic contribution is possible and can create quality outcomes for students.

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Overcoming the Difficulties Faced by International Students Undertaking Engineering Coursework Dissertation Projects: A Web-based Troubleshooting Guide

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Abstract: *A large majority of international postgraduate students in the Faculty of Engineering and Information Technology, Griffith University, commence their Masters Program with limited research experience. In particular, some international students were never encouraged, in their undergraduate studies, to critically evaluate or to plan and manage their own research projects. Moreover, these students were not generally encouraged to construct an argument and validate it. This problem, in conjunction with language difficulties, makes it very difficult for international students to understand the objectives and expectations of a thesis project. In many cases, it is up to the supervisors to provide a high degree of individual consultation on research fundamentals to bridge the gap between the students' existing research skills and their required proficiency level. The objectives of this paper were to evaluate the research capability and the barriers facing international students when conducting a thesis project. A structured interview approach was proposed for this purpose, addressing questions relating to the difficulties faced when undertaking various elements of the thesis project. Also, respondents were asked to rate provided coping strategies to overcome these difficulties. The primary outcome of the study is the development of an improved supervision approach, which should shift the current one-on-one highly consultative process, between the supervisor and student, to a diversified approach where the student has the opportunity to attempt self-learning. Students who utilise the proposed approach should be better able to visualise the 'process map' for their project and deliver improved research outcomes. The proposed hybrid supervision approach incorporates a web-based troubleshooting guide to encourage students to attempt self-learning.*

Keywords*: international students, thesis projects, supervision process*

Introduction

International students attending Australian Universities frequently encounter problems in adjusting to their new social environment. To address this issue, numerous researchers have examined the general difficulties international students face when adjusting to typically 'western' higher education institutions (e.g. Chartrand, 1992; Rosenberg et al., 1995; Hurtado et al., 1996). However, few researchers have examined the difficulties faced by international Masters students undertaking coursework thesis projects. In addition to 'adjustment' problems facing these international students, they must also embrace a deeper level of learning and thought that is

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usually far removed from their undergraduate experience. In particular, many international students struggle to adjust to a learning environment where students are encouraged to choose a research topic, research approach etc. in mediated consultation with their supervisor. Traversing this 'learning culture' abyss can take some students six months before they are ready to tackle the challenges of their projects.

In an attempt to investigate the difficulties faced by international students undertaking engineering thesis projects, this study utilises a structured interview approach with 10 international students undertaking research projects in the field of engineering management. Specifically, the study sought to discover the significant difficulties faced for the different elements and sub-elements of the thesis project and requested students to comment on suggested strategies to overcome these difficulties.

Difficulties faced by international students

In recent years, the proportion of international students participating in the Australian higher education sector has increased exponentially. Moreover, this same trend is being experienced in the US, in Europe and in other developed nations, resulting in an opening awareness of the international dimension in higher education (Callan, 2000). However, in many cases, international students studying in Australia typically link socially with similar others, hardly interacting with local students (Knight, 1997). Since the English language has come to play a prominent role in internationalising curriculum and linking the academic profession, it has become essential for international students to have a high level of English proficiency prior to commencing dissertation writing. A number of studies from English-speaking host countries suggested that international students' overall ability in English is closely related to their academic success and overall adaptation (Barrett and Huba, 1994; Lewthwaite, 1996). This is particularly true for thesis writing, where a student may undertake a high quality research project but does not receive a commensurable grade because they failed to articulate their literature review and findings in a professionally structured academic writing style.

Although, the mastering of academic writing and verbal presentations in English is one of the fundamental difficulties facing many international students, they also must adapt to different teaching and learning styles to successfully complete their thesis project. In particular, research undertaken by Tompson and Tompson (1996) cite behavioural characteristics such as limited classroom participation, not asking for clarification, and studying only with international students as behaviours that undermine international students' academic performance. Moreover, before international students can become confident self-learners they must make a significant behavioural adjustment by shifting from an instructional method of learning to a free learning environment in which they have to solve problems rather than memorising facts (Ladd and Ruby, 1999). In particular, students needed to be more independent in their approach instead of relying on thesis supervisors.

In summary, international students must typically overcome a number of difficulties when undertaking each element and sub-element of their research projects. Difficulties, such as those mentioned above, were extracted from the literature and were linked to these various elements of the thesis project. For the purpose of this study, the thesis project consisted of eight distinct elements: (1) Formulating the research proposal; (2) Undertaking the literature review; (3)

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Developing the research method; (4) Conducting the experiment; (5) Data analysis and results; (6) Discussion, conclusions and recommendations; (7) thesis write-up; and (8) Research presentations. These core elements are described in Table 1. Moreover, Table 2 details a summary of each thesis element and its' respective sub-elements (activities) where international students may face difficulties.

Research method

The elements and sub-elements of the thesis project, where it was envisaged that students would face difficulties, were collated, screened, and refined through consultation with students and academics. In order to ascertain the significant difficulties faced by international students and possible strategies to overcome them, a structured questionnaire was developed with the aim of achieving the following research goals:

- Determine the background and industry/research experience of Masters coursework students;
- Determine the level of difficulty faced for each element of the thesis project and its' respective work demand requirements;
- Determine the level of difficulty faced for each sub-element of the thesis project and the predominant support method used to overcome this problem; and
- Determine the most effective strategies to be implemented that could potentially make the above-mentioned research elements less difficult to tackle for future students undertaking coursework research projects.

In order to achieve the above research goals, the structured interview process contained questions on the background of the survey respondents (Part A), including, their research experience, industry experience, supervision profile, credit point progression and type of thesis project. This was followed by Part B which addressed each element and sub-element of the thesis project and asked respondents to rate the level of difficulty faced when undertaking that element on a scale of '1' to '5', where 1: *Not difficult* to 5: *Extremely difficult.* Respondents were also required to detail the predominant method used to overcome this problem from a *coded* list e.g. supervisor consultation (**SC**) etc. The third and final section (Part C) provided respondents with the opportunity to rate the effectiveness of a number of proposed strategies and the option to detail other strategies to overcome difficulties faced during the research process.

Data analysis and results

Respondent profile

As this paper only reports on the pilot study component of the research project, only 10 structured interviews were conducted to obtain the data for the results presented herein. However, these results provide some indication of the key areas where international coursework engineering students face difficulties when undertaking research projects. Additionally, it should be mentioned that this study only targeted students undertaking research in the engineering management strand and does not include responses from the structural or civil strands. These students will be targeted in future studies. Students studying the Masters of Engineering in Engineering Management typically come from international Universities and have a wide variety

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of undergraduate engineering backgrounds. The percentage breakdown of undergraduate studies undertaken by the surveyed masters students are as follows: industrial engineering (57%) was the most commonly undertaken undergraduate degree, followed by Mechanical (29%) and then civil/structural engineering (14%).

The most common countries where the students undertook their undergraduate degrees were China (29%) and India (29%). The majority of students commencing the Griffith University Masters of Engineering program have some form of industry experience with 86% of students stating they had 0-3 years experience. Also, it should be noted here, that 57% of students had completed some form of thesis project in their undergraduate engineering studies. The next part of the questionnaire sought to determine the supervision frequency of Masters thesis students: (1) 1 per month – 28%; (2) 2 per month – 29%; (3) 2 per week – 29%; and (4) 1 per weeks 14%. It can be seen that students have a wide range of supervision requirements or access to their supervisors. Finally, all respondents had finished at least 50% of their thesis projects when completing the questionnaire.

Degree of difficulty faced for each element of the thesis project

For the purpose of this study, the research thesis project consists of eight distinct elements described in Table 1. For each of these elements, respondents were asked to indicate the percentage (%) breakdown of time, or envisaged time to be spent, on each element of the thesis project. Additionally respondents were asked to rate the level of difficulty faced when undertaking each element of the thesis project, on a scale of '1=Not difficult' to '5=Extremely difficult'. From Table 1, the data analysis and results (17%) and thesis write-up (19%) stages of the thesis were the most demanding aspects for international students. However, the most difficult elements of the thesis project, for international students, were the formulation of the research proposal (3.29) and the discussion, conclusions and recommendations section (3.29). In general, respondents did not indicate, that undertaking the literature review (2.86) and developing the research method (2.86) was difficult. As expected, international students would have some difficulty formulating the research proposal because they are given a tight timeframe of three weeks to do this task only shortly after commencing their studies in Australia.

In addition to detailing the difficulty faced for each element of the thesis project, the respondents were also requested to rate the degree of difficulty faced for each sub-element (activity) of the thesis (Table 2). For example, for element A: Formulating the research proposal, the thesis sub-element (activity) is Q1: Deciding on a research topic to commence. The highest ten ranked activities where students faced difficulties when undertaking Masters coursework thesis projects are detailed below:

1. H-Q39: Answering questions relating to the thesis project (4.17)
2. H-Q35: Presenting fluently and clearly in English (4.00)
3. H-Q40: Applying suggestions made to improve future research approach (4.00)
4. F-Q26: Compiling the results into the key conclusions of the study (3.80)
5. F-Q28: Linking the key conclusions back to similar research studies (3.80)
6. B-Q9: Collating information into a concise summary (3.67)
7. B-Q12: Identifying the research 'gaps' where your study can add value (3.67)
8. G-Q29: Concisely writing in English (3.67)
9. E-Q22: Determining what data analysis techniques to use (3.60)

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10. F-Q25: Finding and explaining the pertinent findings of the study (3.60)

From the above list, it seems that international students struggle with their research presentations with the top-three ranked difficulties all relating to the thesis presentations element of their thesis project. Also, the students seem to have problems in collating literature into a concise summary, identifying 'gaps' where their study may add value, and explaining the pertinent findings of their study concisely in English. These are the key areas where students should be provided additional teaching and learning support.

Table 1: Demand and difficulty of thesis project elements

***Thesis Element*: description**	**Demand (%)**	**Mean Difficulty**
A. Formulating the Research Proposal: Concerned with the selection and formulation of the research proposal.	10	3.29
B. Undertaking the Literature Review: Concerned with the literature review process, including: finding, reviewing and critically assessing the literature.	12	2.86
C. Developing the Research Method: Refers to the development of a solid research process to answer proposed research questions.	10	2.86
D. Conducting the Experiment: Focuses on the experiment utilised for answering the research question(s). The experiment utilised can be a questionnaire, interview, laboratory experiment, modelling etc., depending on the strand of engineering thesis undertaken.	11	3.20
E. Data Analysis and Results: Covers issues associated with the techniques and tools used to analyse the results of the experiment i.e. statistical techniques, plotting trends, regression analysis, etc.	17	3.00
F. Discussion, Conclusion and Recommendations: Concerned with the formulation of a 'response' to the obtained results. This element includes the examination of key trends, the in-depth examination of results, developing recommendations, and proposing future research to be undertaken at a later stage.	12	3.29
G. Thesis Write-up: Concerned with the structuring and writing of the thesis dissertation.	19	3.14
H. Research Presentations: Concerned with the development and delivery of research presentations.	9	3.14
SUM	**100%**	

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Table 2: Thesis project elements and sub-elements

Q.	Project element and sub-element	Mean
A. Formulating the Research Proposal		
Q1	Deciding on a research topic to commence	2.83
Q2	Writing the thesis brief	1.67
Q3	Finding a suitable thesis supervisor	1.83
Q4	Identifying the 'gaps' in the literature in your research field	3.17
Q5	Deciding on a project scope which matches the available timeframe	3.00
B. Undertaking the Literature Review		
Q6	Discovering how to search and retrieve research articles	2.33
Q7	Reviewing articles to determine their key research outcomes	2.17
Q8	Understanding how to properly reference different types of articles	3.33
Q9	Collating information into a concise summary	3.67
Q10	Critical analysis of reviewed articles	3.33
Q11	Determining the current state of the research	3.00
Q12	Identifying the research 'gaps' where your study can add value	3.67
C. Developing the Research Method		
Q13	Deciding on an appropriate experiment to answer questions	3.00
Q14	Examining the feasibility of the experiment in the given timeframe	2.83
Q15	Ensuring that the experiment will successfully answer the question	3.00
Q16	Determining whether adequate research facilities are available	2.83
D. Conducting the Experiment		
Q17	Obtaining a suitable amount of data from the experiment	3.00
Q18	Obtaining adequate and timely support from relevant parties	2.80
Q19	Completing the experiment in the scheduled time	2.50
Q20	Designing and conducting the experiment	2.75
Q21	Collecting, sorting and collating data	3.40
E. Data Analysis and Results		
Q21	Learning and using statistical techniques and tools	3.40
Q22	Determining what data analysis techniques to use	3.60
Q23	Utilising data analysis software e.g. SPSS, Excel, design software	3.00
Q24	Compiling data to determine key trends/outcomes/results	3.00
F. Discussion, Conclusion and Recommendations		
Q25	Finding and explaining the pertinent findings of the study	3.60
Q26	Compiling the results into the key conclusions of the study	3.80
Q27	Formulating recommendations for the industry and future research	3.20
Q28	Linking the key conclusions back to similar research studies	3.80
G. Thesis Write-up		
Q29	Concisely writing in English	3.67
Q30	Formatting and structuring the thesis Chapters and Sections	2.33
Q31	Presenting the thesis in a professional format	2.83
Q32	Developing professionally presented Figures and Tables	2.80
Q33	Using reporting software (e.g. Word, Excel, PowerPoint etc.)	2.20
Q34	Referencing articles (books, journals, conferences etc.)	2.20
H. Research Presentations		
Q35	Presenting fluently and clearly in English	4.00
Q36	Developing PowerPoint presentations	2.33
Q37	Determining what information needs to be presented	3.33
Q38	Concisely presenting the overview of project and findings	3.33
Q39	Answering questions relating to the thesis project	4.17
Q40	Applying suggestions made to improve future research approach	4.00

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Learning-support mechanisms utilised

In addition to rating the level of difficulty faced when undertaking individual activities, the respondents were also requested to detail the predominant support mechanism used to overcome this problem from the following *coded* list detailed below:

- **Supervisor consultation (SC):** overcame the problem through individual consultation with the supervisor.
- **Peer consultation (PC):** overcame the problem by consulting peers i.e. speaking to other students, industry professionals, etc.
- **Formal teaching (FT):** the problem was overcome through formal lecturing or tutoring instruction offered in a Course or School workshop.
- **University workshop (UW):** overcame the problem by attending a University workshop i.e. training in SPSS, excel etc.
- **Self-learning (SL):** overcame the problem through self-learning with limited assistance from your supervisor or peers.
- **Professional editor (PE):** utilised a professional editing service to overcome the problem.

The percentage breakdown of the predominant learning-support mechanism used to overcome difficulties faced for the forty (40) sub-elements of the thesis project was determined. In general, the results demonstrate that students mainly utilise only two predominant support mechanisms to overcome their problems throughout the thesis process, specifically, self-learning (42%) and supervisor consultation (33%). Following these two key mechanisms, peer consultation (12%) and formal teaching (8%) are used. Students rarely utilised University workshops (3%) and the provided professional editor (2%) to assist them. As results illustrate that supervisors and their students are carrying the majority of the teaching/learning burden when undertaking coursework dissertation projects.

Strategies to overcome difficulties faced

A number of proposed strategies have been developed to overcome the difficulties that may have been faced by international students when undertaking the above-mentioned activities of the thesis project. Respondents were requested to rate the effectiveness of the proposed strategy on a scale of '1=Not effective' to '5=Extremely effective'. Additionally, respondents were requested to detail other strategies that they perceived to be helpful and their associated effectiveness. Table 3 details the seven provided strategies (A-G) that respondents were asked to rate. In summary, Strategy D (3.86) was rated as the most effective by the respondents. It is interesting to note that the students wanted fixed weekly supervision meetings to guide them, or perhaps push them, through the research process. Moreover, the students would like a mentoring program with senior students to help them through the research process. This option would be beneficial in the sense that it would reduce the level of dependency on supervisor consultation to overcome problems. Only one other strategy was suggested from the respondents *H: The dissertation project should commence in the second semester of the program so that students can discover a field of research, which interests them*. This recommendation should be adopted to enable international students to settle into Australian University life and explore fields of engineering management that interests them, particularly those students who come from a strictly technical background.

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Table 3: Mean effectiveness of proposed strategies

Code	Strategy Description	Mean Effectiveness
A	A web-based step-by-step electronic guidebook detailing an overview of the thesis research process with illustrative examples of each element and sub-element	3.57
B	A comprehensive course on Research Methods that must be completed prior to commencing the Dissertation	3.57
C	On-going School-based workshops detailing various techniques and tools that could be used to assist with the research process	3.14
D	Fixing hourly meetings with supervisors on a weekly basis (i.e. Monday 10-11 am every week)	3.86
E	Develop a mentoring program whereby commencing thesis students are assigned to senior students who are responsible for helping them through the project	3.71
F	Having a fixed weekly workshop, for a two-hour period, with the Supervisor and only his/her thesis students. At these workshops, each student is required to present to the group their progress-to-date and the supervisor will teach relevant research skills to the students. Additionally, students can ask questions specifically relevant to their research project.	3.14
G	Develop a formal course or conduct School workshops in thesis writing and presentation skills i.e. a course in academic writing to provide students with the necessary skills to write concisely in English.	3.00

Web-based dissertation trouble-shooting guide

One of the higher rating coping strategies was the development of an electronic guidebook detailing an overview of the thesis research process and illustrative examples of each element and sub-element of the thesis. The web-based dissertation guidebook was designed in the form of a troubleshooting manual where students could have access to a range of resources and examples to help them overcome problems that they will face throughout the thesis process. It is perceived that the troubleshooting guide should not only enhance the research effectiveness of international Masters students but also reduce their supervision demands. Figure 1 illustrates the basic design of the troubleshooting guide. As detailed in this figure the troubleshooting guide has a number of elements and associated sub-elements to assist students to overcome difficulties that they may face over the duration of their thesis project. Once the troubleshooting guide is completed (Semester Two, 2004), it is proposed that it be disseminated to commencing and existing thesis students via CD and through the learning@griffith web site. Upon completion of their thesis projects, the author proposes to conduct interviews with the users to ascertain the degree of effectiveness of the troubleshooting guide for overcoming difficulties faced during the research

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process. Additionally, supervisors and examiners will be interviewed to determine any variations to supervision demands and the level of quality of completed thesis projects, respectively. This study is proposed for late 2005.

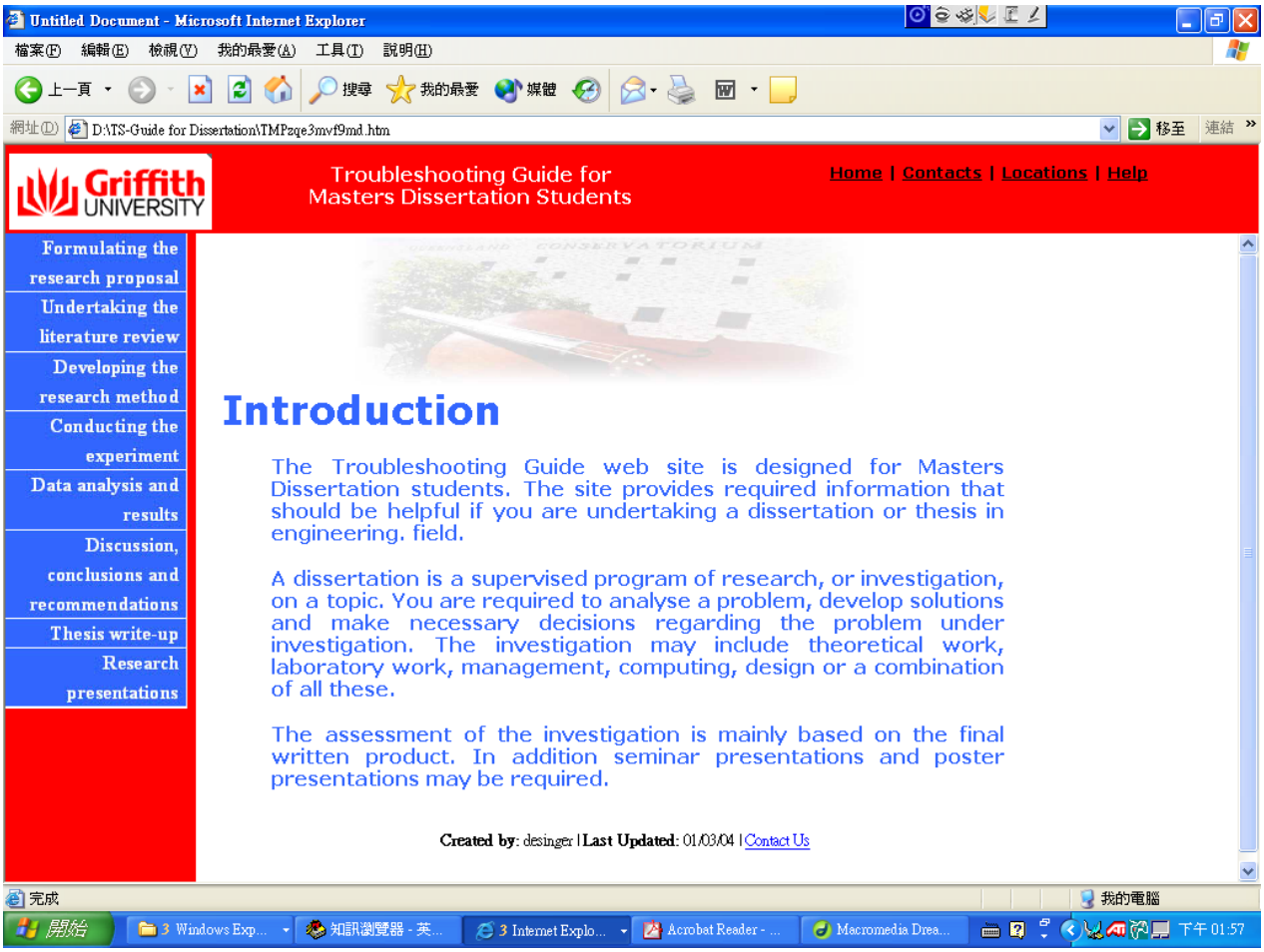


Figure 1: Screen shot of web-based dissertation trouble-shooting guide

Summary

International students undertaking the Masters programs in the Faculty of Engineering and Information Technology at Griffith University typically have limited research and industry experience. This is particularly true in the engineering management stream where many of the international students did not undertake any management-focused courses in their undergraduate studies. Additionally, these students fight an uphill battle when delivering oral presentations and trying to master academic writing in English. In an attempt to improve the current learning approach, this study sought to determine the key areas where students faced difficulties when undertaking their thesis project. To achieve this aim, a structured interview approach was adopted to solicit and consolidate knowledge on the difficulties faced by international students undertaking coursework research dissertation projects. This was undertaken, in an attempt to formulate a set of strategies to improve the research process. In summary, the most demanding

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(i.e. time) elements of the thesis project were the data analysis and results and thesis write-up sections. However, students faced the most difficulties in formulating the research proposal and writing conclusions and recommendations. The predominant learning-support mechanisms to overcome the listed problems were self-learning and supervisor consultation with formal teaching and peer consultation as only minor support mechanisms. The respondents indicated that fixed hourly meetings with their respective supervisors and a mentoring program with senior students would be the most effective ways to overcome the difficulties faced during the thesis research process. Future work will target a larger sample of respondents as well as include results from other engineering streams (i.e. civil/structural). Moreover, the author will attempt to evaluate the effectiveness of the developed web-based troubleshooting guide.

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Opportunities for twinning and collaborative teaching with India in engineering coursework programs at undergraduate and postgraduate levels

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Abstract*: India offers exciting opportunities for Australian Universities for setting up collaborations and twinning in coursework programs in engineering disciplines both at undergraduate and postgraduate levels. In spite of the downturn in the IT industry there is still a healthy demand for engineering education in India at undergraduate (UG) and postgraduate (PG) levels. Current demand in engineering places in India is unmet locally. It is well known that Indian students look at institutes with foreign partnership favourably for tertiary education. Therefore, by establishing twinning arrangements with Indian partners in teaching at UG and PG levels, Australian Universities can attract many more quality full-fee paying students.*
Twinning arrangements can provide flexible learning paths for overseas students and also provide articulation and advanced standing opportunities into Australian programs at both UG and PG degree level programs. Such programs often require that a certain part of the degree program be taught in the students' home country. The fee charged by the home partner is often half of the fee charged by the foreign institute. Thus the education becomes more affordable for many more students. There are several American and British Universities who have taken advantage of the vast demand for such places in Indian Institutes, but Australian Universities have not yet exploited this opportunity.
This paper provides guidelines for establishing twinning arrangements for joint teaching, especially in engineering disciplines both at UG and PG levels with Indian education partners.

Keywords: *Twinning, internationalisation, memorandum of understanding*

Introduction

One of the several activities that strengthen internationalisation of a university is its interaction with overseas partners in onshore and offshore teaching. Joint teaching and twinning programs ensure growth and development of both parties. Such an arrangement also adds to the experience of students as they are exposed to global teaching practices and curricula. Joint teaching interactions are useful in building international links and relationships. Such a relationship can only be productive and sustainable if it is based on mutual trust, respect and reciprocity and must meet the joint needs of the two partners (Sharda 2003).

Autonomous colleges in India provide a golden opportunity for twinning arrangements as they have flexibility of curriculum changes and freedom to negotiate education linkages. The

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Government Institutes are not a suitable target due to the rigidity of curricula and the red tape surrounding the approval processes (Sharda: 2003). The undergraduate (UG) and postgraduate (PG) markets are well established and many Australian Universities attract very large numbers of international students from India particularly in IT and Business postgraduate programs. Vocational Training Institutes also offer a golden opportunity for twinning and articulation/advanced standing partnerships to Australian Universities.

In June 1999, the Association of Indian Universities (AIU) and the Australian Vice Chancellors Committee (AVCC) signed an agreement to cooperate in education. This agreement provides a framework for developing closer ties between Indian and Australian universities. The two organisations are implementing a number of initiatives in the areas of information sharing, faculty and student exchange, development, research exchange programs and university management (Australian High Commission, New Delhi).

Opportunities for twinning programs at UG level

The Australian education system and Indian education have great similarity in structures of program design, as both follow the British model of education (Sharda: 1995).

India has continued to follow the British model of education and the following flowchart gives a mapping of Indian Engineering education system from primary school to higher education.

A careful look at the Indian education system indicates that 12 years of school complete the Higher Secondary education similar to that in Australia. This is followed by 4 or 5 years for an engineering degree depending on whether the program is single degree or double degree. In India the admission to engineering degrees is strictly based on merit and admission tests.

The entrance exams are highly competitive and from class A and class B levels universities in India, (classification provided as per the National office of Overseas Skills Recognition - NOOSR guide) one can attract quality students whose knowledge base would be at a par with the degree level students in an Australian university.

An earlier paper (Sharda 1998) gives detailed information about the steps involved in the selection of twinning partner Institutes. This paper will concentrate on establishing twinning arrangement for teaching in course work programs and how to facilitate a formal memorandum of understanding with an Indian partner for a degree program.

In India the first year of an engineering degree is common to all disciplines. Some of the Australian Universities tend to have separate intake and separate first year curriculum for various engineering degrees. The first year engineering curriculum in Government funded engineering colleges in India is common and does include all disciplines of engineering. A student is allowed to move into a specific discipline only after scrutinising their performance after first year. However, recently autonomous colleges in India have moved to separate intake into various engineering disciplines and moved away from having a common first year.

A case for twinning arrangement set up for Computer Systems Engineering program can be analysed as follows.

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For example, if we choose an autonomous college in India for twinning which is classified as class A, then this classification would mean the college would have similar standing in education standard, staff and resource infrastructure to an Australian University.

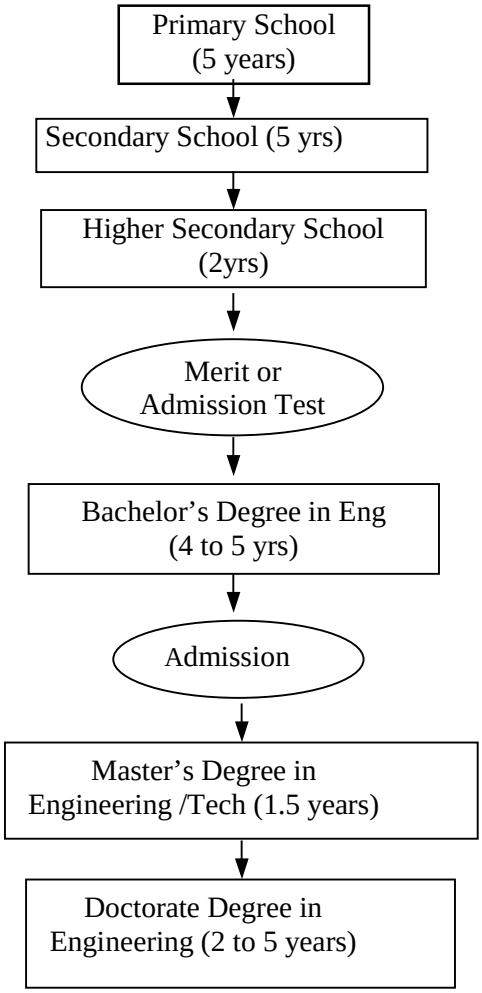


Fig. 1 The Structure of the Engineering Degree in India

Setting up twinning and collaborations in engineering discipline

The twinning and collaboration can be set up for three major objectives

- **For staff development,**
- **For teaching,**
- **For research.**

In staff development the two parties can encourage cooperation, synergy and exchange between their staff in areas of mutual interest.

In teaching the two parties can cooperate in the provision of education and training programs aligned with the needs of industry including components of practical work and on-the-job assignment, to achieve demonstrated competency skills. Australian Universities can establish arrangements to provide advanced standing to students of partner institutes to allow

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articulation students into Australian degree programs. Students benefit as they study in a program, which has international content to courses, and cross – cultural approaches.

In research the two partners can cooperate in industrial research and seeking of grants from industry and government.

Twinning in UG programs

A careful selection of twinning partner requires careful evaluation of curricula, infrastructure, staff profile, and standing of the participating institutes in the national and international scene. All infrastructure and resources should be checked out by personal visits rather than believing from web sites or verbal claims by the Indian partners.

It should be emphasised that the negotiating team members need to have a good understanding of the Indian education system, equivalence of degrees and different boards of examinations. It is not recommended that agents be engaged for carrying out negotiations on your behalf as they all have a vested interest and would never disclose the negative points of the partner institutes or colleges. They can only be employed for making appointments and travel arrangements but must be kept clear from all academic decisions and discussions.

Besides choosing a potential twinning partner, the choice of twinning programs also requires careful evaluation of market demand. It is best to focus on offering twinning arrangements for courses, which are in high demand and have good career prospects.

Setting up twinning arrangements at PG level

Establishing twinning arrangements for partnerships at the postgraduate level would require similar scrutiny as for UG programs. However, given that the typical duration of a PG program in Australia is 3 semesters, it would be required that one semester of the degree program be taught at the host institute and the other two thirds of the program be taught at the Australian University. RMIT had great success in setting up a twinning program in PG programs with Mepco Schlenk College. Students from Mepco Schlenk college complete one semester of course work for the Masters of IT program from their college. The curricula for first semester teaching at Mepco Schlenk College was mutually designed and agreed between the staff of RMIT and Mepco Schlenk College. The College had the responsibility of selecting students into the first semester based on a mutually agreed set of selection criteria. The students were awarded a certificate for first semester completion by the Mepco Schlenk College and after successful completion of first semester, students obtained advanced standing into the MIT program. This resulted in substantial saving in fees for overseas students as the fee charged in India is much less than in Australia. Also the living costs are much less in India than in Australia.

Establishing research links with Indian partners

In order to establish strong research links the two parties must identify common interests and strengths in their respective organisations. Agreements for joint research should be initiated by defining the activities to be carried out together with respective resource contribution and the possible funding source. The research partnerships are best negotiated between individual researchers in their particular field and a formal arrangement can be drawn after negotiations are completed. Only universities which have an international reputation for research should be targeted, as most degree colleges in India do not have a strong research culture as they are mainly teaching colleges.

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The Indian Institutes of Technology (IITs) should be the target for research interaction by the Australian Universities. More scholarships should be given to students from these Institutes as they are the crème in engineering education. The Australian Universities can clearly benefit from such interactions, as the research profile of these institutes is world class.

Intellectual property arising from the activities undertaken within the terms of the agreement should be owned by the parties contributing resources to that activity and an individual agreement should be drawn for each research program arising out of the Memorandum of Understanding (MOU) to define the intellectual property ownership and the sharing of benefits.

Advanced standing arrangements into an Australian university Program

In setting up advanced standing in UG programs, normally the partner college in India would teach the first two years of engineering at their campus with their own resources. In some instances guest staff lectures from the foreign partner institute may be part of the arrangement to give greater confidence to the student body about the involvement of the foreign partner. Some changes in curricula can be carried out to bring out the uniformity in programs between the two partners but they need not be totally identical. After successful completion of the first two years of the degree program from an Indian institute, a student would move directly into the third year of an engineering program of the partner Australian University.

Steps in negotiating a Memorandum of Understanding

The two partners would have to negotiate a MOU that would lay out all the conditions and arrangements which would be formal and binding to both the partners. Some of the points to remember in negotiating an MOU are as follows:

- Set up exchange visits for preliminary investigations between the two partners.
- Have clearly defined aims and objectives, joint teaching and training, joint research or industry interactions, and/or staff development.
- Financial Arrangements: Both parties must carry their own costs unless otherwise agreed. Specific financial arrangements should be settled through consultation between the two organisations in respect of any program of cooperation arising out of a twinning arrangement.
- Action Plan: An annual action plan should be established which should be reviewed and updated as appropriate.
- There should be a termination clause, which should allow either party to terminate the MOU by giving six months notice of termination in writing to the other party. The termination of the MOU should not affect the completion of existing activities where such acceptance or obligations arise prior to the date or receipt of the termination notice.
- Review Process: The MOU should be reviewed by the parties annually.
- It is highly beneficial if each partner understands the legal requirements and cultural expectations of the host countries.

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Conclusion

International teaching partnerships whether onshore or offshore are beneficial in ensuring the growth, development and reputation of participating partners. Such partnerships add value to the experience of domestic and overseas students and foster international relationships and inter-cultural understanding. Joint teaching and research activities also help in playing down the criticism that arises from commercial activities of student recruitment (Stuart: 1998).

The interacting partners must establish clear aims and objectives and set up twinning and articulation arrangements that are based on mutual understanding, respect and reciprocity. Such arrangements must adhere to international best practice and should provide mutually beneficial teaching and research activities. The action plan and conditions should be laid out in a memorandum of understanding, which is clearly understood and agreed by the two parties. Such partnerships help in international visibility, and in the international recognition of Australian universities, provided these partnerships are able to meet the rapidly increasing demand for international education, help in expanding and building new networks for knowledge creation, provide innovative credit transfers and exchange arrangements and maximize the market reach.

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Student-Accessible Tools & Techniques to Aid in Teaching Network Protocols

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***Abstract**: This paper describes some of our experiences in using freely available network diagnostic aids as an adjunct to teaching the TCP/IP (Transmission Control Protocol/Internet Protocol) suite, and discusses our impressions of their suitability for teaching in both on-campus and off-campus modes. A particular focus is on the suitability of such tools for off-campus distance-mode learning, where several problems are present in the acquisition, installation, and use of such tools. Although there are many reviews of such tools from a network administration point of view, these invariably assume an expert level of knowledge, and as such are somewhat inaccessible to the student beginning in this area. Additionally, as they necessarily impact on the computing infrastructure and network security at the installed location, care must be taken in terms of advice given to students – either explicitly or implicitly. We briefly mention the ethical aspects of enlightening students to the possible subversive use of such software for spying, hacking and other activities.*

***Keywords**: TCP/IP, teaching software, ethics*

Background & Motivation

There is no doubt that knowledge of the TCP/IP family of protocols is essential to engineers specializing in data communications and software engineering. The extent to which TCP/IP is studied appears to vary somewhat from one institution to another. In some cases, a superficial treatment is given in a generic "data communications" course which purports to cover the outdated OSI model, whilst in others the treatment appears to be more in-depth. Often, the low-level details – of TCP's flow and congestion control in particular – are relegated to postgraduate courses.

Currently, all students undertaking any courses in the Electrical Engineering & Computer Systems Discipline (EECS) at USQ are required to have both a Windows-based PC, together with Internet access. Certain types of networking experimentation are able to be undertaken off-campus, in the students' home or workplace. For various reasons – including "low-level" access to more than one computer and security considerations – some types of practical experimentation are best done in an on-campus, isolated laboratory situation. These two modes of experimentation are complementary to each other.

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The EECS discipline currently has one undergraduate theory course addressing IP protocols, which is supplemented by one laboratory course. Approximately 50% of the theory course is devoted to network protocols. The laboratory course requires students to attend a lab session for three hours per week over 13 weeks for on-campus students, or one full week for off-campus students. Difficulties with these arrangements are twofold:

1) The attendance requirement for off-campus students creates a considerable financial burden – particularly on overseas students.
2) Not all students who undertake the theory ("academic") course are required to study the practical component. In particular, coursework master's students only undertake the theory course.

In order to address these issues, the possibility of operating laboratory courses at off-campus locations presents itself. Ideally, these would require a minimum of laboratory setup and maintenance. Another possibility, which also addresses the second issue, is to more fully integrate laboratory work into the theoretical course component, thus developing an investigative student-directed approach to learning.

The remainder of this paper presents some of our initial experiences in this area, and discusses some possible future directions. It should be viewed as an exploratory work, as it is under considerable development. It is hoped that such a presentation may initiate some debate into both the practicality and efficacy of investigative practical work as a learning methodology.

Textbook Approaches

There is no doubt that teaching communications protocols from a textbook-only approach is very dry and uninteresting, even for the most motivated students. Our position is that students today are equipped with a superb but underutilized learning vehicle in this regard – their Internet-connected PC. Having noted that, there is a plethora of network software available – most of which is either not suitable for instructional use, or at the very least requires considerable tutorial guidance in its correct application. Without careful guidance, the student is quickly overwhelmed in a sea of meaningless data.

Standard textbooks such as Steven's classic text (Stevens 1994) have served well as a definitive reference, but it is our position that the pedagogical value for anything other than advanced-level students is less apparent. Hall's text (Hall 2000) is arguably more approachable, though still formidable to the beginner. An approach to motivate interest by way of experimentation may be a good starting point.

Problem-Based Exercises and Distance Mode

Our initial experiment in setting problem-based exercises for self-directed learning is available from Leis (2004). Briefly, this approach requires an investigation on the part of the student into some IP protocol data packets, in order to determine the sequence of events in web-browser and other transactions, and to understand the packet checksum calculations. In our academic course, students undertake a small amount of ad-hoc experimental work using their own computer and network. However, the data packet contents are given to them in hexadecimal form – there is no active participation on the part of the student in collecting the packet data. Furthermore, this largely precludes the use of different data packets for different students as one method of combating plagiarism.

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On this basis, and considering the problems discussed in the previous sections, we formed the opinion that a far greater reliance on self-directed learning is appropriate in this context. Given the plethora of software available for network diagnosis and analysis, we have attempted to form an opinion as to what protocol software is suitable in an educational context.

Installation Issues

One issue of paramount importance is the computer user status of students who will be asked to install these software tools. That is, many hardware-level drivers and protocols requiring access to physical devices and privileged IP ports require Administrator privilege under Windows, or Root ("superuser") privilege under Unix systems. This cannot be guaranteed in all environments, and must be made clear from the outset. Any set tasks that erroneously assume a particular account status for the student user is bound to generate a flood of emails, each with a slightly different variation on one or other installation problems. The only mitigating factor is that most students will have access to a home PC for software installation. A more fundamental issue is that of choice of operating system. Anecdotal evidence indicates that the vast majority of students use Windows, with some (around 5% or less) having dual-boot Linux systems, and even fewer having FreeBSD or other systems. In addition, it appears that very few overseas students (certainly in South-East Asia) actively use Linux or other alternatives. Of course, it is dangerous to extrapolate such informally gathered evidence, but as a starting point it is not an unreasonable assumption to assume that all students will have access to a Windows system of some sort.

We should also mention the network issues, which the student may only have limited control over. Company LANs, intranets, and ISPs have varying configurations and policies that may produce false or misleading results when performing network experiments on a "live" system. Examples of this include:

- port-blocking firewalls;
- non-forwarding of ICMP traffic;
- caches and proxy servers, and
- policies forbidding the capture of data from shared networks.

If the possibility of any of these is not taken into account, the results may be somewhat misleading. Examples of problems that may occur include expected responses that do not eventuate, and different responses from proxy servers as compared to origin servers,

Basic Network Tools

We have previously examined the use of inbuilt tools such as *winipcfg* or *ipconfig*, *arp*, *ping*, *netstat*, and *tracert* (Leis & Snook, 2002). These should be relatively straightforward to use, and many interesting and useful experiments can be undertaken with these, provided some caveats are observed. For example, the combination of *ping* and *arp* to illustrate address resolution is likely to produce somewhat different results over shared Ethernet when compared to dialup (PPP) links; switched Ethernet also limits traffic to that directed to/from the local host computer.

The abovementioned utilities are command-line based tools. This in itself is not a bad thing, as it introduces students to the usefulness of the many command-line tools available. A

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Windows tool, which presents a graphical interface to many network functions, is the *cyberkit* set of utilities, available from Neijens (2004).

Figure 1 shows a sample "ping" session, which illustrates packet fragmentation. In this case, the IP headers were set to have the "don't fragment" option set, and the packet size was set one above the underlying Ethernet's Maximum Segment Size (MSS).

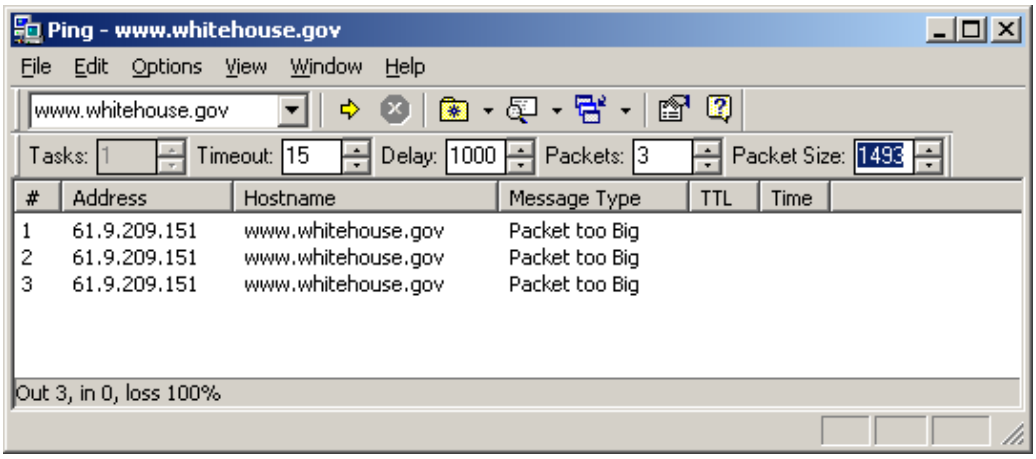


Figure 1: A sample output from the *ping* utility within the *cyberkit* application.

Subnet Calculators

The issue of subnet calculations is one that causes the most difficulty to students. The Windows calculator is an easily accessible tool in this regard – with the options set to "scientific", it is able to perform hexadecimal and binary calculations.

A great many online subnet calculators are available, usually based on JavaScript but sometimes on Java or server-side executables. Examples include AnalogX (2004), Vonkeman (2004), SubnetOnline (2004), and Boson (2004).

Packet Capture Tools

There are several packet capture/analysis tools available. The fundamental drawback is that they require the adapter to be set in promiscuous mode, in order to capture all packets. This invariably requires high-level privileges in order to install the packet capture driver. The widely used Unix Berkeley packet capture library *pcap* has been ported to Windows, as *WinPcap* (WinPcap 2004).

Low-level packet capture can be done using *windump*, which is a port of the Unix *tcpdump* tool (Windump 2004). This is a command-line tool, and although extremely powerful in terms of packet analysis, it is not particularly edifying to the uninitiated. A graphical capture tool, *analyzer*, is available for this task (Analyzer 2004). As shown in Figure 2, analyzer is able to show both a summary of the captured packets, together with an icon-based inspection facility. This performs decoding of the packet contents, and is well suited to instructional purposes with appropriate guidance.
An alternative to Analyzer is Ethereal (Ethereal 2004). Ethereal is a port of the Unix application of the same name, an as such includes a different "look-and-feel" GUI to most Windows programs. We feel this is likely to be confusing to the uninitiated. Ethereal requires the same *winpcap* packet capture library as Analyzer. Yet another packet capture tool in

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common use is “snort”; a Windows port is available at DataNerds (2004), although as of this writing we have not evaluated this tool.

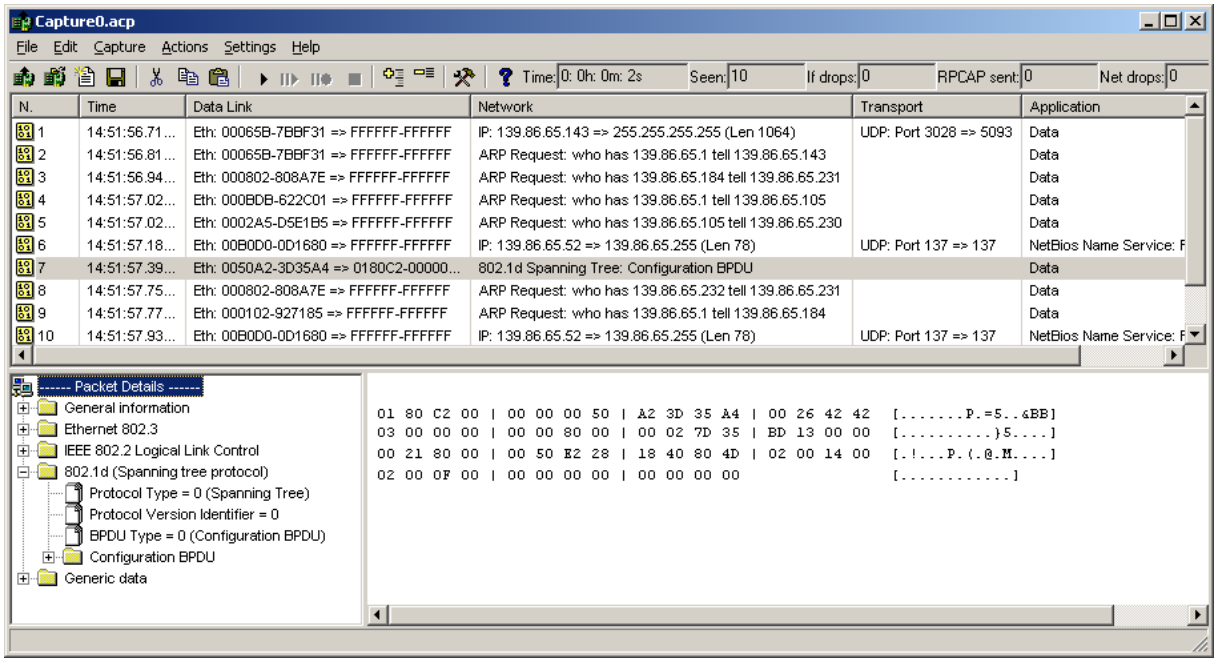


Figure 2: The *analyzer* packet capture tool.

Overall, it appears that Analyzer is the most intuitive for Windows users, as it has apparently been developed for a Windows platform from the beginning. One problem encountered is that whilst *winpcap* works extremely well for Ethernet adapters, it currently does not work for PPP adapters. This precludes its use for the significant number of students using dial-up links.

One other packet analyzer worthy of note is *PacketMon*, available from AnalogX (2004*a*). This particular tool is noteworthy in several regards. First, it is only a very small download. More importantly, it does not require the low-level *winpcap* packet capture driver to be installed. Although at first sight this appears to be a significant advantage, it comes at a price. *PacketMon* uses raw IP sockets, which means that it has access to the IP layer packets, but not the link-layer packets. The net result is that link-layer headers are not visible, and more importantly, neither are protocols such as arp which exist only at the link-layer. Nonetheless, *PacketMon* is a very simple tool and quite straightforward to install. For instructional purposes, it may in fact be easier to interpret packets without the link-layer header, provided this was made clear in any instructional material. Once attractive feature of *PacketMon* is the ability to track a trace of TCP or UDP packets based on source and destination addresses and ports. This allows, for example, a HTTP flow to be identified.

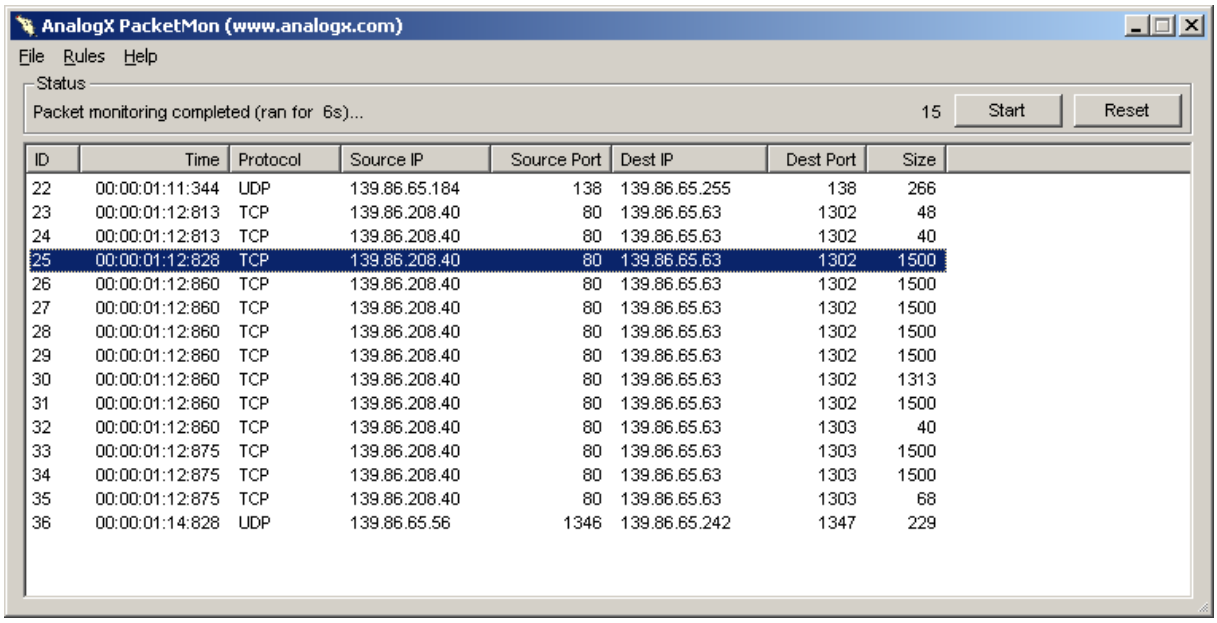
Remote Packet Capture

Winpcap also supports *rpcapd*, a remote capture daemon (Winpcap 2004*a*). This may be useful in setting up remote packet analysis for the student who is unable to capture packets from their local network.

Although seemingly attractive, several problems are apparent:

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1. The security aspects in terms of viewing packets traversing a network may mean that an isolated laboratory LAN may need to be set up for the express purpose of remote packet capture. This implies that some arbitrary traffic generators would also be required.
2. The remote capture port (the default is port 2002) may be blocked by firewalls.
3. Regulating access where there are potentially several remote clients may also present a problem. This would require additional testing, which we have not performed.
4. Analyzer is still required as an executable on the end-user's machine.



ID	Time	Protocol	Source IP	Source Port	Dest IP	Dest Port	Size
22	00:00:01:11:344	UDP	139.86.65.184	138	139.86.65.255	138	266
23	00:00:01:12:813	TCP	139.86.208.40	80	139.86.65.63	1302	48
24	00:00:01:12:813	TCP	139.86.208.40	80	139.86.65.63	1302	40
25	00:00:01:12:828	TCP	139.86.208.40	80	139.86.65.63	1302	1500
26	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1500
27	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1500
28	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1500
29	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1500
30	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1313
31	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1302	1500
32	00:00:01:12:860	TCP	139.86.208.40	80	139.86.65.63	1303	40
33	00:00:01:12:875	TCP	139.86.208.40	80	139.86.65.63	1303	1500
34	00:00:01:12:875	TCP	139.86.208.40	80	139.86.65.63	1303	1500
35	00:00:01:12:875	TCP	139.86.208.40	80	139.86.65.63	1303	68
36	00:00:01:14:828	UDP	139.86.65.56	1346	139.86.65.242	1347	229

Figure 3: The *packetmon* packet capture tool: packets captured in a session.

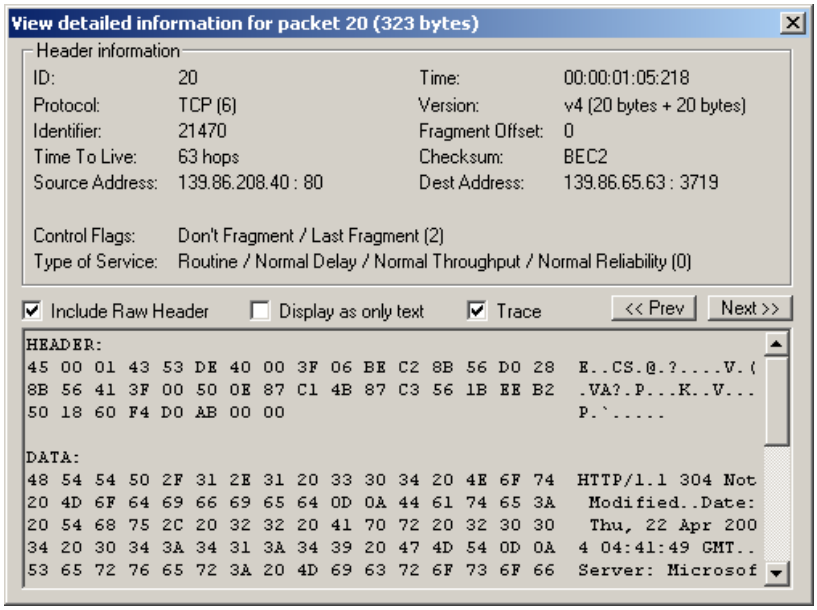


Figure 4: The *packetmon* packet capture tool: examination of an individual packet.

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Web-Based Packet Analysis

One alternative to remote packet capture is to display previously captured packets as a web page. Analyzer is able to save packets in HTML format, using Javascript menus to give dynamic expansion of the decoded packet fields. Although not dynamic capture as such, it does lend some measure of interactivity to the decoding of packets. Figure 5 shows an example of a web-based packet capture session using Analyzer.

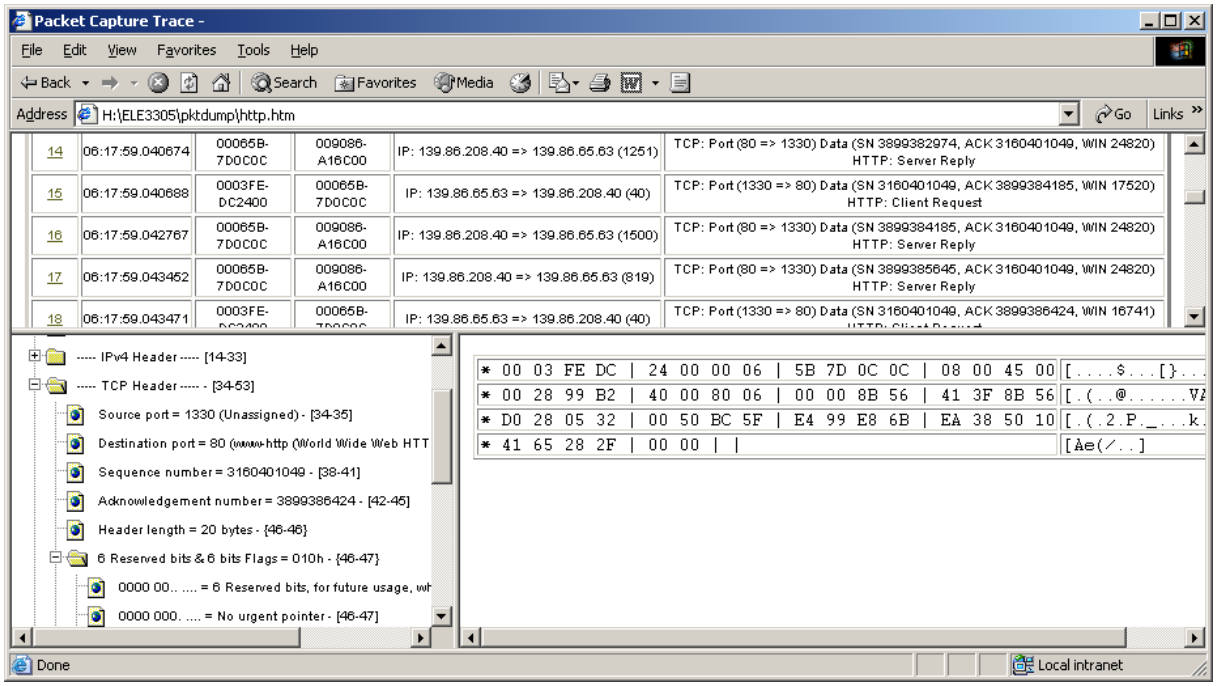


Figure 5: Web-based display of captured packet traces. The display is dynamic, but the packets have been stored previously as fixed HTML pages.

TCP State Analysis

When delving in to the TCP protocol, a number of complications arise both in the packet header format and the state information held at each end of the connection. This is particularly difficult to explain without concrete examples. The TCP state transition diagram (Stevens 1994a, 1994b) shows all the required TCP states and transitions, but is not particularly helpful to the newcomer.

Considering this, the tool *tcpview*, when used in conjunction with the above state transition diagrams, is quite valuable in an educational context (Russinovich 2004). Figure 5 shows a typical *tcpview* diagram. It is useful when performed in conjunction with a web browser refresh, to show the TCP states (ESTABLISHED, CLOSE_WAIT, etc) which a connection goes through in its lifetime. One caveat is that some stages (such as FIN_WAIT_1) are quite short-lived, and most likely will be missed using *tcpview*.

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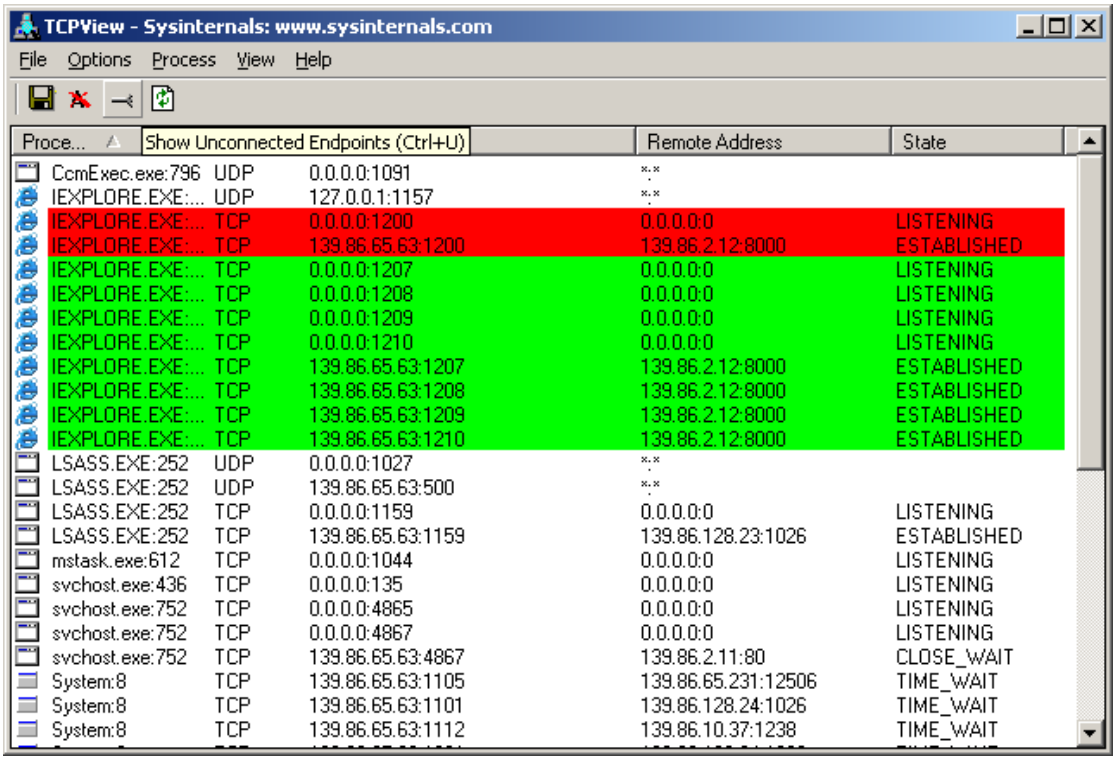


Figure 6: The *tcpview* connection state viewer.

Additional Tools

We have introduced several software tools which may be of use in the teaching the low-level details of networking. There are many other possibilities: tools which access the domain name system (*dig*), routing tools, portmapping (*nmap*), and packet generation (*netcat*). One other possibility is the fabrication of custom-made tools -- either by the instructor or developed as part of the coursework -- for such purposes. This implies a course which has either prior or concurrent exposure to network programming. We have developed several such tools, though their detailed description is beyond the intended scope of this paper.

Ethical Considerations

As well as the technical aspects addressed in this paper, and whilst not the primary focus of this paper, a number of ethical considerations are worth noting when developing such self-directed investigative activities. With such tools being advocated, the question must be asked as to whether a “loaded gun” is being handed to a potentially dangerous individual. These tools can mean access to the capability of “sniffing” for passwords, corruption of network privileges, or obtaining access codes to restricted systems. It raises serious questions regarding liability and culpability (even if only in part) on the provider of the “gun”.

In terms of more local effects on corporate networks or personal computers, these tools raise other questions. These include:

1. The trustworthiness of the software
2. Potential incompatibility with systems.
3. Transgressions of company policy

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The trustworthiness of the installed software is implicit when installing any pre-compiled binary packages. Executables from untrusted sources could introduce trojans, spyware, as well as viruses/worms. The possibility of damage to the user's computer through incompatible software may lead to considerable lost time in re-installing or re-configuring systems because of inadvertent or unforseen incompatibilities.

The use of packet-capture tools in a shared Ethernet environment may lead to transgressions of a company's security policies. Although many newer installations utilized switched Ethernet, where packet sniffing is limited in scope to the installed machine and broadcast packets, some consideration must be given to the fact that shared Ethernets (and wireless installations) may give access to other's data traffic. Not only does this present a dilemma in terms of possible malicious use, it also presents a practical problem where an organization may forbid the use of such devices on their networks. Does the use of such devices for educational purposes provide a mitigating circumstance as defence against breaches of policy? What position, then, does the instructor who recommends such activities hold?

Conclusions

Despite the problems mentioned in this paper, we believe that an approach to introducing network protocols via self-directed experimentation has numerous advantages in terms of motivation, development of self-confidence, development of expertise, and most importantly enhancement of learning outcomes. This paper has presented several software applications which may be used in either a supervised laboratory or an individual learning situation, depending on the specific phenomenon being investigated. It is hoped to present more specific task-oriented examples based on these applications in the near future.

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Part-time employment trends for full-time undergraduate Property and Construction students: results of a 2 year sequential investigation

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Abstract: *This paper reports on the initial findings of an investigation into the experiences and part-time work practices of undergraduates enrolled in the Bachelor of Property and Construction (BPC) and combined degree courses at the University of Melbourne. Initial data was collected from final year students during 2001 and for all four years of the course in 2002. The results suggest that students in earlier years of the course are more likely to work in non-industry (casual) related employment and work fewer hours. Students in later years of the BPC course are more likely to work in jobs in the construction industry and also to work longer hours than those in earlier years. An analysis of final year students shows that the students employed by contracting organisations work significantly more hours than students employed by other types of organisations including architectural practices. The consequences of part-time semester employment on academic performance and students' well-being are considered and proposals are put forward as to how to better manage the industry experience-University relationship.*

Keywords: *Overworked, students' disengagement, career-related jobs*

Introduction

Bachelor of Property and Construction (BPC) students are required to complete three years of study, followed by a minimum of 6 months (12 month industry standard) industry experience prior to entry into the final year. The industry placement is greatly valued by staff, students and employers who regard it as an important learning experience. During their final year of studies, many students continue to work part-time for the same company in which they undertook this practical work. The extent to which BPC students are working during semester time has become a source of concern. Anecdotal evidence from staff suggests that many students are missing lectures and tutorials because of work commitments. In some cases, students report working up to 39 hours each week during semester time as well as endeavouring to complete full time studies. It appears that students' grades are not meeting lecturer expectations. Students' disengagement from University life and the possible impact on their stress and well-being are a concern. The extent and impact of students' participation in paid work during semester time continues to interest higher education researchers.

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The pro's and con's of combining work with study

Lipke, (2000); Curtis and Lucas, (2001) and Curtis and Williams, (2002), have indicated that the cost of financing an education in recent years has increased to such an extent that combining work and study may be a necessity for some students. Curtis and Williams (2002), suggest that students combine paid work and study as a standard routine, suggesting that this is now the norm. British studies suggest that students struggle to pay for basic needs, such as shelter and food and often end up in debt (McCarthy and Humphry, 1995). Some research suggests that semester time work can provide positive benefits to students. The extent of part time work must however be restricted. For example, Watts and Pickering (2000) suggest that skills learned at work are transferable and students who work are more employable due to their development of organisational and time management skills. Working students are also said to develop good inter-personal skills (Lucas and Lammont, 1998). When part-time work is related to students' vocational coursework, it may be particularly beneficial as an aid to academic knowledge and career prospects. Part-time work experience is very valuable when students are seeking permanent jobs upon graduation. In the BPC programme, many students continue to work for the same employer following graduation thereby relieving the pressure of finding employment after graduation. Students hold down their jobs for long periods evidencing that work is a source of satisfaction.

Other writers suggest that semester-time work has a detrimental impact upon students and their study. Watts (2002) undertook a qualitative and quantitative study of the effects of part time work on academic performance. She reports that, though some negative effects were reported, so too were many positive effects and there was no difference between the marks obtained by "working" compared to "non-working" students. In a study by Sorensen and Winn (1993), undergraduate students attributed the negative impact of work on study to having less time available for study, tiredness and the need to miss lectures to attend work. Some studies suggest that students who work up to ten and fifteen hours per week benefit from this but that working longer hours than this is problematic (Curtis and Lucas, 2001).

In an unpublished study at Oxford Brookes University in the UK, it is reported that every year, more than 200 students in part time work gain a degree at least one class lower than they would get were they not in paid work (Lindsay and Paton-Saltzberg, cited in Curtis and Williams, 2002). Taylor (1998) found that, although students were often contracted to undertake work hours that do not conflict with University commitments, often employers subsequently place students under pressure to work hours that do interfere with their study. Watts (2002) however concludes that the effect of semester-time employment on the academic performance of undergraduates is complex.

Given this controversy of opinions, a study to discover the extent and nature of BPC students' part-time work was undertaken at the University of Melbourne. Three main research questions were posed:

- To what extent are BPC students engaged in part-time work during the semesters?
- What type of part-time jobs are BPC students doing?
- To what extent does this part-time work make it difficult for them to engage in University life?

Methodology

Study one

In 2001, students in the final year were surveyed, during semester one, to determine the number of hours they worked on average in semester time. Students were also asked to report their course

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stream and the nature of their work, e.g. whether they worked in a construction-related job or in casual, non-industry-related employment. The minimum and maximum and the mean number of hours worked by each group of students were calculated. Standard deviations were also calculated. Forty five students out of fifty six completed the survey, with a response rate of 80%.

Study two

In 2002, a more extensive survey of all students in the BPC programme was carried out. Students were asked to report whether they worked in part-time work during semester-time, and if so, in what type of work they were engaged and for how many hours. Students were also asked to indicate how many hours on average they spend at the University campus, including attendance at lectures, tutorials, participating in study groups and working on assignments or playing sport. One question asked students to rate, on a five point Likert scale, the extent to which paid work interfered with study during semester time from Not at all (1) to Very frequently (5). Another question asked students to rate, on the same five point scale, the ease with which they could adjust their work schedule to meet their study needs on a scale of Very easy (1) to Very difficult (5).

Results

Study one

	Minimum	Maximum	Mean	SD
Average hours worked per week in semester one	8	50	18.9	9.5
Expected hours worked per week in semester two	0	40	17.6	8.9

Table 1: Overall average hours worked

The overall hours worked by fourth year BPC students in 2001 are presented in Table 1. In semester one, these students worked a minimum of 8, a maximum of 50 and a mean of 18.9 hours each week (SD=9.5).

Course stream	Mean	SD	N
Casual work (non-industry)	12.8	3.8	13
Contractor	24.7	9.2	20
Architect's office	14.8	6.8	9
QS Office	18.8	15.4	3

Table 2: Average hours worked per week in semester one by type of work

- Table 2 shows the average number of hours worked each week by type of employment. Casual work (i.e. non-industry work) consumes the fewest hours each week (12.8), while working for a contractor consumes the most hours each week (24.7).

Study two

One hundred and eleven students responded to the questionnaire. Random checks were undertaken to rule out the possibility of non-response bias. Each year level in the BPC comprises between 50-80 students, and in all cases a minimum one-quarter of the cohort responded.

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Q1-Year Level	Building Construction Management	Construction Economics/ QS	Property	B Arch/ BPC	Non-response	Grand Total
Year Level 1	8	2	3		4	17
Year Level 2	13	5	6			24
Year Level 3	13	6	3			22
Year Level 4	18	4	1			23
B Arch / BPC		1		24		25
Grand Total	52	18	13	24	4	111

Table 3: Survey responses by course and year level

The overall response is shown in Table 3. It should be noted that students undertaking the combined BPC/BArch degree were re-coded into Year Level 5.

Time worked in paid employment

Q1-Year Level	Semester 1	Semester 2
Year Level 1	10.3	8.7
Year Level 2	13.4	12.8
Year Level 3	21.3	19.6
Year Level 4	18.8	19.3
B Arch/BPC	17.9	14.1
Grand Total	16.5	15.0

Table 4 : Average number of hours in paid employment in each semester (Hrs/Week)

The results, presented in Table 4 show that students in years one and two work nearly half the amount of time of students in latter years.

Type of work

This question allowed multiple responses and many students indicated that they did both industry based work and casual non-industry work. The results below have been recoded to separate those students that did Casual only (response "Casual") and those that did industry based work. (response "Contractor/Architect/QS)

Q1-Year Level	Industry Work	Casual Non-Industry	Grand Total
Year Level 1	3	12	15
Year Level 2	4	12	16
Year Level 3	7	9	16
Year Level 4	11	7	18
B Arch/BPC	11	9	20
Grand Total	36	49	85

Table 5: Number of students in industry-based and casual work

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The results above show that 77 per cent (85 of 111) of students do some kind of work. The results show that 44 per cent (49 of 111) do casual work only, and do not engage in any work in career-related jobs. Also, the results indicate that 32 per cent (36 of 111) engage in career-related work and do not undertake any casual work. The results indicate that students in early years (Level 1 and 2) tend to do more casual work than those in latter years.

Ease to change to work schedule to suit study demands

Q1-Year Level	Very Easy	Somewhat Easy	Not Easy or Difficult	Somewhat Difficult	Very Difficult	Grand Total
Level 1	2	8	3	2		15
Level 2		6	6	3	1	16
Level 3	2	2	2	9	1	16
Level 4	2	3	4	9		18
B Arch/BPC		7	6	7	1	21
Grand Total	6	26	21	30	3	86

Table 6: Ease of changes to work schedule to suit study demands.

The results in Table 6 indicate that students in years 1 and 2 generally find it easy to change their work schedule. However, the difficulty increases slightly in latter years.

Perception of work interference with study

Q1-Year Level	Not at all	Very Infrequently	Infrequently	Frequently	Very Frequently	Grand Total
Level 1	2	2	9	1	1	15
Level 2		4	11	1		16
Level 3		5	6	2	3	16
Level 4		4	9	5		18
B Arch/BPC		5	9	5	2	21
Grand Total	2	20	44	14	6	86

Table 7: Perception of work interference with study

The results shown in Table 7 indicate that students believe that work interferes more with study in the later years of the course.

Intention to work in University holidays

Q1-Year Level	No	Yes	Grand Total
Level 1		17	17
Level 2	5	18	23
Level 3		22	22
Level 4	2	20	22
B Arch/BPC	1	24	25
Grand Total	8	101	109

Table 8: Intention to work in paid employment during University breaks

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The responses shown in Table 8 show that almost all students do intend to work in University holidays. This result could indicate that very few students are totally financially independent.

Time spent at the University for study

Q1-Year Level	Semester 1	Semester 2
Level 1	18.8	11.0
Level 2	14.3	13.7
Level 3	20.2	14.2
Level 4	17.6	16.0
B Arch/BPC	17.7	13.6
Grand Total	17.6	13.8

Table 9: Average number of hours spent at the University for study (Hrs/Week)

The results, presented in Table 9, revealed that students spent more time in Semester 1 (17.6 hrs/wk) compared to Semester 2 (13.6 hrs/wk). The results shown below indicate that this outcome was representative in all year levels.

Work and study patterns

Q1-Year Level	Work Sem 1 (Q4)	Study Sem 1 (Q10)	Work Sem 2 (Q4)	Study Sem 2 (Q10)
Year Level 1	10.3	18.8	8.7	11.0
Year Level 2	13.4	14.3	12.8	13.7
Year Level 3	21.3	20.2	19.6	14.2
Year Level 4	18.8	17.6	19.3	16.0
B Arch/BPC	17.9	17.7	14.1	13.6
Grand Total	16.5	17.6	15.0	13.8

Table 10: Comparison of work and study patterns

Table 10 compares students' work and study patterns by course level and semester. These results suggest that students are working a similar number of hours per week to the time they spend undertaking campus-based study. These results suggest that students engage in paid employment for a similar number of hours that they spend on campus. The notion of full-time students with the traditional casual "Saturday job" is therefore no longer relevant.

Discussion

The results of this survey are confirmed by other researchers who also indicate that most students are in paid employment and universities need to consider this impact. The fact that so many students intend to work during University breaks suggests that students are not financially independent and that they have to work. . Students in the BPC programme are working about as many hours as they spend studying on campus.

The results of both studies suggest that, by third and fourth year, BPC students are working an average of around 20 hours per week, although some may be working as many as 40 to 50 hours in industry based jobs. These hours are in excess of the 10-15 hours deemed to be beneficial to the

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educational experience (Curtis and Lucas, 2001) clearly indicating that in the third and fourth years, BPC students are "overworked."

Our results suggest that in the latter stages of the BPC, most students tend to work in industry based jobs and this begins to occur from the third year when students reduce their preference for casual-based work. It is also possible that this trend is related to the structure of the BPC program in which employers begin recruiting students for the practical placement year during their third year of the BPC. This result may indicate that:

- Employers are not prepared to take up students who have a limited understanding of the industry;
- Salary levels for industry based jobs improve over time compared to casual jobs that tend to remain static.
- Students perceive industry based work as being of greater educational/ career development value during the latter part of the course.

The results suggest that students perceive industry-based work to have educational or career-development value.

Despite the reality of student employment, universities have not yet fully accepted the benefits of students' experiences in the world of work (Curtis and Lucas, 2001). A recent British report - the Dearing Report on Higher Education - identified the need to link students' part-time work experiences more closely with the curriculum to enable students to make the most of the opportunity to become more ready for work through learning by experience (Leslie, 1999).

There is a large volume of literature on the subject of co-operative education, which is defined as a form of education and experiential learning which integrates classroom study with paid work experience (Anakwe and Greenhaus, 2000; Garavan and Murphy, 2001). The development of a partnership between the University and the construction industry in providing work experience that complements the programme of study may be helpful. Without this partnership, students may not get the range of experience they need and may struggle to find the linkages between theory and practice.

Arguably, one indicator of University's performance is producing graduates who are useful to industry. It is now understood that desirable graduate attributes include a range of personal and intellectual attributes that extend beyond those explicitly developed in traditional higher education courses. They include such things as negotiation skills, action planning, networking, self-awareness and an ability to manage one's own career. The initiative is based upon Kolb's model of experiential learning which postulates four stages in learning process - experiencing - reflecting - generalising - testing (Kolb, 1984). This model is used to enable students to "unpack" their work experience and spend time on the phases in the learning cycle. A similar strategy could be used to assist BPC students at the University of Melbourne to maximise the educational benefits of their extensive, industry based part-time work. Such an initiative would be more likely to yield positive outcomes if undertaken in partnership with the construction industry.

British research suggests that University students experience difficulty in balancing work and study and experience above average levels of stress as a result (Humphrey et al, 1998). Our results suggest that students in the BPC programme experience similar difficulties in balancing work and study, particularly when they reach the third and fourth years of their degree course. The University should explore ways of mitigating these problems perhaps by introducing more flexibility in timetabling and extending University "opening hours" to assist students who are

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working. However, emotional exhaustion and a feeling of not coping have also been linked to disengagement from University which could negatively impact upon the students' educational outcomes.

Conclusions

Universities have a responsibility to their students to assist them in obtaining the best educational outcomes from their degree courses. Given the reality of student employment, this must include being flexible and supportive of students in paid work. It is also evident that closer co-operation between the University and industry may be necessary to realise the potential for the development of desirable graduate attributes through experiential learning. However, the University also has a responsibility to protect students against excessive demands of work during semester time and to ensure that workloads remain manageable.

The next survey will be completed at a national level with other similar property and construction courses throughout Australia. The research work is ongoing and will explore BPC students' work motivations and the impact of work on educational outcomes and individual well-being and will include questions on the reasons as to why students work.

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Sustainability: Change and Challenge for Teachers, Learners and the Engineering Curriculum

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Abstract: *This paper endeavours to examine the challenges that introducing sustainability into the curriculum brings for academics, students and engineering programs. The paper addresses the various international, national and regional drivers for increasing curriculum sustainability content and environmentally responsive behaviour by Universities. Finally, the consideration of triple bottom line reporting within a common first year engineering subject at The University of Ballarat is discussed as a recent curriculum development to incorporate current sustainability thinking.*

Keywords*: sustainability, triple bottom line, engineering curriculum*

Introduction

Introducing sustainability into the educational system brings a significant challenge for all system elements including educators, learners and the educational programs. Sustainability can be implemented within the educational system, but the road from challenge to change is not smooth or rapid. Identifying the drivers for change provides an important insight to the transitions necessary within the Universities.

Drivers for change: international declarations, resolutions and statements

Agenda 21, the United Nations Programme of Actions from the Earth Summit in Rio has indicated that education is critical for promoting sustainable development (UN, 1992). In preparation for the World Summit on Sustainable Development (WSSD) in Johannesburg, September 2002, Ministers of the Environment from United Nations Economic Commission for Europe (UNECE) had called for initiatives in education and agreed to "improve education systems and the design of learning programmes on sustainable development to increase general understanding of how to implement and promote sustainable development in practice" (UNECE, 2001). WSSD put special emphasis on integrating sustainability into education systems at all levels of education, from pre-school to school to higher education and non-formal education (UNECE, 2003).

In December 2002, the UN Assembly proclaimed the United Nations Decade of Education for Sustainable Development starting on 1 January 2005 and requested the United Nations Educational, Scientific and Cultural Organisation (UNESCO) to develop a draft international

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implementation scheme for this decade (UN, 2002). UNESCO was acknowledged as the lead agency with regard to education for sustainable development.

The UNECE Environment Ministers stated that education for sustainable development should consider diverse local, regional and national circumstances and "encourage broad cooperation at the international, regional and state levels involving all stakeholders including public authorities, the educational community, non-government organisations, business, youth and the media"(UNECE, 2003). They also noted that education for sustainable development was an investment in the future and emphasized that the educators could play an important role in facilitating dialogue between the authorities and civil society.

Driver for change: international strategy for education

The draft UNECE Strategy for Education for Sustainable Development identified the role of education as "a fundamental tool for improving patterns of consumption and production, laying the ground for research and development of technologies that may improve the environment as well as for enabling people to integrate environmental, social and economic issues into their perspectives and actions, starting at a young age." (UNECE, 2004) The draft indicated that the education should be based on an integrated approach to economic, social and environmental development.

Drivers for change: international guides

One of the most important events at the World Summit 2002 was the launch of Sustainability Reporting Guidelines defining the international reporting framework, developed through a multi-stakeholder process by the Global Reporting Initiative (GRI).

GRI is a collaborating centre of the United Nations Environment Programme and works in cooperation with UN Secretary-General Kofi Annan's Global Compact (GRI, 2002). It was established by the Coalition for Environmentally Responsible Economies (CERES) and the UN Environment Program (UNEP) in 1997 to develop and disseminate globally applicable Sustainability Reporting Guidelines and to elevate reports on sustainability to a level equivalent to those of financial reporting; or to put it metaphorically, to develop an environmental balance sheet.

GRI is the internationally accepted framework for sustainability and the guidelines organise sustainability reporting in terms of economic, environmental, and social performance or triple bottom line reporting (TBL). TBL is a planning and reporting mechanism and at the same time decision-making framework used to achieve sustainable development. While recognising the integrated relationships between three elements this structure allows for performance measurement and quantification against the goal of sustainable development.

Various international business sectors are rapidly developing their approaches to sustainable development and managers in these sectors are expected to equally quickly become "sustainability literate". A significant example is the Equator Group of banking organisations. This group has adopted voluntary set of guidelines for managing social and environmental issues

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related to financing projects in all industry sectors, including mining, gas, oil and forestry (The Equator Principles, 2003). Loans will be granted on the condition that projects are developed in a socially responsible manner and according to sound environmental management practices.

A further example is the mining industry's collaboratively funded "mining, minerals and sustainable development project" (Breaking New Ground, 2002). This report indicates that one of the principal difficulties in adopting the agenda of sustainable development is the multiplicity of the individual issues, problems, and proposed solutions.

However, in the first of four major categories of actions to support sustainable development in the minerals sector, it highlights the need to increase the understanding of sustainable development among employees of minerals companies, relevant government agencies, labour and civil society organisations, and others with important roles in the sector. Institutions such as mining schools that have a role in educating future mining and minerals professionals should incorporate sustainable development in their curricula. Also, donors to these institutions should support, encourage and assist on these broadened curricula.

Australian Federal and State Government context

Australia refers to its process for making our way of life sustainable as Ecological Sustainable Development (ESD). The prefix "ecological" was added to the normal international usage "sustainable development" in recognition of the great importance of protecting ecosystems in the context of a continent in which many unique ecosystems were under threat (Australian National Assessment Report, 2002). However, this might have contributed to the belief amongst some that the subject belongs with the discipline of environmental science.

The ESD process, launched in Australia in July 1989, was the first formal government initiative aimed at institutionalising sustainable decision-making. Initially, the ESD process involved a summit of industry, union and conservation organisations. A Federal Government discussion paper, outlining the concept of ESD in Australia, was subsequently released for public comment. Nine Working Groups were then established with independent chairs to consider the implementation of ESD principles in nine sectors of Australia's economy which have major environmental impacts: agriculture; forest use; fisheries; mining; energy production; energy use; manufacturing; tourism and transport (Australian National Assessment Report, 2002).

The final reports from these Working Groups, containing over 600 recommendations, were published in 1991. Although the Working Groups included some State and Territory representatives, not all States were represented in the Groups. Consequently, the original ESD process never received endorsement from all State and Territory governments.

A Commonwealth-State process was established to convert the outcome of the ESD process into something that all Australian Governments could endorse. Hence, in 1992, Australia produced its National Strategy for Ecologically Sustainable Development.

The National Strategy, which was endorsed on a whole of government basis by all Australian Governments and the Australian Local Government Association, agreed to a set of core

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objectives and guiding principles for the Strategy as a whole, and to specific objectives and broad strategies for eight sectoral issues (more or less the same as those covered by the original ESD process but with energy production and use combined) and for 22 cross-sectoral issues (including education and training).

The National Strategy identifies a number of guiding principles (Australian National Assessment Report, 2002), which can be summarised as:

- integrating short and long-term environmental, economic and social considerations in decision-making;
- taking measures to prevent environmental degradation even in the absence of scientific certainty;
- broad community involvement in decisions and actions which affect them.

One of the challenges identified in the National Strategy was that of increasing awareness and application of ESD principles and approach in education and training policy and programs. It identified the most effective strategy for achieving this as being to incorporate ESD principles into curriculum, assessment and teaching practices in the school, technical and further education (TAFE) and higher education sectors. Hence the stated objective of governments working through the Curriculum and Assessment Committee, the Australian Committee on Training Curriculum and Australian Vice Chancellors' Committee with a view to incorporating ESD principles into future curricula.

Generally since the development of the National Strategy, progress on sustainable development has tended to be on a sectoral and specific cross-sectoral basis (Australian National Assessment Report, 2002). Various State Governments have moved to further embody sustainable development into strategies and legislation. Examples include the State Sustainability Strategy in WA (2003) and the appointment in Victoria of a Commissioner for Environmental Sustainability (2003).

Sustainability has also been introduced into the primary and secondary school curriculum by the States. For example, the Victorian Association for Environmental Education has developed a resource kit for VCE environmental science students "Issues of sustainability" (2001), where energy, global warming, biodiversity and biodiversity management are addressed and accompanied by practical exercises.

Environment Australia plays an essential role in promoting TBL reporting in Australia. Among its key publications are: A Framework for Public Environmental Reporting – An Australian Approach (2000) and Triple Bottom Line Reporting in Australia – A Guide to Reporting Against Environmental Indicators (2003). The latter is designed to complement the GRI indicators with specific Australian conditions in mind and link already established Australian indicators and methodologies with the international indicators.

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Local Government initiatives

Many Australian local governments have already made a commitment to sustainability and are seeking to establish effective partnerships between state and local government that effectively supports and recognises the important role that local government plays in sustainability. One such area is in the reduction of their greenhouse emissions by participating in The Cities for Climate Protection™ (CCP) Program. This international program assists councils around the world to achieve sustainable reductions in emissions and is delivered by The International Council for Local Environmental Initiatives (ICLEI) in collaboration with Australian Greenhouse Office.

ICLEI is an international democratic association of local governments (currently over 500 worldwide) implementing sustainable development. Its mission is to build and serve a worldwide movement of local governments to achieve tangible improvements in global environmental and sustainable development conditions through cumulative impact of local action. In Australia, 183 local governments are participating at February 2004, representing over 72% of the Australian population.

CCP™ Program is a good example how greenhouse policies and declarations are translated into practical actions. It provides the councils with a structured milestone framework to identify and quantify the emissions for their own corporate activities and communities they work for, set reduction goals for both sectors and develop and implement an action plan to achieve the reductions. It recognises the crucial role the local government can play in the community through planning powers, policies, regulations, education and its influence on residents and businesses.

Local governments are big businesses themselves – for example, the City of Melbourne has a consolidated annual budget of over $359 million a year, with many regional city annual budgets being over $50 million. Like any other business they make substantial impacts on the environment and are accountable for their emissions from waste disposal, energy consumption, transport and land use.

However, climate protection and preventing the global warming are not the only reasons the councils participate in CCP™ Program. There are financial benefits like saving money on energy, opportunities for local employment, industry partnerships, development of new products and local community leadership.

Engaging universities in sustainability

Universities as major organisations whose business is education and research provide qualified and professional workers for the community and many excellent examples of community leadership in sustainable design exist in Australia and overseas. As indicated by Downey (2004) the universities “contribute towards sustainable development through their roles as:

- places of learning and research – forming and informing the leaders and decision makers of the future;
- major businesses – where prudent resource use not only saves money but safeguards reputations;

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- key community players – as employer, purchaser and amenity provider with a major impact on the wider word of influential ideas and technological development."

The economic, environmental, social and educational impact of a university, especially a regional one, on the community it serves extends beyond just workforce supply. Some universities have started to produce their own triple bottom line reports (MEI, 2002) and are integrating sustainable development into their strategic planning, policies and curriculum.

However, it has been reported that the adoption of sustainability by universities is "hindered by a recent trend towards a business model in higher education where students are regarded as clients, and short-term thinking and competition are promoted over long-term vision." (Bekessy *et al*, 2004). Therefore integrating sustainable development will depend to a certain extent on availability of financial resources that currently are mainly directed towards achieving economic gains. Here significant energy savings, and hence economic savings, by local government, documented by ICLEI via the CCP program, should be readily transferable to universities.

Partnerships

The value of building partnerships between government, business and universities is realised in Australia and a number of Australian universities have signed up to the "Greenhouse Challenge", a Commonwealth Greenhouse program aimed at cooperative agreements between organisations to reduce greenhouse gas emissions through energy efficiency and headed by the Australian Greenhouse Office.

Accreditation

Another way of engaging universities with sustainable development is directly through their roles in education and research. Accreditation of professional undergraduate education programs is a vital component for the assurance of quality and standards against national and international benchmarks.

At the University of Ballarat, Engineers Australia and the Australasian Institute of Mining and Metallurgy (AusIMM) carry out the responsibilities of accreditation for academic engineering programs. D. Jones, the National President of Engineers Australia has stated that the engineering profession must intensify its focus on sustainability and "through the accreditation system of university courses in engineering we can ensure that sustainability becomes an integral feature of every engineering student's education" (Georg, 2003).

Research funding

The Government has nominated "An Environmentally Sustainable Australia" as one of four national research priorities (Research Priorities, 2002). This priority is about transforming the way Australians use the nation's land, water, mineral and energy resources. It will depend on a better understanding of the environment and the application of new technologies to natural resource industries. In addition, all research proposals are expected to consider issues relating to sustainability, taking a triple bottom line approach. One has to pose the question, how prepare are research-active academics to address these issues?

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Student expectations

Yet another way of engaging universities with sustainability is demand and expectations from students. It is perceived that informed knowledge and education in sustainability will improve chances of employment and brings competitive advantage not only among engineers but graduates from other disciplines.

Cortese (1999) indicates increasing student demand at colleges and universities in the United States for environmental education and for institutions to reduce the ecological impact of their own operations.

Downey (2004) provides examples of contributions that American and British students made to the development of the sustainable agenda in their campuses.

The Australian National Union of Students offers an Australian Sustainable Universities Information Resource Kit that includes best practice guidelines, some text materials, useful contacts and links. (NUS, 2001)

Curriculum Challenges

For academic engineering curriculum, sustainable development is a relatively new fundamental concept accompanied by huge amounts of information. It requires methodologies and a practical framework enabling undergraduate engineers to incorporate sustainability into their thinking and deliver Triple Bottom Line performance in their future projects. It also poses a number of questions like:

- What are the best ways for integrating sustainability content?
- What are the barriers for integrating sustainability content?
- Should a separate module on sustainability squeeze into already overloaded curriculum?
- Should a sustainability unit or part of it be included in all engineering subjects?
- Should it be offered as elective?
- Is it better to set up an interdisciplinary approach underpinning the making of a new subject universally applicable?

A sound attempt to devise a new methodology of integrating sustainable development principles into undergraduate teaching is being made at the University of Ballarat. Coming at a time when the course structures have changed from the traditional four-year Bachelor of Engineering (BEng) to one of a three-year Bachelor of Engineering Science (accredited at Engineering Technologist) followed by a 18-month Master of Engineering Technology (accredited at Professional Engineer) in three engineering disciplines – mining engineering, civil engineering and mechanical engineering.

The four-year BEng programs included a third year unit, common to all disciplines, entitled “Technology and Society”. In addition to a consideration of engineering ethics, this unit has evolved over recent years to cover sustainable development including triple bottom line reporting, similar to other reported unit contents (Table 1). This unit also included significant

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student project work such as energy audit projects in collaboration with local government that supported student learning in a community environment.

The recently introduced three-year program did not contain this unit; however it is clear that it was imperative to retain the subject matter and, if anything, further develop sustainability considerations throughout the program. The quantifiable indicators required by triple bottom line reporting were incorporated into the common first semester first year unit "Fundamentals of Engineering (Materials)". This is a logical position for introducing the quantifiable indicators of sustainability such as energy, greenhouse gas emissions, water, waste, the national pollution inventory and materials, and engages students in considerations of units of measurement, formulae incorporating conversion factors and reporting procedures. Further developments will be the introduction of taught units at Masters level and the dissemination of teaching materials across all disciplines of the University.

ENGINEER AND SUSTAINABLE DEVELOPMENT	TBL	ENERGY	WATER	AIR	RESOURCES	WASTE
Role of an Engineer Engineer as Policy Maker Engineer as a Trend-setter Engineer as Leader Ethics in Engineering	TBL framework TBL reporting Environmental Social Economic Indicators	Consumption Global Warming Climate Change GHG Gasses Renewables: options and availability	Availability Consumption Conservation Technologies	Pollution Barriers to sustainable technologies	Constraints Conservation Biodiversity	Prevention Minimisation Recycle Reuse Refuse Clean Production

Table 1: Generic Unit Content: SUSTAINABLE DEVELOPMENT

Educators challenge

The academics delivering engineering programs are expected to be "sustainability literate". What if they are not? The minimum standards for literacy in sustainability similar to computer literacy have not been established yet and competencies for educators have to be developed.

Appropriate teaching recourses are paramount in successful integrating sustainability issues into the curriculum. This applies to conventional educational aids like visual materials, case studies, websites, textbooks and use of modern technologies like multimedia and the Internet. Case studies are being developed at The University of Ballarat, via a project funded by Environment Australia (www.ballarat.edu.au/projects/ensus/), aimed at Schools and with a regional Australia focus – but equally valuable for a range of higher education disciplines.

There are two main problems with teaching resources: their initial cost and availability.

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Development of the new resources takes time and inevitably, will cause a financial outlay. Engineering budgets are often stretched. That is why Internet, and shared Internet resources, can be invaluable.

Brave academics involved in teaching the subject are basically on their own. They face more hurdles to the new practice than expected: lack of teaching materials or high cost, accreditation, quality issues, capacity building, demand from industry that is to be established. The highest hurdle is often the absence of a sustainability strategy in their University.

In the author's opinion the best way to support sustainability learning is to organise students in teams for effective collaboration and engage them in solving real life problems. Staff and students of the University of Ballarat together with a sustainability consultancy based on the University's Technology Park have assisted two local Councils (Hepburn Shire Council and Ballarat City Council) with various stages of CCP™, resulting in energy audits and development of Local Action Plans to reduce emissions.

The University has also become involved with the activities of the Central Victorian Greenhouse Alliance (CVGA), a consortium of regional Councils, industries, businesses and educational organisations whose members share a common commitment to climate protection and emission reduction targets. CVGA strategic priorities are: energy efficiency, renewable energy and carbon sequestration planting. It is also working to achieve technical and attitudinal change and promote community adoption of "the zero emission ethic".

The exposure of students to such initiatives, supported by lectures and tutorial work on Triple Bottom Line Reporting, quantifies sustainability through internationally accepted key performance indicators. Student project work in later years is expected to report on sustainability issues relating to their individual project work.

Learners challenge

For learners the challenge is that they have to understand the framework of sustainability, the TBL approach and appreciate how they as future engineers can influence sustainable development. At the same time they must acquire knowledge and skills to become professional engineers and solve technological problems in a sustainability responsible way. While working on the project they were encouraged to do self-assessment and be in charge of their own learning.

Conclusions

If challenges are met and change embraced, with sustainability incorporated in the teaching programs and in engineering practice, Australia has a good chance to become a leader in education and sustainable development.

Making sustainability an integral part of engineering curriculum by engaging students into real problems during their studies involving the local community, local government and industry is the suggested approach.

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Universities as business entities have to also engage in sustainable reporting and behaviour. This must be effectively communicated to the students, staff and community in which the university operates. While the inertia to change in Universities must be overcome, there are promising signs that this is happening.

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Industry and Institutes of Higher Learning: Towards a Synergistic Partnership

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Abstract: *Institutes of Higher Learning such as universities and Institutes of Technical and Further Education (TAFE) have traditionally provided the skilled workforce which finds employment in industry. In this respect, industry may be viewed as the core market for which learning and training institutions provide the needed skilled workforce. As in all enterprises, forces of supply and demand are expected to influence, the economic well being of both. However, in the case of Institutes of Higher Learning, it may sometimes be the case that courses are offered as a consequence of non-market driven demand- for esoteric reasons following a popular TV series; following new developments in science with a perceived potential of substantial technological demand in the future, such as nano-engineering; or even as a result of the particular academic vision of the Institution itself.*

On the other hand, industry driven initiatives, which more often reflect the commercial demands of the market right now, often providing the impetus for innovative courses such as Simulation Engineering and Virtual Manufacturing, currently in high demand world-wide. In order to respond in a timely manner to such market place demands, learning/training institutions have to be sensitive to these shifts in demand for their services, adaptable and flexible enough to predicate the best way forward for their course offerings in line with the demands of industry, Government and the wider Community.

This paper aims at combining three personal viewpoints on this proposition - from industry and two different learning/training institutions, looking at ways of creating and maintaining industry/institutional interaction, how to better provide for utilisation of specialist resources to meet the demands of this process and to identify the specific strengths of this liaison for the ultimate well being of the broader community. The particular emphasis will be on synergistic aspects of collaboration. It is hoped this will provide an effective stimulus for further action.

Keywords: *industry, higher learning, partnership &, collaboration.*

Introduction

It is common knowledge that academic institutions are experiencing funding difficulties. The media reflects almost daily accounts of dire consequences of the impact of this drawback of

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funding which is affecting education at all levels. In Australia, the majority of institutional funds come from decreasing Government allocations, forcing universities to rationalise, restructure or downsize in areas not deemed viable, while at the same time trying to generate funds through intellectual entrepreneurship and commercially competitive activity.

While this paradigm change in the way academic institutions operate is taking hold, another manner of adjusting to this seemingly irreversible change is that of resource sharing and collaboration amongst not only institutes of higher learning but with the very industry as well. In this manner, all the parties involved in the education and skilling process share in the utilisation of its fruits and are brought together not unlike a supply chain. The particular strength of such a partnership lies in its synergistic outcomes, which tend to better deliver a product exactly matching the market requirements.

In Australia, the traditional education process of an engineering professional is usually through a university involving a four-year term after graduating from a high school. The transformation of a recent high school student into a raw engineer is rapid and highly successful, in part due to the exceptional receptivity to new ideas of those willing to learn. The academic material is of increasing complexity, content and rigour with a substantial element of exposure to experiential learning. From the point of view of an academic service provider, the latter is particularly costly, especially if the latest technology is involved, quite apart from the need for a specialist intellectual input to produce the required outcome.

This paper looks at a range of potential solutions to this problem as seen through the joined objectives but personal visions of three participants from an industry perspective, an Institute of TAFE perspective and that of a university academic. The bottom line of their argument is that a synergistic partnership is not only of benefit to all, but provides a superior calibre graduate with exceptional skills who is well prepared to be a part of a productive team in an industrial organization in the minimum time.

Universities link up with Institutes of TAFE

Universities may be regarded as centres of educational and learning excellence, often having a particular focus which makes them distinctive. While as entities in their own right they have great potential to enrich the wealth of a nation, their distinctiveness might also provide hindrances to inter-institutional mobility not only for students, but staff as well. This concern has been the cause of massive reforms now taking place in Europe following the Bologna Declaration (1999), in which diverse academic offerings in engineering are being brought into line with the US model. Such a scenario is not so critical in our island-continent as we are but one nation. However, parity of engineering qualifications across English speaking countries has been achieved through the accreditation signatories of the Washington Accord (1989).

While the academic quality of an Australian engineering graduate is well regarded internationally, the manner in which this standard can, not only be sustained in the increasingly adverse economic climate, but also improved at no additional cost, is through inter-institutional collaboration. The most immediate and obvious way of achieving this is through recognising the inordinate amount of duplication which occurs in the two main streams of professional education delivery: that of a technologist and that of an engineer. It is asserted that within the training curriculum of an engineer there is a substantial element of technological training, particularly in the experiential component of a degree, which can be

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most efficiently provided by those institutions of higher learning that have traditionally trained technologists – the Institutes of TAFE.

In one author's experience, the provision of a superior laboratory experience and expert staff in Engineering Hydraulics provided for students by a well equipped TAFE Institute could not be matched by any university. On the other hand, involvement of TAFE Institutes in training of engineers provides for their increased relevance and status in the education of professionals. In both instances, it is the students, the customers, who benefit the most.

This serves to illustrate just one of a multitude of practical ways that inter-institutional interaction can serve the greater or holistic approach to service delivery to our customers. By disregarding traditional demarcation boundaries, which are fast becoming not only irrelevant and artificially sustained, but unaffordable, educational outcomes will improve while facility utilisation for both sectors will also improve. This concept can also be translated into the process of curriculum development such that courses are designed around the needs of the customer rather than the availability of resources simply within the single educational entity for the benefit of all involved.

Universities and links with industry

TAFE Institutes, by their very nature have participated in a much more intimate interaction with industry than universities, particularly through the delivery of apprenticeship education schemes and training of technologists – providing a much needed skilled workforce to keep the wheels of industry turning.

Universities have been traditionally regarded as the coalface of technological progress and sources of valuable theoretical insight and professional wisdom contained within their dual roles of education and research. External perceptions, however, have often reflected the proverbial "ivory tower syndrome" of universities in performing these roles because of their perceived remoteness from industry, which they claim to ultimately serve.

It is for this reason, perhaps for no better reason than a reality check and as a feedback mechanism, that meaningful partnerships with industry are essential for all educational institutions.

These can take many forms, one of which might be to have captains of industry actively involved, not only in curriculum development, but integrated into the teaching staff. Yet another is through university Courses' Advisory Committees.

Tangible input from industry is an essential element of curriculum design in all universities, however other issues, often of an administrative nature, frequently thwart its effectiveness. While such omissions or lack of adequate consultation may pass unnoticed at the time, the effectiveness of an education provider (and its ultimate reputation) and the relevance of the educational offerings borne of such administrative expediencies, are not only impaired, but the careers of their graduates are jeopardised from their very start.

It is therefore suggested that universities must pro-actively seek liaisons with industry to ensure not only the relevance of their educational offerings, but to provide opportunities for joint interaction through research, consultancies, teaching/learning and fostering of entrepreneurship amongst the student participants. The key element in the successful adoption

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of this proactive stance is the energetic and active participation in the process by all levels of university management in the first instances.

The challenge facing the industry and a way to cope

The wealth of a nation is measured in what its industry can produce and sustain. In Australia this has been traditionally the province of primary industry and mining. The manufacturing sector has found itself under increasing pressure from overseas competitors, and has shrunk considerably. If the trend continues for the next ten years, Australia will import most of its manufactured goods. Such a situation is highly undesirable if measured in terms of self sufficiency and development of its own potential.

This is particularly reflected in the Tooling Industry, which provides the means with which to manufacture goods. The Australian Tooling Industry is largely comprised of Small and Medium Enterprises (SMEs) operating on low profit margins, and with little vertical integration. Firms have limited funds for investing in new developments; face strong competitive pressures and few are active exporters. Demand fluctuates significantly and there is relatively low take-up of emerging or new initiatives in the latest technology.

Although the current workforce has good skill sets, the ageing workforce and low rate of entry level training are major concerns with only 9% of the workforce in the 20-24 year age group, 35% are more than 45 years of age and the average employee age is 38.4 years (Productivity Commission, 2003). The industry already faces skills shortages across the trades and these will increase as the bulk of the workforce reaches retirement age (around 55 years of age currently in Australia).

Up skilling is also a major concern and new technology development in this industry is outstripping the capacity of the current participants to maintain relevance. The pressures of global competition, which require even those serving a domestic client base to compete with suppliers from across the globe, are changing all aspects of the industry in a way that demands highly skilled participants. The outsourcing of functions from large companies to SMEs has also arguably increased the skills demands on SMEs, where more people need to be multi-skilled than in large firms, which allow for more skills specialisation.

The consequence of this fundamental change is a major imbalance in the capacity of industry to respond to shifts in market demands because of a lack of new blood. In industry sub-sets such as Forging, Pattern Making and Boiler Making, skills have all but disappeared and been lost as viable industry capacities in Australia. While tooling might also appear to be ‘on the brink’ of extinction, the deterioration of the Industry can be arrested but it can only occur through partnering with ALL of the input components of the industry and this particularly relates to training and educational institutions.

There is considerable export potential for Australian industry if technology and skills can be upgraded in line with the technological changes reflected in the marketplace. Despite the image of a dying manufacturing industry, and the current limitations placed on industry by removal of tariffs, etc., the industry is growing with employment increasing by 4.8% in 2002 alone and industry GDP increasing by 15% in the past 5 years (Productivity Commission, 2003). The benefits of collaborative groups such as Austool (www.austool.com.au) to educational institutions are significant and go beyond the opportunity to manage training and technology diffusion more effectively. In particular, they provide a vehicle for Institutions to

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work with SME's to not only drive the educational and course development function, but also to help develop better access for Institutions to joint funding through industry/institution joint projects.

The relationship between Austool and Government at all levels, for example, should be seen by educational Institutions as a means of adding value to their activities not as a threat to their own funds allocation from Government. How to establish an effective and mutually beneficial liaison between industry and particular institutions is at the centre of an expanded and more successful future for both parties to the process.

Industry has also argued to Government that the focus and nature of government support and anticipated or accepted interaction with training and educational institutions needs to change. Industry believes that Government and educational institutions need to take a more strategic and collaborative approach to the development of industry policy and curriculum development which enables all players - Government, educational and training providers and the industry itself – to better react to the ever changing demands of the international marketplace.

Essential to the success of this transition is the transcending of party political agendas with a national, bipartisan and collaborative response, which focuses national attention on the future growth of the industry. The consequence of this approach would build a long term capability which would enable institutional interaction with industry to assist them to "sense" shifts in technology utilised within industry. This in turn would create consequent changes in course offerings and flag the need for changes in the educational product offering.

A clear example of the consequences of not having an effective interactive partnership in place relates to the fact that Australia only trains Simulation Engineers in two universities. One of those universities took their first enrolments in the two year program this year. International contracts in the aerospace industry will be let within the next five months but only to those countries with the capacity to produce outcomes from the use of simulation or virtual manufacturing systems. Four years is the indicated minimum time it would take to develop a course, enrol students and complete the program. We are, therefore, at least four years behind the major new product developing nations of the world and our capacity to become a supplier to these opportunities is severely limited as a result.

Industries response to our educational institutions is simply why have you let us down so badly?

Universities, TAFE and Industry – Complementary Roles

Traditionally, educational institutions have operated as independent organizations with TAFE Institutes offering vocational education and training whilst the tertiary institutions provided professional education. TAFE Institutes have operated under a supply driven model of Vocational Education and Training (VET) to meet the needs of industry. The skills taught by TAFE have focused on the practical needs of industry in an applications mode.

The university sector has provided professional qualifications, at a higher academic rigour than TAFE, in such areas as Management and Engineering. There has been little linkage between the two educational institutions except for some limited credits or granting of advanced standing for TAFE graduates seeking to enter into tertiary courses.

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Prior to the late 1980's, TAFE's VET provision consisted of standardized courses, which reflected a "one size fits all" approach. In effect an apprentice undertook a course of study, which did not vary except for some elective subjects in the final year of the course, irrespective of the particular sector of industry in which they were employed.

The Metals and Engineering industries, in response to the need for a more flexible workforce, initiated a radical change to a demand driven model that sought to ensure VET provision more clearly reflected the needs of industry. This has now spread across all industries. The effort and focus of various governments in recent years has been directed at increasing the numbers of school students who complete year 12.
The expectations generated amongst young people by these two factors are of advancing from year 12 to higher education and therefore more highly paid employment.
Mathew Thompson (Sydney Morning Herald, 2004) reported a statement by the new Chairman of the Australian National Training Authority (ANTA), David Hind, who said:

> *"Social attitudes to industry courses needed updating. Vocational education is still regarded as second prize, particularly by parents . . . but they are both first prizes."*

The pool of available entrants to trades has historically and to a large degree, been drawn from year 10 school leavers. Students who wished to enter the trades and related areas at year 10 have been, and are; discouraged in their attempts to do so by parents, schools careers advisors and our Government's of all political persuasion. As a result, many school leavers, who would have in the past undertaken a trade or similar course, continue to year 12. The aspirations of these students have been raised to believe that tertiary entrance is open to all and to consider employment at a trade level was very much a second choice.

As a consequence many students with lower University Admission Index (UAI) scores have entered a course of study in higher education for which they are unsuited and fail to finish the course. Thompson reports that of the 230,000 students who started at university this year, 40 per cent will drop out by the year's end, according to the Federal Department of Education. Many of these students then drift into other positions but find it difficult to enter trades areas as they are competing with recent school leavers. Many university students do not even see out their three or four years before abandoning their studies.

The relevance of courses delivered by tertiary education for industry needs to be carefully scrutinised. One ANTA study has indicated, "As employers place skills and industry experience above a grasp of academic theory on the list of hiring factors, record numbers of graduates are heading to vocational finishing school." (Karmel & Nguyen, 2004).

In 2001 around 7% (15,000) commencing undergraduate students were admitted to university on the basis of VET study. In 2002, 88,500 VET students had a bachelor or higher degree. A further 24,700 had an advanced diploma or associate degree. (Karmel & Nguyen, 2004).

SWSI has embarked on a joint project, the Macarthur Apprentice Recruitment Strategy (MARS), with the Australian Industries Group and Macarthur Group of Companies to raise the profile of the engineering industry and demonstrate to parents, students and careers advisors the career paths and opportunities the industry offers. As part of this program it is stressed that learning is a lifetime experience and tertiary studies can be pursued as mature aged students to gain additional knowledge and skills.

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Cooperative Arrangements

Each of the post-compulsory sectors has unique and specialised facilities, which have developed over time to meet the perceptions of prior needs.

With increasing limitations on available resources and industry seeking personnel with a broader range of applicable skills it is timely for these institutions to investigate ways in which to better use these scarce resources in a cooperative manner. As technology changes at an ever increasing pace neither TAFE nor the University sector has the capacity to maintain state of the art equipment as used in industry. In recognizing that industry needs to accept some level of responsibility for assisting this process, the response from one sector in manufacturing has been the establishment of the Austool - Australian Centre for Toolmaking Innovation.

Through close co-operation with TAFE, University of Western Sydney (UWS) and technology suppliers and owners, this is a prime example of how effective the development of synergistic partnerships between educational institutions and industry can be. Opened just recently in Ingleburn New South Wales (NSW), Austool conducts industry lectures, tutorials, "share the experience" seminars and courses to increase industry awareness of emerging technologies and new opportunities for export activity.

This activity in turn links to an interactive capability for TAFE where demonstration and new technology equipment on display in the Centre can be utilised by TAFE for apprentice training. The structured education and training program delivered by TAFE will be tied into the Austool demonstration and display facility providing effectively more than 3,000 square metres of workshop and training space. Tutors working on equipment or on the latest technologies incorporated in the Austool Centre will be the same technicians employed by the supplier firms and be at the cutting edge of their trade.

South Western Sydney Institute (SWSI) of TAFE has also been in discussion with UWS to provide access for UWS students to teachers and equipment in the specialized engineering workshops of SWSI colleges. This will provide UWS students with "hands on" experience in such areas as hydraulics and pneumatics.

Links between Austool and UWS are also being developed with technology capacity in design and advanced manufacturing systems placed within the Austool Centre for use by the university in expanding their range of relevant course offerings in this area. Utilisation of industry experts as guest lecturers and as course advisers will also add to the relevance of course directions for UWS and this partnership approach is expected to further build the value of product offerings from the university for industry.

Developing Social Capital

The very real consequence of an effective synergistic partnership incorporating the three identified sectors is a major lift in the social capital available to an economy, which is critical to the growth of a competent, productive and innovative nation.

The Organisation for Economic Cooperation and Development (OECD) defines social capital in the following terms:

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> *Social capital is networks together with shared norms, values and understandings that facilitate co-operation within or among groups.*

This conceptualisation of social capital turns primarily on the degree to which people associate regularly with each other in settings of relative equality so that relations of trust and mutual reciprocity are built up. The OCED definitions focus our attention on the key components of the concept of social capital:

- the *networks* that link people in communities for joint action;
- the *norms* and *values* that bond these networks;
- the significance of these norms and networks in the *culture* of a community.

Benefits of Social Capital

Social capital may bring a range of social, economic, cultural, and educational benefits to a community. These include (Kearns, 2004):

- combating exclusion and building inclusive and cohesive communities;
- enhancing quality of life for citizens;
- supporting lifelong learning for all citizens;
- supporting communities in adapting to changing circumstances.

Conclusions

Exploiting educational resources to their maximum in a climate of decreasing funding provisions and opportunities predicates an essential paradigm change in the tertiary education sector. This change involves pooling of resources rather than institutional duplication, collaboration rather than competition and an active role for industry in the whole process of supply chain management.

Clearly this process cannot become anything more than a philosophy if the commitment of all levels of management within each sector is not forthcoming. Paying lip service to the principles will not move the theory into practice. Vision and a strong sense of the need for educational institutions, in line with industry, to adopt commercial approaches to good customer service, are essential.

The frustration of industry with the separation of what they need in an output from the educational process and what they currently get will drive change. The ability of the educational institutions to hear and respond to this frustration will determine whether Australia can regain its former glory as the lucky country.

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Liaison with Industry in Modelling Work Integrated Learning for Engineering Undergraduates

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***Abstract**: Traditionally, engineering degrees require evidence of a 12 week work experience program before graduation. This allows students to be admitted as graduate members of Engineers Australia. To a large extent this program is not integrated with the curriculum in the true sense. Currently students find the work themselves or are assisted by the Faculty. The assessment report evidencing their industry experience is submitted under strict guidelines and is reviewed by an academic staff member who certifies that the student has gained the experience. In order to respond to employers' needs, a project is being undertaken as part of a large teaching and learning grant to investigate the incorporation of learning during work experience as part of the curriculum. This requires the co-operation of industry. This paper describes the process of consulting and liaising with industry to formalise learning in the workplace as part of the curriculum. Surveys and focus group techniques were used in obtaining responses of industry.*

***Keywords**: Work Integrated Learning, Industrial Experience, Co-operative Education*

Introduction

It is almost universal that some form of industrial experience is required for graduation in all professional disciplines. Engineering degrees require evidence of twelve weeks work experience before the award of the degree. This is the basic requirement for them to be admitted as graduate members of Engineers Australia. At the Queensland University of Technology, by and large, engineering students find a place to work during their vacation. After completion of their experience they submit a report together with a single page evaluation from the employer verifying the nature

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of work undertaken and the general behaviour of the student during their work experience. This report and the certificate are examined by a member of the academic staff, usually the course coordinator, who certifies that the student has completed the work experience requirement. Some students prefer to undergo work experience in two periods, while others prefer completing it in one session. The preferred model is for the students to do it in two periods, with the first being an introduction to the industry and the second requiring more involvement in the organisation, by doing a project or an investigation or a simple design etc. The work experience program carries no academic credit nor is it in any way integrated to the curriculum. Students are free to choose any work that is on offer with an expectation that the experience will improve some of their skills. In general, students are not required to reflect upon their experience nor evaluate it to determine whether they have really learnt anything at all.

There are other parts of the curriculum which involve the work place in a more organised manner. An example of this is the CEED (Cooperative Education for Enterprise Development) Program, in which a student will undertake a project with an industry partner with a formalised contract. The student is supervised by an academic supervisor as well as by one from industry. A set of deliverables is written into the contract for the student to achieve. The student uses this as his/her final year capstone project with academic credit equivalent to two or three (sometimes four) units. There is anecdotal evidence that the students become better learners after they have been through an industrial experience program in a discipline related organisation. The students who have been involved in industrial experience were also observed, from presentations of their final year projects, to have better generic skills, especially communication skills. Examples of other forms of work integrated learning are:

- Industry Cooperative Programs such as at QUT (Bodnarova, et al, 2002), Central Queensland University, Flinders University
- CEED program at Royal Melbourne University of Technology
- Internship type program at the University of Technology, Sydney

All of these programs offer credit towards the relevant degree and thus are integrated with the curriculum, including their work experience requirements.

It is quite clear that there is a need for a formal approach to integrating the students' work experience with the curriculum and providing a means for students to enhance their experience and integrate it with their study at the University. The Faculty of Built Environment and Engineering (BEE) at the Queensland University of Technology is currently undertaking a University Large Teaching & Learning Project (Boles, 2004) titled "*Integrating Workplace Learning and Professional Education: Implementing a Student Centred, Objectives Driven and Outcomes Focussed Framework*". This project is referred to here as the WIL Project. This paper describes the process of consulting and liaising with industry to formalise learning in the workplace as part of the curriculum within the WIL project.

What is Work Integrated Learning?

Work Integrated learning is a form of (practical) education that integrates periods of academic study with periods of work experience in jobs related to the students'

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studies (WACE, 2001). Hager (1999) described the process as, "Learning in one's discipline occurs within the slipstream of engagement." It may be called by a different name, for example, "industry experience", "practicum", "co-operative education, or as in nursing, "clinical practice", but all mean basically the same thing: an opportunity for undergraduate students to apply and develop their knowledge and skills in a working environment. The common function of all work integrated learning is twofold: to accelerate professional readiness for the workplace, and to provide organisations with better educated and work-ready employees.

There is no doubt that students acquire the skills of their discipline profession by being immersed in the corporate culture; learning how to process information and solve real problems within context, as well as working and communicating with technical and non-technical colleagues. The experience of QUT is that on their return to university after such an experience, students apply themselves more diligently to their studies and appear to achieve better results.

Preliminary findings of a student survey conducted by the WIL project indicated that students thought the following aspects of their work experience most helped their development as professional engineers:

- Communication - oral, written, graphical (70% of all respondents)
- Work practices (time management, goal setting, etc)
- Interpersonal skills (teamwork, negotiation skills)
- Understanding the work environment
- Discipline knowledge
- Thinking and problem-solving skills

On return to university, students said that their work experience helped them in:

- Writing better reports
- Learning the importance of networking and extra-curricular activities
- Understanding the important parts of real engineering practice
- Knowing what is done out in the real world
- Understanding how knowledge is used and how effectively it is implemented in the real world
- Focussing on what's important to work to ensure better preparation for work on graduation
- Improving study results that are directly attributable to increased understanding
- Acquiring more knowledge in practice and application
- Discovering what they don't currently know.

Complementing the above, a survey of employers conducted by the WIL project, revealed that 64% of employers found an improvement in students' knowledge and skills between starting and finishing their work experience.

There is an explicit need to ensure that the engineering curriculum integrates some element of professional development, apart from the accreditation authorities' requirement for work experience. In this respect it is worth looking at the current position of Engineers Australia (EA)which strongly encourages the integration of

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experiential and academic principles (Hargreaves, 2004). One of the criteria used in the accreditation of engineering degrees by EA is curriculum. Several performance indicators are used to evaluate curriculum and these include:

- Enabling skills and knowledge development
- In-depth technical competence
- Personal and professional skills development
- Engineering application experience
- Practical, hands-on experience
- Exposure to professional practice

The third and the last points are relevant to the WIL project and EA further goes on to elaborate on these indicators:

- A commitment to safe and sustainable practice
- Information literacy and ability to manage information & documentation
- An understanding of and commitment to ethical behaviour
- An ability to communicate with the profession and community
- Exposure to engineering practice used as an integrated learning activity embedded within academic units.
- Appropriate systems for recording, tracking and assessing outcomes of professional practice exposure
- Formal work placement requirements documented with appropriate learning outcomes and means of evaluation.

EA further specifies that academic programs will embed experiential learning activities within the curriculum.

The WIL Project aims to enable students to achieve and demonstrate a number of assessable learning outcomes, including:

- Enhanced technical skills in an applied context,
- Ability to benefit from and integrate the theoretical knowledge and actual workplace practices,
- Greater understanding of the workplace environment and protocols, health and safety, management, and performance appraisal, and
- Improved appreciation of the role of their chosen profession in the community.

There are many facets to this project. These include researching existing formal work integrated learning systems, consulting the students, looking inwards to see how the course objectives relate to the work experience, distilling objectives that can easily be included in the work experience, consulting industry on how they can enhance the students' experience and their expectations and so on. Distilling of the objectives is presented elsewhere (Campbell et al 2004).

Industry Liaison

The WIL Project focuses on enhancing student outcomes arising out of their work experience. However, the WIL team recognised the need to ensure that Industry was

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consulted for its views on any proposed improvements to the current student work experience model. The improved WIL model has to dovetail with Industry's current commercial environment because WIL can only operate successfully with the Industry partners' support.

This means that prior to convening the Industry Focus Group (IFG) to liaise with Industry, the WIL team focussed on the assumed factors it considered of most benefit to Industry arising from accelerated work readiness of students. These factors for industry organisations were assumed to be:

- better engineers
- reduced costs associated with recruitment of graduates
- increased income
- more flexible workforce
- more innovative & competitive firm
- better triple bottom line benefits

In addition, certain assumptions were made about Industry's long and short term needs and wants regarding student employment and their development as engineers. The assumed long term needs for engineering graduates were to have engineers who could:

- display leadership qualities
- communicate effectively
- immediately contribute to the profitability of the organisation
- understand an organisation's commercial environment
- exhibit technical excellence

The assumed short term Industry needs and wants from providing students work experience were:

- To obtain technical expertise from students with fresh cultural perspectives
- The ability to fill gaps created when current staff were allocated on projects
- To assist in recruiting for undergraduate programs. According to a survey by the National Association of Colleges and Employers, 70% of employers who hire recent college graduates use internships and/or cooperative education programs to help find qualified employees (Frazee, 1997).
- To provide inexperienced young students with some immersion in the workplace
- To obtain cutting edge ideas & skills/technology

Furthermore, assumptions were made as to what Industry could realistically do in the perceived current environment to help create better prepared professionals under the proposed WIL improvements. These included:

- Being an industry host
- Providing good work experience
- Assessing progress of the student with QUT
- Collaborating with QUT on R&D or consultancy matters
- Providing feedback to continuously improve WIL

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These assumptions were tested for validity in the IFG meeting and allowed a focussed and efficient debate of the important issues. The outcomes of the workshop are discussed below.

Prior to the IFG meeting, the project team conducted a preliminary survey of some of the employers who had provided work experience for students in the past. The survey sought to find the relative importance of some aspects of work experience, to see how the students had fared in these aspects and to judge some of the skills that could be gained during work experience. The results of this survey are summarised in Table 1.

Skills and attributes	Industry's rating of the relative importance of skills and attributes		Employers' satisfaction with students (ranked as good to very good)
	Critical	Important	
Knowledge of basic science and engineering fundamentals.	50%	50%	79%
Practical application of technical skills to projects or other engineering work.	41.6%	50%	58%
Ability to solve technical problems using critical and analytical thinking	58%	42%	65%
Understanding of ethical issues and their application in the workplace.	25%	75%	66%
Communication skills with technical and non-technical colleagues.	42%	58%	82%
Appropriate IT skills	42%	58%	91%
Work practices, eg, time management, prioritising, achievement of deadlines, acceptance of responsibilities and obligations.	58%	42%	52%
Ability to integrate with a multidisciplinary team	50%	50%	66%
Awareness of the relationship between the engineering profession and global and community issues.	8%	75%	25%

Table 1: Indication of industry's importance rating of skills

The preliminary survey also reinforces the need to formalise and integrate the work experience with the curriculum and to provide the employers with better during students' Industrial experience.

The IFG workshop in which seven senior members of industry organisations participated, was convened in February 2004. The objective was to identify the representative reactions of Industry to the formalisation of work experience and its integration into the curriculum, as well as how they saw their part in this program. The focus group's discussion concentrated on the importance of workplace learning for students and the proposed WIL model as well as the current stage of development of a web based facility to service the program.

There was unanimous opinion that it was vital for students to get some industry experience before they graduated and they supported the EA's requirement for 12 weeks of industrial experience.. It was also emphasised that the student's experience depends on who was assigned to the student during his/her stay in industry. Some were of the opinion that the students must be thrown in at the 'deep end' to allow

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them to find their feet. Others thought that the students brought with them (especially in electrical & electronic industries) an extra value to the work place with cutting edge technology.

Importance of Work Experience

The IFG confirmed the findings of the survey in relation to what the employer's looked for in work experience students. Attributes such as a good work ethic (attendance, time management, focussed on the job etc.), communication skills, understanding the context of the business and to value all levels of skills. There was difference of opinion amongst the industry partners on whether first year students (mainly working in labour intensive jobs) would benefit from work experience while others were of the opinion that working in this manner gave them an appreciation of the various skills involved in Engineering. They also felt that the first year students should be motivated to continue with their engineering development. Further, there was general agreement that work experience could develop many of the requisite generic skills.

Industry Feedback on the WIL Model

The proposed and refined WIL model seeks to integrate industrial experience with the curriculum by focussing on the objectives of the courses and identifying those components that are best achieved in the practice of the discipline. Appropriate assessment methods that facilitate and ensure student attainment of workplace learning objectives will be significant. A web-based facility and resource centre that supports students and staff and enables the incorporation and achievement of these objectives will also be delivered. This will facilitate the processes of initiating, documenting, monitoring and assessing the work experience. This will be achieved by the following:

1. Industry hosts access the web site and post suitable work experience positions for students.
2. Students identify positions of interest based on the type of work and experiences available.
3. Students make application, selecting from a database the objectives (technical and generic) they wish to focus on in their industry experience
4. Students select an academic supervisor based on the sub-discipline involved
5. Students negotiate a draft work plan with the industry host, supported by the academic supervisor, that identifies three categories for attention: Observation, Reflection, or Application.
6. Students finalise the tripartite work plan with industry and academic supervisors.
7. During industry experience, students access the Student Portfolio (a separate but linked facility available to all QUT students) which allows the recording of observations, reflections and details about the application of knowledge and skills to the work tasks.
8. After the work experience period, students are required to submit a formal report to their academic supervisor which aligns with the negotiated work plan, for assessment. Where the actual work carried out differs from the work plan, they must clarify the reason for change.

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9. The industry host evaluates the student's performance, based on the objectives comprising mandatory generic skills and selected technical skills. This may be submitted either electronically or in hard copy.
10. Students complete self-evaluation of all objectives.
11. Feedback from industry on the process will be encouraged.

The IFG was of the opinion that the model presented was too complicated, especially in relation to the input requested from industry. Industry preferred that no additional work be required of it, particularly in relation to student assessment. This, they considered, should be performed by the academic staff with only an 'evaluation' from industry. It was suggested that it may also be worthwhile considering student self-evaluation which has significant benefits for students in their future workplaces and on aspects of their lifelong learning (Sivan, 2000; Orsmond, Merry & Reiling, 1997). Some panel members also expressed the opinion that the first three or four weeks of work experience was spent inducting students into the organisation, and during this period, the students were not productive. So from the organisation's point of view, the students were initially considered an expense rather than a good return on investment. The focus group also suggested that the students should be given some preparatory advice and training as to how they should behave in industry.

From the concluding remarks of the industry partners, the following points emerged:

- Work place learning was imperative to enhance the learning experience
- There were definitely some gains for industry
- Industry would not be interested in the new WIL if it meant additional costs
- To be successful, the program must be viewed by industry as "best practice".
- Industry was aware of the depth of student learning in the workplace, but there was no hard evidence for this belief.
- WIL should not be made complicated for the students as well as the employers. It was necessary to "Keep it simple"
- Industry did not have resources to apply to WIL.

Where to from here?

It is quite clear from EA's accreditation requirement, as well as from the Industry Focus Group discussions that engineering curricula must integrate work experience with the curriculum, and must also be assessable. It can further be concluded from the IFG consultation that the new WIL program must be simple and student-centered. Industry would not expend any more time than currently expended in the management and evaluation of the students and outcomes. Students must be trained to ask, look and seek the necessary skills through consultation with their industry supervisors. These valuable suggestions are now being incorporated in the development of the WIL program and the supporting web based facility.

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The role of alumni in increasing university/industry interaction

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Abstract*: There are many examples of positive contribution of alumni employed in industry in fostering strong university and industry links. As universities seek stronger industry links alumni can enhance and increase the involvement of universities and industries in mutually beneficial projects and research areas. Universities have traditionally focused on formalised arrangements with industry such as cooperative research projects and such arrangements are normally set up by the senior management of the university and industry. Today's need is to increase this interaction on several fronts and small project interactions should take place between a researcher and an industry without red tape surrounding the agreements. Alumni, with their knowledge of industry as well as the university can act as invaluable facilitators between the two. It is therefore essential that alumni be nurtured and valued as they can foster sustainable university/industry linkages. In Australia such partnerships have been largely overlooked in favour of more formalised relationships.*

Keywords*: alumni, industry interaction, sustainable linkages*

Introduction

One of the most important distinctions between American universities and their Australian counterparts is the concept of the alma mater and the importance given to the alumni of the university. In America, very strong cultural links exist between alumni and their universities that are not present in Australia. This paper investigates some ways in which the active participation of engineering alumni in their universities can open new windows of opportunities in industry/university co-operation.

Traditionally, Australia universities have seen their alumni primarily as a source of funding and little more. A recent white paper entitled "Crossroads" produced by the University of New South Wales attracted criticism from the president of the University's Alumni Association for having only mentioned alumni as a source of revenue under the heading "Revenue Diversification Section" (Milner 2002). The alumni of a university represent the largest natural constituency that the university has. Therefore developing synergy between alumni and university should not be a difficult process.

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The fundraising potential of the engineering alumni is obvious, another less obvious benefit from tapping this under-utilized resource is the role that engineering alumni can have in fostering and strengthening industry linkages.

"In this sense, the recent surge of commercial activity is best understood as only the latest in a series of steps to acquire more resources, beginning with the use of aggressive marketing to attract tuition-paying students in the early twentieth century, and moving on to the determined search for government and foundation funding after World War II, and the increasingly sophisticated and intensive effort over the last fifty years to coax gifts from well-to-do alumni and other potential donors," Bok (2000).

In technical areas, where the life cycle of products is very limited, many advantages are to be gained by the acquisition, fusion, and diffusion of ideas by the alumni body. Investment in research and development is crucial to both university and industry. Coordination of joint projects can be enhanced when there are common members (alumni) who interact and share pertinent information, protect areas of common interest, and look to maximising resources to promote collaboration between university and industry. Alumni participation can help secure large projects through successful strategic alliances and leveraging knowledge, physical, man power and financial resources and infrastructure for mutual benefit (Moorthy 2002).

Alumni of engineering disciplines can play an increasingly important role in today's environment where universities are in search of excellence and industries are seeking survival.

Cultural Barriers to Alumni Capitalisation

Even a cursory examination of the American (or Indian) experience shows there is a fundamental cultural difference in the way that alumni view their alma mater and the way that the university views their alumni.

The bonds that tie a graduate to his alma mater are far less prevalent in Australia – in part due to the universities themselves who have reduced this relationship to one of periodic solicitation for money.

That said, given the importance that one's university education plays in one's life, it is not unreasonable to assume that most alumni have some interest in their university although the opportunities may not be available to take an active involvement.

Before the value of the alumni community can be effectively leveraged, it is important that universities change their thinking when it comes to looking at alumni as, first and foremost, a source of fundraising. This is in fact the greatest barrier to alumni involvement in their alma mater because it is discouraging and a disincentive when alumni feel that the only connection their alma mater wishes is one based around a one-way flow of cheques.

Donations are important – especially in the current economic climate; however, it should be remembered that alumni will be more inclined to donate to their alma mater if they feel a connection with it. Such connections can only be fostered through mutually beneficial involvement.

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Benefits and Mechanisms for Alumni Involvement

Given appropriate support and encouragement, alumni can play an effective role in research, teaching and project activities. Alumni need to be involved in the on-going activities of universities in more fundamental ways. With the challenges of working towards increased self sufficiency facing many universities, alumni can provide the missing link by way of resources and assisting universities to remain in touch with the changing demands of the industry and society.

Knowledge Transfer

Alumni, particularly those with some industry exposure, can offer the university and its students' knowledge and experience that cannot be found within an academic setting. For example, they can provide valuable advice and assistance in finding employment for graduates; and they can offer, through involvement in projects and cooperative research engagements, an injection of industry ideas and provide a real-world context to otherwise theoretical research.

This is particularly important in technical disciplines, such as engineering, where there is the potential for a disconnection between directions in academia and directions in industry. In technical disciplines, more so than the humanities or social sciences which depend more directly on case-studies, surveys and the like, there is a risk of developing ideas and engaging in research that is isolated, practically and theoretically, from industry. For instance, it is conceivable that, without any contact with industry, universities might invest in research to solve problems that are either non-existent in industry or are not considered problems of any importance to the wider community although they may offer the intellectual challenges that many researchers may find attractive. By engaging with engineers in industry, the university can ensure that knowledge is flowing in both directions: that engineers in industry are leveraging and capitalising on the research and developments of the universities, and the universities are ensuring that, to some extent, their research trajectory is based in real-world need and not on some vacuous and isolated notion of what constitutes "valuable research".

Some of the mechanisms by which the knowledge and expertise of alumni can be transferred to the university are through their involvement in projects, in policy and standard setting functions within the schools, and through involvement in lectures or seminars. The participating of alumni in post-graduate classes is also a powerful means of knowledge-transfer through their participation in tutorials and their ability to provide industry context to otherwise context-free and theoretical aspects to their courses.

Marketing the University

As universities compete for students, alumni can play an important role in acting as defacto recruiters and marketers for the university in industry. This is particularly important in the lucrative international student market where word-of-mouth and reputation are invaluable factors in attracting new students.

When international student alumni return to their home countries, they can act as a useful means of attracting new students to the university, if they are supported and encouraged by the university to do so. When alumni enter management positions in companies and have the opportunity to influence decisions related to further study for employees or the engagement of external training services, alumni have a natural inclination towards their alma mater provided that they have retained some connection to it and provided their initial experience has been positive.

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Alumni themselves are also a source of students that can be capitalised upon. For instance, graduates of bachelor degree programs can be marketed post-graduate coursework programs.

Building Community Support

Alumni are, in many ways, the agents of the university in the community. They have the capability of promoting a culture of supporting educational institutions in the community. They also have the capability of lifting the profile of the institution and moulding community perceptions of the quality of that institution.

Given that alumni will be researchers, inventors, entrepreneurs, managers, technocrats and other professionals, they have the capability of being powerful advocates for the university in their respective domains. Some alumni may even be influential government officials. Therefore, it is essential that long term partnerships are nurtured with them and that the relationships are strengthened and leveraged to deliver the maximum benefit to the university and students.

Building Industry Linkages

It stands to reason that the alumni of a university represent the most loyal and important industry link that the university has. These relationships should be maintained and nurtured in the hope that as graduates rise through the ranks of their respective institutions, they will create links with their alma mater through the engagement of the university in cooperative research projects or the like.

This should be actively pursued by the universities. Many industries have problems or challenges that are of sufficient complexity to warrant either research at a postgraduate level or the input of academics. For such reasons as the complexity of formalized agreements with the university, the perceived cost of such engagements, or simply an unawareness of the opportunities, many companies choose to ignore opportunities for improvement or the development of new solutions because they are “too hard”. It is advantageous to the university and industry for cooperation on industry problems to improve and alumni make an excellent conduit between industry and their alma mater that should be developed. They have an existing relationship with the university, trust their university and are aware of what benefits it and its academic staff can provide to their respective part of industry.

Complex discussions about intellectual property are complicated in part because there is an implicit distrust between all parties. This is more so the case with technical disciplines, such as engineering, where the outputs of research and development can be relatively easily applied to industry. It is hoped that alumni would not hold such attitudes to the same degree as their non-alumni colleagues; and likewise it is hoped that a university would recognize, through the ongoing involvement of a person in his alma mater, a commitment to the wellbeing of the school. As suggested by Milner (2002), this would make otherwise costly negotiations simpler and parties could opt for less formalized structures of cooperation and engagement.

It should also be remembered that alumni are more likely to offer their services to a university for free than non-alumni. This is provided they feel some attachment or involvement in the university after graduation. It is also important to note that alumni will have the best interests of their alma mater at heart and so any involvement in a project will see them fulfill their role

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much more diligently than would a person with no historical connection or emotional investment in the other party (the university).

Evaluation of Teaching

Is there any better test or criterion for the effectiveness of the education offered in university than the experience of the graduate in, firstly, finding employment and then functioning in the workplace?

As Tesch et al (2004) have found, alumni can be surveyed and used as a resource for evaluating the success of the university. They can be given exit surveys on graduation that will capture their experience during the course and assess their level of preparedness for industry. Once employed for some time they might be surveyed to assess the extent to which they were prepared for their role by their university education.

This is also important because the satisfaction of alumni on graduation is very important. If they are not satisfied or happy with the quality or type of education offered, then that will have a long-term effect for the university through affecting community attitudes and also creating an atmosphere where it is difficult for the university to take advantage of some of the benefits that alumni can offer.

Most universities include some sort of alumni survey, but few survey their alumni after some years in employment to assess how, with the benefit of hindsight and industry exposure, they view their course, their former teachers and the overall education experience. If one considers students as customers, then that paradigm can be continued to the alumni who should be viewed as either satisfied or dissatisfied customers. Satisfied customers return, bring other business (students) and improve the perception of the business (the university); whereas dissatisfied customers can ruin the reputation of an organization and dissuade others from patronizing the university.

Setting Direction for the University

One of the challenges that universities face is how to ensure that the courses being offered or the research being undertaken is relevant to the community and brings some sort of tangible benefit to the society – whether to industry or to individuals. The challenge has been exacerbated by the fact that traditionally universities have operated in relative isolation to industry. When students graduate they leave the university setting and, as there is no strong alumni culture, retain little if any links with their alma mater. Whilst they hold fond memories for their old institution, they have few opportunities to benefit the university with their experience and accumulated wisdom from having taken the skills and knowledge imparted during their degree and “road testing” in industry.

The knowledge that alumni can bring in terms of industry needs, strategy and the direction that universities should go in is invaluable.

They should be involved in decision-making and strategy setting for the university. For example, alumni should play a role in setting the curriculum for courses to ensure they are industry-relevant; they should be involved in setting priorities for research; they should be involved in all levels of university decision making.

If they are involved in this, then they will share the universities’ vision. By conflating the interests of the university with their own, it strengthens the bonds and helps inculcate an

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alumni culture that supports the university and sees the success of their alma mater as an important part of their own success.

Conclusion

Universities must start seeing their alumni as more than just a source of funding but as partners in the ongoing development of the institution. If they are able to inculcate in the alumni a feeling of partnership and shared interest with their alma mater, then the fundraising will be a natural extension of that.

Universities should recognise that their alumni are in important means by which the university can be marketed – particularly in international settings; that alumni are the agents by which community perceptions of the university are formed and should therefore be seen as critical stakeholders in the institution's future; and the role that alumni can play in improving the quality of education and strategic direction of the university should be recognised and leveraged to its full potential.

Critical amongst all these is the need to provide alumni with an opportunity to work with their alma mater beyond graduation and beyond the usual one-way transfer of donations into university coffers. Some of the practical means by which this can be achieved include the formation of positions on key university councils and policy-setting bodies for alumni; the encouragement and pursuit of cooperative research projects with alumni; the invitation of alumni to provide assistance and employment advice to graduates; and regular communications between university and graduates that extend beyond solicitations for funds but include news and updates on how their alma mater is progressing and what the university needs from their graduates at that time.

Once these links are formed then there will be a shift in the culture wherein alumni will see their old university as something they have a continuing relationship with. It then stands to reason that we will see all the benefits mentioned in this paper begin to materialise because everything hinges on this change in alumni perception which in turn depends on a change in university behaviour towards them.

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A transdisciplinary approach to reducing workplace injury through the use of coronial reports

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Abstract*: The concept of the engineering profession working with the Coroner in an attempt to reduce the rate of injury in the workplace is presented. The paper briefly looks at the role of both the engineering profession and the coroner in relation to safety. The output of the coroner – findings and recommendations following death – is considered as an input to engineering design. Two uses of the coronial information are suggested. Those are case studies in undergraduate education, and the development of publicly accessible databases identifying root causes of workplace accidents. Current work in both areas is presented. All this is presented with the background of a transdisciplinary approach.*

Keywords*: design, safety, coroner*

The Engineering Profession and Safety

The Engineering profession sees itself as providing a service to the community. The Code of Ethics of Engineers Australia, specifically says that engineers must put the interests of the community ahead of any other parties. As a profession, engineers have been addressing community issues for many decades. The recent emphasis on sustainability as the driving factor behind decision making only reinforces this concept.

If it is recognized that sustainability balances on the three legs of economic, environmental and social agendas, then it is easily seen that social responsibility is now a vital factor in any engineering decision. When we consider social responsibility, we must realize that it includes the broader area of community issues as well as the narrower area of the individual. However these two concepts are not mutually exclusive. As the profession is already geared toward considering the broader community issues, it is now worthwhile considering what issues impact on the individual, and how they are to be reconciled with the issues of the community.

One important area that the profession can address immediately is the issue of health and safety. The National Occupational Health and Safety Commission (NOHSC) echoes that sentiment in identifying safe design issues (including engineering design) as one of five national priorities in reducing death and injury over the next decade. In 2000 NOHSC conducted a review of workplace deaths (NOHSC 2000). The review suggested that in Australia there are on average 10 deaths per week in the workplace. A large proportion of these can be traced back to poor design of equipment or systems. Poor design in this case

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does not mean technically poor, but poor from a user's perspective. All design must address both technical and user issues. For this reason this paper will focus design rather than other aspects of engineering.

The Coroner and Safety

The Engineering profession is not the only profession to recognize its responsibility toward health and safety. According to Johnstone (2002a, p30), about 7500 violent, unnatural or accidental deaths are reported to Australian coroners each year. Of these, approximately 200 are homicides. Johnstone goes on to say that

> *… Whilst the coroner's work in the area of specific unsolved or 'hidden' homicides is important…it is in the area of health and safety that there is a need for a far greater level of work.(Johnstone, 2002a:30)*

Coroners have historically been seen as people who apportioned blame after an accident. Through their work however, it has been realized that many deaths throughout Australia and New Zealand repeated the same root causes and industry was not learning from the deaths of individuals.

A Transdisciplinary Approach to Safety

So here we have two professions who are both aware of their social responsibility in the area of health and safety. One group has the ability to reduce hazards in the community, and one has the ability to identify hazards in the community. This suggests that there should be value in the two professions working together. Once we start considering having various professions working together toward the common goal of health and safety, there is a third obvious group that should be included, and that is the Health and Safety (OHS) professionals. This brings together an interdisciplinary group to address the issues. However if a transdisciplinary approach was used, there could be learning within the professions as well as problem solving.

A transdisciplinary approach is an approach that fosters joint solving of complex problems across science, technology and society. Transdisciplinarity requires that stakeholders participate from the beginning and remain active over the entire course of the project and mutual learning is the basic process of exchange, generation and integration of existing or newly-developing knowledge in different parts of science and society (Klein et al, 2001).

So how can the professions benefit each other? From the point of view of the engineers and the health and safety professions, what are the benefits of Coronial inquiries, in Australia, for the community? The benefits of in depth coronial inquiries to the community are many and varied. However we see the principal benefit of 'in depth' coronial inquiries as being the ability for the Coroner to conduct the inquiry in an interdisciplinary environment, without the burden of apportioning blame. This allows the Coroner to identify the root cause (both direct and system wide failures) of an accident, so that issues can be acknowledged and addressed.

Benefits to all stakeholders

There are many benefits that can be derived from this approach. The obvious benefactors are the workers who stand a chance of working in a less hazardous environment and to go home safely to their families once more. The other winners are the employers who will reap the

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rewards of good corporate citizenship and less chance of prosecution or litigation. However, the professional groups also gain significant rewards.

Benefits to the Engineering Profession

The engineering profession can benefit, by furthering its' understanding of how and why accidents occur, and the nature of safe design. The profession prides itself on improving the human condition and having community interests at heart. Engineering designers do not purposefully build hazards into their products and systems. However, there have been many cases of similar accidents or disasters occurring in different products or systems, indicating that designers do not necessarily learn from the past.

High profile disasters that have had similar root causes are the cases such as the Piper Alpha oil platform fire and the Esso Longford explosion (Johnstone, 2002b). Both of these cases had frighteningly similar technical and communication root causes. While major disasters are normally known of and discussed within the industry in which they occur, disasters and accidents with similar root causes can occur in different industries. Accidents involving only one person may not even be heard of outside the workplace in which they occur. Designers need to be aware of previous incidents and disasters.

So how are engineers expected to learn from the past? A designer may be conscientious about health and safety, but how can individual designers be aware of a root cause that occurred in another industry? By learning from coronial reports, the profession can ensure that safer designs are the norm, and so create a safer environment. In doing so, community trust in the profession is enhanced and consolidated.

Benefits to the OHS Profession

Effective Occupational Health and Safety management depends on useful and timely anticipation of hazards in the workplace. The OHS profession is able to use the findings and recommendations of Coroner's inquiries to inform the design of management systems, workplace practice and environments. This allows the profession to assist organizations to learn from accidents without repeating them.

The coroner's cases are also used in the classroom to prompt problem-solving activities that replicate the real situations that students may find themselves in. They are able to practice many of the core skill set, for example, writing legal position papers, investigating accidents, developing an understanding of direct and latent error sources, and applying their knowledge of hazard control. Context is extremely important in OHS education and practice. Learning from Coroner's inquiries allows students and practitioners to hone their skills in a safe and non-threatening environment.

How Can the Coroner Contribute

The next generations of the professions must be educated. If cultural change is to occur, then the next generations of the professions must be the drivers. To do this, the resources must be there for them to use in their learning. The resources include availability of case studies and databases. The use of case studies to demonstrate how people can be injured, and how systems can be designed to ensure they are safe, is vital. The undergraduates also need the opportunity to work in interdisciplinary or preferably transdisciplinary teams. If this is done at undergraduate level, it becomes easier to work in this manner as a graduate.

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The outcomes from the Coroner's reports – the recommendations – can provide a stimulus for treating problems at the system level, which has great potential in the prevention of accidents. Engineers have a duty of care to end users of the systems they design under current statutes and at common law. That engineers contribute to human error in systems through latent design error and poor management decision-making is well documented (Toft, 1999). Therefore, the role of engineers can be considered integral to positive outcomes in safety.

Ultimately, it reasonable to expect, that when engineers have a better understanding of the human component in their system designs there will be reduced design related human error, therefore, better health and safety of Australia's workforce and community in general. The 'in depth' Coroner's inquiries can fill this much needed gap in knowledge.

A further benefit of the 'in depth' enquiries is that the reports become public domain, and therefore can be used as a source for organizational learning, or simply as a source of identifying issues, particularly in design, that must be addressed so that accidents or disasters are not repeated. An example of this is the Linton Wildfire inquiry and report (Johnstone, 2002c). While the inquiry found the cause of death, it also identified some previously unrecognised flaws within the original design decisions. For example, issues such as identifying exactly what volume of water is needed to be kept in reserve for self-protection of the firefighters, rather than just a percentage of a tank. The rule of thumb that the firefighter worked on was to keep ¼ of a tank in reserve to use as an umbrella for self protection should they find themselves in the path of the fire. As various tankers have different size tanks, using a percentage of the tank means that the different tankers have different levels of self-protection. The coroner's recommendations also highlighted unsubstantiated assumptions as to how much water is actually required for self-protection.

The inquiry also identified that there had been no research to identify exactly how much water was needed for self-protection. In this way, the Coroner's findings and recommendations can inform the future and direction of community centred research. However, the effectiveness of this potential learning is dependant on whether allied professionals are able to access and use the information, and on the quality of the reports.

The outcome for the community in general is then an improvement in the products and processes that are made available, and the confidence to know that accidents should not be repeated. This should be possible where there is a detailed documented analysis of how the event occurred and where the Coroner makes recommendations. For example, the cause of the series of Mistral Fan fires was identified through the detailed analysis of seemingly unrelated cases (Johnstone, 2002a). It was the Coroner's "bird's eye view" of the commonalities within the cases that led to unravelling the mystery. It is through the recommendations that action is identified and made possible.

How Can the Coroner's Data be Used?

The following section outlines some uses for the coroner's data. New and creative uses are encouraged so these examples provide a starting place only.

Undergraduate Education

Engineering undergraduate programs have traditionally valued and emphasized technical excellence, and so they should. This has resulted in graduates who are technically proficient, and consequently looking for technical solutions to community problems. The emphasis within the profession on sustainability has however led to recognition that if graduates are to

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be socially responsible, then they must address social issues at the undergraduate level. This is evidenced in the current accreditation requirements by Engineers, Australia, for engineering programs in Australia (IEAust 1999).

Engineers as designers have a responsibility to ensure that the designs that they create are safe for the users. Unfortunately engineers, being people, are only able to create safe designs based on their knowledge and understanding of what is safe. This knowledge is often developed through experience, and through learning from the past. If disasters, and their causes, along with the issues raised are kept hidden, or not fully investigated, then it becomes difficult to learn from the past. Traditionally engineers have been taught that designing to Australian Standards will ensure a safe design. Standards have been proven to be inadequate at times, and a reliance on them can be dangerous. Development of coroner's reports into case studies that would inform educators and provide a learning stimulus for students is one potential use of the coroner's data.

This approach would afford engineering students the opportunity to practice 'risk management'. The following is an excerpt from a lesson plan using the Linton case study as an example from our own teaching:

> *How could an engineer have been expected to anticipate, identify and act on these issues? The following process provides a useful guide. The main steps in the process are:*
>
> *1. Anticipate and identify hazards*
>
> *2. Assess risks that may result because of the hazards*
>
> *3. Decide on control measures to minimise the level of, or eliminate, the risks*
>
> *4. Implement control measures*
>
> *5. Monitor and review the effectiveness of the implemented measures.*
>
> ***1. Anticipate and identify hazards***
>
> ***1.1 Thorough problem definition.*** *At the design stage, problem definition itself has to include more than the technical specifications. It should also include*
>
> - *A thorough understanding of all tasks involved.*
> - *A thorough understanding of the intended environments.*
> - *User requirements eg. Information on when tank is at low level.*
> - *Recognition that the designer is not normally the typical user. Therefore the designer needs to consider the user in the design process. This can be achieved by:*
>
> *1. Consultation with typical users (not just their supervisors).*
>
> *2. 'Walkthroughs'–these could be computer generated simulations or even a simple mental walkthrough of actual usage, preferably with a potential user.*
>
> *3. Looking at the way people actually interact with similar pieces of equipment i.e. the model of usage for similar tasks or control configurations.*
>
> *4. Talk about any problems the user has using current equipment in their workplace.*
>
> - *Use the human factors advice available, for example HB59 Human Factors (Australian Standards Handbook)*
>
> ***1.2 Learning from the experience of others.*** *Use this information to inform future design. For example:*
>
> - *Accident reports*

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- *Safety alerts from the various state and federal government agencies responsible for OHS (e.g. NOHSC– all others jurisdictions can be found from NOHSC website)*
- *Coroner's reports*
- *OHS Practical Solutions database (NOHSC website)*

2. Assess risks that may result because of the hazards

Many factors must be considered when assessing risk.

- *Nature of the **environment** in which the design will be used (contextualise the actual use of the design) for example in this case consideration that the operator would be concentrating on putting out a fire, not watching a gauge.*
- ***Processes** carried out within that environment, that is, did the designer consider any other operations in the environment that might impact on the safe operation of the equipment? (e.g. desealing/resealing of the tank, and workers exposed to a cocktail of hazardous substances.)*
- ***Characteristics of the users**, such as age, anthropometrics (size of people) level of skill, knowledge and experience. For example, how did the design take into account the various people who might be using it, and how differences between those people might change the way they carry out the process.*
- ***Existing hazard control measures** and their effectiveness. For example, have any accidents ever occurred previously in similar fires?*
- *Consider the **range of environments** in which the design will be used. In this case they could range from grass fires to forest fires and house fires; in flat of hilly country. Also consider the stress that emergency situations might induce in worker behaviour; other lives may be at stake too.*

3. Decide on control measures to minimise the level of, or eliminate the risks

- *Revisit the hierarchy of control, and ensure that control measures are aiming at the top, not the bottom of the hierarchy. Eg, in this case realise that if the ¼ tank rule is taught then people will expect teams to use it, but this is use of PPE. So elimination of the hazard in this case would mean not needing to use the ¼ tank rule.*
- *Controls must be based on a life cycle approach. This means that the concept design phase is the ideal place to consider identifying hazards and appropriate control measures.*

4. Implement control measures

- *Systematic evaluation of both the probability of a hazard occurring and consequences of injury or illness that may arise from exposure to identified hazards is the central mechanism for applying the OHS hierarchy of controls.*

5. Monitor and review the effectiveness of the implemented measures.

- *It is important to ensure that you are not introducing new hazards into the system as you plan and implement the controls. The risk management process is an iterative process, and each of the steps should be applied until you are sure that new hazards no longer exist. This is a continuation of the concept that the design process is an iterative process.*

While construction / manufacture and maintainance are important areas of engineering, the focus of the learning experience has been on the use of the risk management process to improve design. This enables students to work at the top of the hierarchy of control measures as a first option for elimination of hazards.

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User Friendly Databases

If the engineers and the health and safety professionals are to learn from, and work with the coroners and each other, there is much groundwork to be covered. A common language must be developed (Toft, Howard and Jorgensen, 2000). Even in disciplines where similar language and approaches are used, the same words can have different meanings, and communication becomes an issue.

The knowledge and databases must be developed. If the engineers and health and safety professionals are to learn from the coroners, the information must not only be available, but available in a format that can be accessed and used. Coroner's reports have findings and recommendations that are usually filed and go unimplemented by the vast majority of industry. The company that is affected by the death is usually the only company that implements the recommendations from the inquest. Companies not associated with the death can prevent many failure modes by learning from the death of an individual. The National Coroners Information System, while a commendable project and eminently suitable for its intended purpose, however is not a suitable tool for the designers to use.

If a designer is looking for potential hazards in a new product or system, it would be of great value if they could access a database that identified where accidents had already occurred. As the designer is not usually a typical user, their familiarity with the system can (and does) easily lead to overlooking hazards. While they could work with a health and safety professional to identify hazards, access to databases of previous accidents would only add to the safety of the design. The information in the coroner's reports can provide the basis for such databases.

Current Work

Undergraduate Education

As a research team, we have used information from the Coroner's reports to build case studies of poor design in relation to safety. This work was funded as part of the NOHSC Safe Design Project. The publication we have recently completed is to be called "Occupational Health and Safety for Engineers – A resource for engineering education".

This series of case studies is aimed at demonstrating the multi factorial nature of accidents, within the context of real environments, with all the inherent complexities. It is expected that the use of such case studies will go towards the development of engineering graduates with a more holistic appreciation of the interaction between people and the products, systems and processes that engineers design

The types of cases (Coroner's reports) that we used are those that have poor design as a root cause. Poor design does not necessarily mean technically poor, but poor in terms of usability or the way in which people react with the product or process, or the way in which the project is managed. We also looked for real situations, with real people, telling a real story. The reality is very important for the students to understand the human in that situation. The reality also helps the students realize that this is a situation that they, as designers or managers, could find themselves in. It also challenges their developing sense of ethics.

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User Friendly Databases

This research team is now involved in the CRC - Centre for Integrated Engineering Asset Management (CIEAM). There are currently two projects run by this team that have emerged from that association. They are:

- a pilot project to deliver workshops to industry partners on the use of the coroner's data to prevent accidents through design, and
- a project working with Ford Australia to bring a database of root causes of potential hazards based on coronial data to the Central Queensland University web site.

These projects came about because the Plant Manager and the Corporate Manager of OHS for Ford Australia approached the State Coroner to gain input to setting up a project whereby all industry would learn from the mistakes made in industrial deaths. Ford Australia would set up a database and input all historical data, findings and recommendations from Coroners findings all across Australia. The information would be shared amongst all industries. The State Coroner was supportive of the project and lobbied other State Coroners.

At Ford Australia, a team was formed to establish the techniques for collecting the data, and developing the database. The result is a database that can search on keywords, incident type or incident title. The database's central location was Ford Australia, but it was hoped that a Government Agency would host the database on their web site for all industry to access. CQU has become this partner.

The measurable results from the collection and logging of the data to date is as follows:

- Over fifty cases have been identified and logged onto the database
- Over 300 findings logged
- Over 600 recommendations to avoid industrial death thus far
- Historical data has been loaded from the Australian states of Victoria and South Australia and from New Zealand.

This database has already helped Ford Australia identify the size of manholes as a safety issue. It was identified through deaths in a number of confined spaces that manholes, even if designed to the appropriate standards, could be a hazard particularly in a rescue situation.

Ford Australia as a result of some of the findings and recommendations has reviewed and implemented changes in the following programs:

- Size of manhole covers
- Confined spaces
- Auditing processes
- ECPL procedural review.

Funding has now been obtained to develop and host the Ford database on the CQU website, to allow public information to the information.

Conclusion

The concept of the three professions learning together as an interdisciplinary group could have positive outcomes for the community. However, the real differences will be seen when the transdisciplinary teams of the three professions start working together to develop and implement solutions. The community problem has been identified – safe products and systems are required. The solution is not so easy. What is required is a cultural change

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within the professions. While the governing bodies, for example Engineers Australia, may require its members to produce sustainable designs, if the knowledge does not exist, then the outcome is difficult.

Socially robust research in this area will require several prerequisite conditions for success. The most important being good quality investigation and reporting, that documents are public domain, and ensuring access to the learning occurs across professions and industries.
It is vitally important that the neutral community partner (the Coroner) has a voice that can provide credible advice and inform change. That the loss of life is not in vain, but that the living can learn from the findings and recommendations, is possibly the greatest benefit for the community.

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Engineering Education: Enculturation, assimilation or just passengers on the bus?

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Abstract*: Engineering Education has been described as "enculturation into a well-established system of practices, meanings and beliefs" as students "learn what it means to be an engineer" Tonso (1996a, p.218). In a recent case study, it became apparent that for many engineering students the educational process has been one of assimilation, adopting instrumentalist attitudes of compliance, rather than enculturation into the shared values and norms of the engineering disciplinary culture. This paper uses a model, developed to define the dimensions of the engineering education culture, as the framework for an examination of the role teaching and assessment practices play in the processes of enculturation. Many of these practices explicitly acknowledged and manifested the "engineering way of thinking and doing" but student behaviours and cultural norms were found to reflect a "hidden curriculum" of knowledge and understandings, often in direct contrast to espoused learning objectives.*

Keywords*: enculturation, teaching and learning, Engineering education*

Introduction

The focus of this paper is to use the lens of a cultural analysis to investigate:

- firstly, whether undergraduate students develop shared beliefs and assumptions, the essence of enculturation, around what it means to be an engineer; and
- secondly, to provide a cultural model which will enable an examination of how, or whether, the teaching and assessment practices manifested in engineering education, are translated by students into cultural norms which determine and shape their learning outcomes.

The concept of culture is common within educational discourse and definitions, perspectives and understandings of culture and enculturation abound. Central to all is the notion of sharing - sharing of experiences and values which guide action and reactions. Shared understandings, knowledge, symbols and experience are expressed as cultural norms in the behaviours and practices of an affiliated group which give them social definition and a sense of association. Not all students attending lectures in a subject will be enculturated into a discipline, just as passengers on a tour bus do not necessarily share a common culture. Academic disciplines, however, have been described as involving a sense of identity and personal commitment, "a way of being in the world"… "a matter of taking on a cultural frame that defines a great part of one's life" (Geertz, 1983, p.155) or in Becher's (1989) view as "academic tribes". Engineering is a professional academic discipline serving, as it were, the needs of two masters. The culture of engineering education is therefore likely to be a blend of the values,

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beliefs and attitudes common throughout higher education and those of a long standing profession with a strong sense of identity.

The concept and existence of a disciplinary culture for engineering education, was brought into the spotlight in1996 by the Australian Review of Engineering Education which was entitled "Changing the Culture" (IEAust, 1996). In recommending a “more outward looking culture attuned to the real concerns of communities”, better communication skills, and political and social awareness, the Australian review echoed discussions occurring simultaneously in the UK, USA and Canada. In the years since 1996, institutions have reported on a range of initiatives to implement the recommendations of the Review but few have addressed the concept of culture change as explicitly as the University of Queensland (Radcliffe, Crosthwaite & Jolly, 2002). Inherent in any discussion of culture is the assumption that newcomers to the culture undergo a process of learning cultural norms and values from everyday behaviours and practices.

Learning what it means to be an engineer has been approached from the perspective of situated learning theory and communities of practice (Lave and Wenger, 1991; Tonso, 1996b), and the "construction of identity" (Stonyer, 2002; Walker, 2001). It has also been described as “enculturation into a well-established system of practices, meanings and beliefs” (Tonso, 1996a, p.218). To effect cultural change, it is suggested that a clear understanding is necessary of how, and indeed whether, disciplinary values and cultural norms are reinforced both explicitly and tacitly in day to day practices. In developing that understanding, a cultural analysis could also reveal whether the educational process has involved enculturation at the level of shared beliefs and assumptions, or only a process of assimilation, with students adopting instrumentalist attitudes of compliance to fulfil their goal of graduating.

This paper uses a model developed in a recently completed study (Godfrey, 2003) as an effective and accessible analytical tool with which to examine our practice. The aim of the study was to define the dimensions of the engineering education culture, embodied at one institution (University of Auckland), and their interaction with gender particularly in the processes of enculturation. An interpretive case study methodology using predominantly ethnographic methods of data collection was used with checks for validity and trustworthiness build into the research design. The transferability of this research lies in the development of a model for cultural analysis, and a set of cultural dimensions for engineering education, which have the potential to enable other institutions or disciplines to similarly examine their own unique manifestation of their discipline culture. A brief description of the model is presented in the next section

A Theoretical Model for Cultural Analysis

Schein's (1985) influential cultural framework was used as a starting point. It proposed three levels of culture: observable and tangible manifestations, underlying values and behavioural norms and, at the deepest level, unconsciously held shared beliefs and assumptions that Schein saw as the core or essence of a culture.

Schein’s model was amended (Figure 1), to take account of an evolving understanding of the sense of depth and interconnected layers within the outermost, observable level of culture and the dynamic relationships between the levels of culture. The first level of culture was teased out into three categories for the observable and tangible manifestations. Firstly, named as Artefacts, there was the level visible to a visitor or newcomer; written documents, mission

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statements, buildings, dress, gender and ethnic composition. Secondly, after a longer period of observation and investigation the structures and practices, including those which were not written rules or regulations, were revealed and this second level was named Practices. Practices were defined in the context of this study as "the usual manner of doing something" referring to those aspects of the culture which represented "the way we do things round here" and included curriculum and teaching practices, assessment, regular events and reward systems. Thirdly, after trust had been established, insightful discussions with members of the culture illuminated observed behaviours and the reasons behind them. These were grouped as responses to the academic environment, relationships, language and humour. In many instances this grouping encapsulated the "lived experience" or "enacted" aspects of the culture.

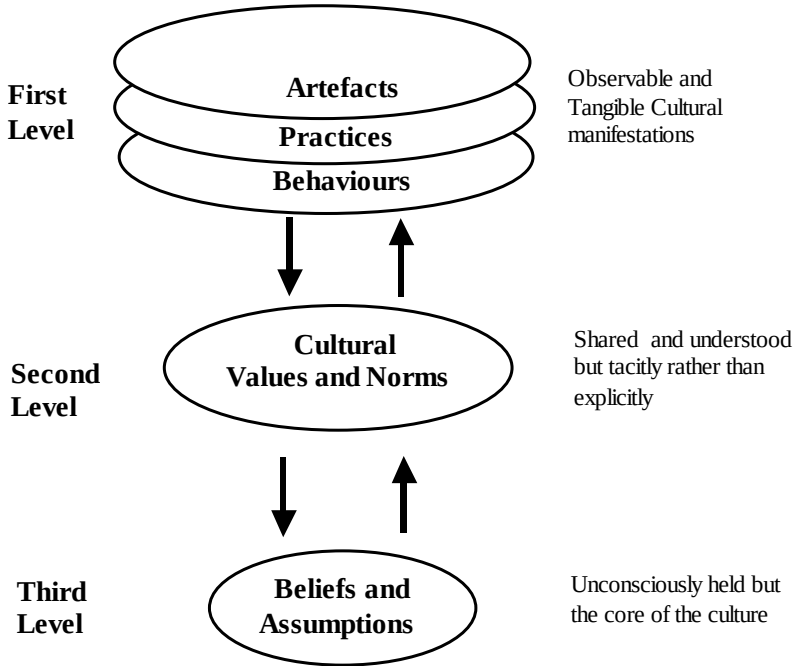


Figure 1: Theoretical model for cultural analysis (Godfrey, 2003)

Bringing together evidence from a variety of data sources, gathered under each of Artefacts, Practices and Behaviours, values and shared cultural norms were then identified. This second level of analysis was particularly revealing of enculturation processes. The aim of this second level of analysis was to constantly seek underneath the observable behaviours and practices, using the voices and experiences of members of the culture to interpret which cultural norms or shared values were being manifested. Analysis, even to this level revealed information: firstly, about whether espoused values and goals had become embedded in cultural norms and secondly, the enculturation processes by which students developed shared understandings and learned cultural norms from the daily reinforcement of artefacts, behaviours and practice.

The dimensions of the engineering education culture

The third level of the cultural analysis, the shared basic beliefs and assumptions which were viewed as forming the essence of the engineering education culture were then distilled from the previously identified values and norms and grouped into six dimensions. Despite

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individual differences, it was observed that these beliefs and assumptions were rarely discussed, appearing to be unconsciously held and taken for granted by both engineering academics and students but acting as the source of the values and norms which in turn were then manifested in Behaviours and Practices. The six dimensions and a brief summary of the associated shared beliefs and assumptions emerging from the case study institution are listed below. The complexity and web-like interplay of these beliefs and assumptions cannot be adequately displayed in this brief listing, and referral is suggested to Godfrey (2003) for a more complete discussion.

- Engineering way of thinking:
  - dealt with a tangible, definable, measurable, quantifiable reality proven and described by mathematics.
  - focused around problem solving and design – a solution must work, it could not be hypothetical. It must do the task specified, within the limits specified.
  - looked for "best" answers rather than "right" answers.
  - knowledge, the mathematical procedures and scientific processes, and the laws on which problem solutions were based assumed to be race and gender free.

- Relationship to the environment
  - strongly integrated faculty with a sense of independence and self sufficiency within the wider university
  - strong links to the profession of engineering

- Engineering Identity
  - Pride, almost arrogance in identity as engineers
  - "Can Do" people, proactive achievers, who if given the resources would accomplish tasks efficiently and effectively.
  - Numerate; competent and confident with technology and computers; tough, self-reliant, and capable; not emotionally demonstrative ; trust logic, analysis and reason; Conservative ; Pragmatic rather than idealististic; valued humour often self deprecatory; not overly concerned with style in dress or appearance.

- Engineering way of doing (teaching and learning)
  - belief that anything worthwhile was hard - devaluing of content or subject areas which were seen as "easy" or "soft" – learning seen as "shared hardship"
  - "challenge and stretch" approach to teaching - pushing or pulling students to new limits
  - sizeable core of essential, inflexible technical content
  - both competition and co-operation important as appropriate forms of behaviour
  - goal of student learning was to pass rather than to understand

- Relationships
  - strong interdepartmental cooperation
  - importance of "mates" - supportive academic/ task oriented friendships essential for success
  - egalitarian – low power differentiation amongst staff
  - relatively informal staff/student interactions

- Homogeneity
  - Relatively homogeneous core of long serving male staff

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- Likelihood of lack of homogeneity in personal values with increasingly diverse student body

Some features of the culture at the case study institution may have been unique, such as the tradition and valuing of integration between the sub-disciplines, and the School of Engineering's sense of identity and isolation from the wider university but many of the beliefs and assumptions identified in these cultural dimensions appeared to be the source of practices and behaviours commonly identified in the international research literature.

Enculturation - learning the culture

Using the proposed model, learning the culture can be described as a top-down process. From the observable and tangible manifestations of the culture, the day-to- day practices and behaviours contained in teaching and assessment practices, events and relationships, students interpreted the values and cultural norms which empowered them to operate successfully within the learning environment.

Staff played the major role as transmitters of the academic side of the culture. They had the power to set curricula and pedagogy, affirm culturally appropriate behaviours and reward, using assessment, ways of thinking and reporting. In the engineering case study, senior students played an important role in transmitting social values and cultural norms. The students' peer group also contributed, by affirming appropriate behaviours and practices, particularly in the formation of task-oriented friendships and support strategies.

The common Part I program, taught "in-house" rather than by science faculty, was an explicit manifestation of the value placed by staff on enculturating students right from the beginning and introducing them into the "engineering way of thinking".

> *Diverse range of courses -not one overriding philosophy. Some courses seem to be teaching us to think as engineers whereas others, rightly so, are concerned with basic knowledge, the calculations, the details* *Laurie 1st year*

As students moved through the degree program, the process of repeatedly finding out what "worked" and was rewarded, led them to learn and identify with the values and cultural norms which they perceived as congruent with the identity "engineer". Similar processes would occur in any institution or discipline in which a history of shared experience and stability had allowed a distinctive culture to emerge.

The following student comments, demonstrated that engineering students, even in their first year, had gained some appreciation and ability to recognise an "engineering way of thinking" and "way of doing" and what it meant to be an engineer:

> *Thinking like an engineer, kind of being taught it I suppose. The whole course is directed at making you think differently, that is how I feel it.* *John, 1st year*

> *I think that thinking as an engineer is thinking of the theoretical best solutions to problems and then the best practical way of doing it* *Joshua, 1st year*

Do we teach what we value? What do students learn?

Teaching and assessment practices played a particularly important role in the processes of enculturation. The brief examples presented in this section show the potential of these

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practices not only to reinforce for students the beliefs and values shared by staff, but also to lead students to unintended learning outcomes.

Some practices in the case study institution were the explicit manifesting of espoused values formulated during a major curriculum restructuring. As an example, one goal of this restructuring was the valuing of communication and professional skills. The inclusion of a Professional Development course in each year of the degree, utilising a variety of assessment methods – both written and oral, manifested the value placed on these skills. As a consequence of making these values explicit in the curriculum and reinforced by assessment practices, even first year students had developed shared understandings exemplified by these comments :

> *You do have to think about that, they have been drumming it into you. Engineering is communicating, you have to know how to write, and how to talk with people and communicate* *Angus, 1st year*

> *I think engineers need this stuff – they need to be able to look at the bigger picture, emotions, costs, whatever else is there and just – sort of moves into things I think engineering is lacking.* *Richard, 4th year E&E*

As Jolly, Crosthwaite and Radcliffe (2002) also noted, despite the efforts of staff to forefront non- technical aspects such as social and environmental issues, there was a tendency for these issues to be marginalised in the Professional Development core papers, rather than integrated into the technical papers. Students therefore had developed other shared understandings which led to comments like:

> *I think they tended to marginalise the information about environmental stuff. Maybe they should have it integrated into all the papers if they really value it... What they are saying in their values is that this stuff is not an important part in engineering -it is an aside that we throw in because we have to, but it is not a core part of engineering...* *Megan, new Civil graduate*

Other practices were the result of taken for granted, rarely articulated, shared understandings, such as the pervasiveness of mathematics as an efficient, effective means of communication. It was common practice to see lecture notes and whiteboards completely taken up with mathematical formulae and computations. Students and staff shared understandings about the role of mathematics, both as a tool and a language.

> *Engineers have to be able to, have a mathematical mind, and enjoy maths I guess or at least tolerate it. I think it is the most important thing* *Alex, 1st year*

> *Mathematics is a nice vehicle for delivering these ideas I don't think you could really function without mathematics in these sorts of systems* *SStaff6*

> *We use maths like a language -a language to express ideas -so unless they can understand what the parts of the equation mean they cannot see how it can be manipulated and a higher level of understanding cannot be attained.* *JStaff 4*

Students were constantly reminded by repeated examples that mathematics was important: engineers had to provide solutions that actually worked, bridges, materials and power systems that could withstand their loads, structures and systems that could work within predictable constraints and tolerances.

The level and role of mathematics established status and contributed to assumptions about the hard/soft positioning not only of other academic disciplines, but even sub-disciplines and individual courses within engineering.

> *Although we all focus on applying knowledge and use mathematics for analysis and modelling, there is definitely a difference in the department in the way we view subjects like Control, Thermo, Strength of Materials ...which require mathematical analysis and are dominated by people with mathematical*

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> *strengths and the more practical ones like Management and Manufacturing -their analysis is also complex but sort of more wordy and descriptive. They don't command the same respect and aura.* *Sstaff10*

Tensions and contradictions were often apparent at the second and third layer of analysis, as cultural norms revealed in the shared understandings around behaviours and practices a mismatch with espoused values. Individual assessment items, for example, were sometimes perceived as not matching goals:

> *The lectures in Geomechanics were really interesting and included stuff about the environment but the exams were all mathematical – easier to mark I suppose.* *Trish, 4th year Civil*

> *The lecturer said the test would be based on understanding concepts and ideas and the test was all multichoice rote learning or numerical problems. Some people were a bit dismayed and asked "What the heck is going on"* *Laurie, 1st year*

Deep learning (Ramsden, 1992) was an espoused value expressed in course aims which used terms like "understanding" and "application of knowledge". Perceptions by both staff and students however evidenced an instrumentalist or surface learning approach. This is not a new phenomenon. Snyder as far back as 1971 had suggested that an instrumentalist student had a pragmatic approach to education where the validity of an action was determined by its successes, the validity of an idea by its utility. A "go for grades" or "just in time" approach to learning and assessment was prevalent, often blamed on the high workload of on-course assessment, but perceived as a cultural norm.

> *I am concerned that lecturers believe that they are teaching for understanding and that this is what students should be striving for – understanding and challenge – but my observation is that students only think of grades – "Is it in the exam?" "What does it count for?"* *JStaff2*

> *sometimes we did not have the time to learn, just to hand in the assignments on the date they were due* *Simon, 1st year*

> *too much in too short a time, we never had time to get into anything in depth* *Questionnaire M3*

Another mismatch between espoused values and cultural norms was the incidence of cheating or inappropriate co-operation. In a culture which highly valued co-operation and teamwork this mismatch created ongoing dilemmas for equitable assessment and seemed driven by the perceived need to pass.

> *They don't want to fail and if you don't know what you are doing you probably go to any lengths to keep passing – maybe the risk is worth it.* *Helen, new graduate EEE*

Assimilation or enculturation? Which is needed for success?

It might be asked "Is enculturation different or more imperative for the professional disciplines where there is a greater "buy-in" to a shared identity?" A strong sense of identity as engineers ran throughout this study and even the few examples discussed in this paper have evidenced cultural norms and shared beliefs and assumptions which implied a level of enculturation. Three levels of enculturation were evident.

The first was like a passenger on a tour bus - they have paid the money, taken the trip with other people, gained the piece of paper. Such students would have a very shallow approach to learning with little understanding of the discipline and would be unlikely to be able to apply the facts and knowledge gained. Questionnaires returned from a diverse group of students revealed a very small number of students in this category. The long period of close contact and compulsory courses resulted in some degree of shared understandings having developed even if as one student expressed it:

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Am I happy I did engineering? – Happy is not a word I would use for engineering!

There was, however, considerable evidence that for a large number of students the second level of enculturation, Assimilation, was more common. This level appeared to imply a strategic or instrumentalist approach to learning. These students used an expedient mixture of deep and surface approaches to ensure academic success, with a sharing at the level of cultural norms and some values, but without a sense of whole hearted commitment at the level of beliefs and assumptions. Staff saw this, in part, as:

> *A factor of the pedagogical climate -idea of university as a place where they find things out for themselves has gone -some of that can be based on having to pay their own fees -their attitude is "I paid my fees -now just help me get out of here " SStaff4*

This concept of an education as a "transaction" was also evident in comments such as:

> *Lecturers need to realise we pay a lot of money and should therefore receive a quality education Questionnaire M27*

In a discipline such as engineering where students progress as a class group for four years, and in an institution such as the U of A where the faculty has long standing traditions, with long serving staff, the process of enculturation as described by Tonso (1996a) did appear evident for many of the students. Interviews and questionnaires with final year students revealed a high degree of commonality, which demonstrated that many of these students had interpreted and internalised "what we do round here" to the level of shared beliefs and assumptions about the engineering way of thinking, doing and being. The following comments illustrated that although these shared beliefs may not have superseded personal social values a sense of "what it means to be an engineer" was evident.

> *Engineering does have a special and valued identity. It is "I am an engineer" based on getting a job, working harder, doing something practical and useful... .The pride in being an engineer, combined with how much time you spend with classmates results in a family feeling. Trish, 4th year Civil*

> *I think there is a culture in terms of "I am an engineer" and the way of thinking in terms of an academic attitude ...but on a social level there isn't a distinctive social type, there is a distinctive thinking type Angus, 1st year*

Several questions appear to remain. How necessary is it that students at undergraduate level are enculturated into a discipline? Is assimilation sufficient if what is “taught” (curriculum teaching and assessment practices) explicitly manifests “espoused values, beliefs and attitudes”. Is this sufficient to ensure appropriate and desirable learning outcomes for the majority of students? It is argued that at undergraduate level, with increasingly diverse students, it may be an unrealistic expectation for enculturation to have occurred for all students, and that a pragmatic assimilation may be sufficient. Further exposure to the beliefs and assumptions of engineering education, developed over time in employment or postgraduate study are seen as likely to consolidate the values and norms learned as a student.

The cultural model presented in this paper demonstrates that for students to be enculturated into this disciplinary culture, to gain an understanding of and commitment to what it means to “be an engineer”, the outermost level of culture - the observable manifestations of behaviours and practices i.e. teaching, curriculum content and assessment, must reflect and manifest the desired values and goals in as explicit a manner as possible. If not, students will interpret for themselves what they believe is valued and their learning outcomes will reflect that interpretation.

As teachers, (assuming a desire for student outcomes to match espoused goals), a cultural lens can be used to ask the questions:

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- What are the learning objectives (espoused values) I am aiming for in teaching this course/programme?
- How does my teaching make these explicit? - content, teaching style…
- Do my assessment methods and content reflect these espoused values?
- Have students internalised these values?

Although initially developed to be accessible in theory and discourse to engineering educators, the model presented is offered as a tool suitable for use at both strategic and operational levels to assist in reflecting on our teaching and assessment practices and their connection to learning outcomes.

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Why do Deakin students elect to study engineering?

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***Abstract**: Responses were collected from commencing engineering students and an inventory of reasons stated for electing to study engineering was developed. Commencing engineering students were strongly career oriented, they believed that engineering would be an interesting and rewarding career that would offer enjoyment and career options. No difference was found in the principal reasons stated by respondents based on gender or course of study. On-campus students nominated principally career-related reasons for their choice of study (71 percent). While career-related reasons were still important for off-campus students, the most frequent type of responses were related to career upgrading (43.9 percent).*

***Keywords**: Commencing students, engineering and technology, career*

Introduction

The School of Engineering and Technology at Deakin University offers a three-year Bachelor of Technology (BTech) and four-year Bachelor of Engineering (BE) (together referred to hereafter as 'engineering courses') at the undergraduate level, in both on- and off-campus delivery modes. No previous comprehensive investigation as to why students choose engineering courses at Deakin University had been carried out. If there existed robust and reliable information about the reasons why students elect to study engineering courses at Deakin University, then the attraction(s) of these courses could be better understood, recruitment of potential student groups likely to be attracted to study at Deakin University could be more effective, and the courses could be developed to help ensure that student expectations for the courses can be met. As part of undergraduate engineering studies at Deakin University students take a unit entitled SEB121 Fundamentals of Technology Management in the first semester of the first year of their studies. The enrolment in this unit includes both BE and BTech students, as well as a small number of students not studying engineering-related courses but who take this unit as either an elective or (more commonly) as a requirement in their course. Surveying students enrolled in this unit should provide a comprehensive snapshot of the reasons why commencing students elect to study engineering courses at Deakin University.

Methodology

During the period 2000-2002, the assessment for the unit SEB121 incorporated the use of an on-line conferencing system into which students submitted their assignments. In all three years, the students were required to introduce themselves in a public on-line conference area

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by posting a resume of themselves, including their name, course being studied and their reason(s) for electing to study engineering or technology. The archives of these on-line conferences yield a comprehensive picture of the reasons why commencing Deakin University students elect to study engineering courses.

The archives of student responses to the assignment question identified above for the years 2000-2002 were examined and an inventory of the reasons stated for electing to study engineering and technology was developed. For each respondent in each of the three identified years, the student's stated reason(s) for electing to study engineering or technology was classified according to the previously developed inventory and recorded, along with their reported course of study. Demographic information about gender and mode of study (on- or off-campus) was attached to each identified student response. All information permitting identification of individual respondents was then deleted. Descriptive statistics on the reasons stated for electing to study engineering courses were compiled. The results were statistically analysed to determine if there were any significant differences in the stated reasons of the demographic groups in the sample (year of cohort, course of study, gender and study mode). For this research project a significance level (p) of 0.05 was used.

Results

Response rate

In 2000 128 students were enrolled at the time the on-line assignment question was completed, 116 assignment submissions were received, hence the response rate was 90.6 percent. In 2001 141 students were enrolled, 134 submissions were received and the response rate was 95.0 percent. In 2002 134 students were enrolled, 127 submissions were received and the response rate was 94.8 percent. Combining data from all years, 377 responses were received out of 403 enrolments, giving an overall response rate of 93.5 percent.

Inventory of reasons

Following examination of all student responses to the assignment question for the years 2000-2002, the following inventory of the reasons stated for electing to study engineering courses was developed.

1. To work 'in the field', not in an office all day
2. Parent, family member or friend works/worked as an engineer
3. A career that I will enjoy and allow me to pursue my interests
4. A rewarding career with a wide range of options for employment
5. The course that I had the tertiary entrance score to get into (not course of first choice)
6. As an engineer I will be able to help build a better world
7. No response stated
8. Changed into engineering from a course I didn't like
9. Upgrading my qualifications / change of career
10. My current employment requires me to obtain a bachelor's degree in technology
11. I'm not sure why I chose engineering
12. To be involved in shaping the future
13. SEB121 is a required unit in a non-engineering course
14. The course description in the handbook sounded interesting
15. I enjoy creating/designing things and solving problems
16. To advance my quality of life
17. To study a course that has definitive answers to questions

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Demographic information

In 2000 the gender proportions of respondents were 10.2 percent female and 89.8 percent male. In 2001 the gender proportions were 14.2 percent female and 85.8 percent male. In 2002 the gender proportions were 9.0 percent female and 91.0 percent male. Combining data from all years, the overall gender proportions were 11.2 percent female and 88.8 percent male. The gender proportions were not significantly different between the three years ($\chi^2_2 = 2.09$, $p > 0.35$). Each year pair (2000/2001, 2000/2002 and 2001/2002) of gender proportions were also compared and no significant differences were found. In 2000 the course of study proportions of respondents were 71.1 percent BE, 25.0 percent BTech and 3.9 percent Other. In 2001 the course proportions were 64.6 percent BE, 33.3 percent BTech and 2.1 percent Other. In 2002 the course proportions were 66.4 percent BE, 25.4 percent BTech and 8.2 percent Other. Combining data from all years, the overall course proportions were 67.2 percent BE, 28.1 percent BTech and 4.7 percent Other. The course proportions were not significantly different between the three years ($\chi^2_4 = 8.27$, $p > 0.08$). In 2000 the study mode proportions of respondents were 81.3 percent on-campus and 18.7 percent off-campus. In 2001 the study mode proportions were 85.1 percent on-campus and 14.9 percent off-campus. In 2002 the study mode proportions were 76.1 percent on-campus and 23.9 percent off-campus. Combining data from all years, the overall study mode proportions were 80.9 percent on-campus and 19.1 percent off-campus. The study mode proportions were not significantly different between the three years ($\chi^2_2 = 3.61$, $p > 0.16$). Each year pair of study mode proportions were also compared and no significant differences were found.

No significant differences were found in any of the demographic characteristics measured between the three year groups of students. This suggested that the results obtained for individual years could also be validly pooled and considered as a single larger group.

Reasons stated for electing to study engineering and technology

Table 1 gives the indicated proportions for each of the reasons stated for electing to study engineering and technology by respondents for each year 2000-2002 and all years combined. The stated reasons are ordered using the rank order of all years combined. The indicated proportions of reasons stated were not significantly different between the three years ($\chi^2_{32} = 27.24$, $p > 0.7$). Each year pair of indicated proportions of reasons stated were also compared and no significant differences were found. Note that in Tables 1-4, responses of less than 2 percent have been omitted for brevity.

Reason Stated	Year 2000	Year 2001	Year 2002	All Years
3. An interesting career I will enjoy	41.9 %	45.2 %	41.7 %	43.1 %
4. A rewarding career with options	22.6 %	21.4 %	21.9 %	21.9 %
15. Enjoy creating/designing/problems	5.8 %	8.6 %	10.9 %	8.6 %
9. Upgrade qualifications/career change	7.1 %	6.2 %	7.8 %	7.0 %
6. Help to build a better world	5.2 %	4.8 %	1.6 %	3.8 %
2. Parent/family/friend was an engineer	3.2 %	3.3 %	3.6 %	3.4 %
5. The course I could gain entry to	1.3 %	3.8 %	2.6 %	2.7 %
10. Job requires me to get tech. degree	1.9 %	1.4 %	2.1 %	1.8 %
7. No response stated	3.2 %	1.0 %	1.0 %	1.6 %
1. To work ‘in the field’, not an office	1.3 %	1.4 %	1.6 %	1.4 %
12. To shape the future	1.3 %	0.0 %	2.1 %	1.1 %

Table 1: Reasons stated for electing to study engineering and technology

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Reasons stated for studying engineering and technology by gender

When considering the indicated proportions for each of the reasons stated for electing to study engineering and technology by gender it was found that there was a significant difference between genders in 2000, a borderline significant difference in 2001 and no significant difference in 2002. When the results for all years were pooled, the indicated proportions of reasons stated by gender were significantly different ($\chi^2_{16} = 31.55$, $p < 0.012$). Table 2 gives the indicated proportions for each of the reasons stated for electing to study engineering courses by gender. The stated reasons are ordered using the rank order of all years combined.

Reason Stated	Male	Female	All Years
3. An interesting career I will enjoy	43.2 %	42.3 %	43.1 %
4. A rewarding career with options	22.2 %	19.7 %	21.9 %
15. Enjoy creating/designing/problems	8.4 %	9.9 %	8.6 %
9. Upgrade qualifications/career change	7.4 %	4.2 %	7.0 %
6. Help to build a better world	3.7 %	4.2 %	3.8 %
2. Parent/family/friend was an engineer	3.7 %	1.4 %	3.4 %
5. The course I could gain entry to	2.5 %	4.2 %	2.7 %
10. Job requires me to get tech. degree	2.1 %	0.0 %	1.8 %
7. No response stated	1.6 %	1.4 %	1.6 %
1. To work 'in the field', not an office	1.4 %	1.4 %	1.4 %
12. To shape the future	1.2 %	0.0 %	1.1 %
8. Changed from a course I didn't like	1.0 %	1.4 %	1.1 %
13. Required unit for another course	0.4 %	5.6 %	1.1 %
14. Course description was interesting	0.4 %	4.2 %	0.9 %

Table 2: Reasons stated for electing to study engineering and technology by gender

Reasons stated for studying engineering and technology by course

When considering the indicated proportions for each of the reasons stated for electing to study engineering and technology by course of enrolment it was found that there was a significant difference between courses in all three years 2000-2003. When the results for all years were pooled, the indicated proportions of reasons stated by course were significantly different ($\chi^2_{32} = 120.14$, $p < 4 \times 10^{-12}$). Table 3 gives the indicated proportions for each of the reasons stated for electing to study engineering and technology by course of enrolment. The stated reasons are ordered using the rank order of all years combined. Because students enrolled in 'Other' courses may come from non-technology study areas, it was considered important to identify any differences in the reasons stated for electing to study engineering courses between BE and BTech students. When responses from students enrolled in 'Other' courses were removed, it was found that there was no significant difference between BE and BTech students in individual years 2000-2003, however, when the results for all years were pooled, the indicated proportions of reasons stated by course (BE or BTech) were significantly different ($\chi^2_{16} = 27.47$, $p < 0.037$), though the results in Table 3 suggest that the significance was marginal.

Reasons stated for studying engineering and technology by study mode

When considering the indicated proportions for each of the reasons stated for electing to study engineering and technology by mode of study it was found that there was a significant difference between study modes in all three years 2000-2003. When the results for all years were pooled, the indicated proportions of reasons stated by study mode were significantly different ($\chi^2_{16} = 203.63$, $p < 2 \times 10^{-34}$). Table 4 gives the indicated proportions for each of the reasons stated for electing to study engineering courses by mode of study. The stated reasons are ordered using the rank order of all years combined.

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Reason Stated	BE	BTech	Other	All Years
3. An interesting career I will enjoy	42.6 %	43.6 %	47.6 %	43.1 %
4. A rewarding career with options	23.3 %	21.5 %	0.0 %	21.9 %
15. Enjoy creating/designing/problems	10.6 %	4.7 %	0.0 %	8.6 %
9. Upgrade qualifications/career change	7.8 %	4.0 %	14.3 %	7.0 %
6. Help to build a better world	3.1 %	5.4 %	4.8 %	3.8 %
2. Parent/family/friend was an engineer	3.6 %	3.4 %	0.0 %	3.4 %
5. The course I could gain entry to	1.6 %	6.0 %	0.0 %	2.7 %
10. Job requires me to get tech. degree	1.6 %	0.7 %	14.3 %	1.8 %
7. No response stated	1.6 %	2.0 %	0.0 %	1.6 %
1. To work 'in the field', not an office	1.3 %	2.0 %	0.0 %	1.4 %
12. To shape the future	1.0 %	1.3 %	0.0 %	1.1 %
8. Changed from a course I didn't like	0.8 %	2.0 %	0.0 %	1.1 %
13. Required unit for another course	0.0 %	1.3 %	19.0 %	1.1 %
14. Course description was interesting	0.5 %	2.0 %	0.0 %	0.9 %

Table 3: Reasons stated for electing to study engineering and technology by course

Reason Stated	On-Campus	Off-Campus	All Years
3. An interesting career I will enjoy	46.8 %	25.5 %	43.1 %
4. A rewarding career with options	24.2 %	11.2 %	21.9 %
15. Enjoy creating/designing/problems	9.2 %	6.1 %	8.6 %
9. Upgrade qualifications/career change	1.3 %	33.7 %	7.0 %
6. Help to build a better world	3.1 %	7.1 %	3.8 %
2. Parent/family/friend was an engineer	3.9 %	1.0 %	3.4 %
5. The course I could gain entry to	3.3 %	0.0 %	2.7 %
10. Job requires me to get tech. degree	0.0 %	10.2 %	1.8 %
7. No response stated	1.5 %	2.0 %	1.6 %
1. To work 'in the field', not an office	1.7 %	0.0 %	1.4 %
12. To shape the future	0.9 %	2.0 %	1.1 %

Table 4: Reasons stated for electing to study engineering and technology by mode

Discussion

It can be seen from Table 1 that the first four ranked reasons for all three year groups were identical, and in all cases these four items account for more than 75 percent of responses obtained, suggesting a high degree of agreement between year groups as to the most important influences on the students' choice of reasons for electing to study engineering courses. Additionally, for all three year groups the first two ranked reasons account for the majority (more than 63 percent) of student responses. Interestingly, these two reasons relate to engineering as an interesting/rewarding career, suggesting that engineering students are particularly career-orientated.

A 1994 report on a survey of 1180 18-year-old UK students intending to study at university (Woolnough, 1994) (including 92 students intending to study engineering) that investigated the factors affecting students' choice of higher education study found that, of all university courses, engineering students reported the highest affirmative response (70 percent) to the question, 'Have you decided on a career yet?' – this was nearly three times as high as the lowest rate reported by any student group. One possible contributing factor to this strong career orientation at a relatively early age is the need for the educational preparation for a career in engineering to begin early with a foundation in math and science that is

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progressively built upon throughout the student's schooling (Mau, 2003). Woolnough's investigation also asked respondents to rate 26 influences on a five-point Likert scale as to whether they encouraged or discouraged them towards or away from engineering or one of the physical sciences. The highest mean response given by any group was 4.3 by engineering students for the influence 'The likely job satisfaction in science and engineering'. Other important influences reported included, 'The intellectual satisfaction of doing science', 'Scientific hobbies and fiddling with gadgets at home' and a school environment that provided a positive experience in science. Once again, supporting the proposition that intending engineering students are strongly career orientated.

In an investigation of why US science, mathematics and engineering (SME) students swap study majors (Seymour & Hewitt, 1997), a group of SME students were asked to indicate the reasons for selection of their original study major. Interestingly, the most significant reason reported for selection of study major was the 'Active influence of others', reported by 18% of all respondents, although, this result was strongly influenced by students who eventually switched out of an SME study major, suggesting that many of these students may have been 'forced' into studying an SME course when they really didn't want to. When 'switching' students were excluded, the most frequently reported reasons for choice of study major was 'Intrinsic interest' and 'Pragmatism / materialism', although the 'Active influence of others' still remained the third most frequent response. Here, once again, selection of a career that will be interesting and/or rewarding were highly ranked reasons for choice of study major.

When considering the impact of gender on the indicated reasons for studying engineering courses it is important to remember that female students made up only 11.2% of all respondents in this investigation, and a clearly significant difference in the indicated proportions for each of the stated reasons was observed in only one of the three year groups. However, when the results from all three year groups were pooled, some differences in responses by gender were observed. Male respondents were more likely to indicate that they were studying to upgrade their qualifications or that their job required them to obtain a technical degree qualification. Presumably, many of this group of respondents were already members of the engineering workforce, which in Australia is predominately male (females make up less than 7 percent of the Australian professional engineering workforce) (Association of Professional Engineers Scientists and Managers Australia, 2002), and hence males reporting these reasons at a higher rate was not unexpected.

Male respondents were more likely to indicate the influence of a role model (parent, family member or friend) who was/had been an engineer. Female respondents were more likely to indicate that engineering or technology was the course they could gain entry to at university, indicating that engineering or technology was not necessarily their first choice of study. Female respondents were more likely to indicate that they were taking the engineering and technology unit SEB121 as part of another course of study. It was known that the majority of students taking this unit as part of another course were education students taking a science studies major, and education undergraduate students in Australia are predominately female (79.1 percent of 2001 graduates from bachelor level education courses were female) (Department of Education Science and Training, 2001). Hence, females reporting this reason at a higher rate was not unexpected. Female respondents were more likely to indicate course selection on the basis that the course description sounded interesting. Even though there were some observed differences in response rates between genders, the first three ranked reasons were identical, had similar indicated percentages and made up the majority of the reasons stated (73.8 percent for male and 71.9 percent for female) for both male and female

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respondents. This suggests that the previously observed strong career orientation of commencing engineering students applies to both male and female students.

When considering the impact of course of study on the indicated reasons for studying engineering and technology, the principal interest here was in the responses from BE and BTech students. The first two ranked reasons were identical, had similar indicated percentages and made up the majority of the reasons stated for both BE and BTech respondents (65.9 percent for BE and 65.1 percent for BTech); again, highlighting the previously observed strong career orientation of commencing engineering students generally. BE students were more than twice as likely to indicate reasons associated with design/creating/problem solving than BTech students, this is perhaps due to fundamental difference between these two occupational classifications in the engineering workforce: "The essential competencies of Professional Engineers include the ability to plan and design original and novel solutions using well developed powers of analysis and synthesis. They challenge current thinking and apply fundamental principles to situations which lie outside their prior experience…Engineering Technologists modify established engineering practices, and apply newly developed engineering practices on a regular basis. These skills are applied…with an understanding of the application and advancement of engineering technology…" (Institution of Engineers Australia, 1999, p 7). Broadly speaking, professional engineers would be expected to have a deeper theoretical understanding of technology upon which novel designs are based, while engineering technologists would be competent in the practical application of technology.

BTech students were nearly four times as likely to indicate that their course was the one that they could gain entry to. One of the principal differences between the BE and BTech courses at Deakin University is the underpinning mathematical approaches in key units of study; in the BE course a calculus foundation is employed, and in the BTech course an algebraic mathematical approach is used. This has ramifications for the prerequisite secondary school mathematics entry requirements for both courses. So, while a commencing student may have aspired to the BE course, they may find that their background in secondary school mathematics studies only permits them entry into the BTech course. Students in this situation may undertake bridging studies in mathematics and transfer courses when they have achieved the appropriate prerequisite competency.

When considering the impact of mode of study on the indicated reasons for studying engineering courses the career-related reasons of interesting/rewarding career come through very strongly for on-campus students, together representing 71 percent of responses. This was perhaps not surprising given that commencing on-campus students at Deakin University are generally full-time students who have come directly from secondary school and have selected a particular course of study to obtain a degree after which they would intend to get a job and commence a career. Career interest is likely to factor strongly in the planning of these students. Contrast this result to off-campus students who give upgrading qualifications/changing career as the principal reason (33.7 percent) for study. Off-campus students at Deakin University are generally mature age students who are working at least part-time. This suggests that a significant number of off-campus students use this mode of study as a means of gaining access to tertiary education (and hence new qualifications) that they would otherwise by precluded from because of the need to work.

For off-campus students the next two highest ranked reasons were the career-oriented ones, accounting for 36.7 percent of responses. The career focus was still a significant reason for

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choice of study for off-campus students, but was reported at about only half the rate compared to on-campus students. The next ranked reason given by off-campus was that a degree qualification was required by their job – reported by 10.2 percent of off-campus students, compared to nil responses from on-campus students. If the reasons 'upgrading qualifications' and 'required by job' are considered together as 'career upgrading', then 43.9 percent of off-campus responses related to this reason, which reinforces the proposition that off-campus study facilitates career advancement for students who are currently employed. Interestingly, off-campus students were significantly more likely to report their reason for studying as 'building a better world', 'shaping the future' or advancing quality of life', which was perhaps an indication of the maturity that comes with the 'mature age' typical of off-campus students.

Conclusions

Commencing engineering students at Deakin University, as a whole, were strongly career oriented in their stated reasons for electing to study engineering courses. This result is in agreement with results observed in the UK and USA. They believe that engineering will be an interesting and rewarding career that will offer enjoyment and career options. While some differences in the ranking of stated responses for electing to study engineering courses were noted between gender and course of study, the principal reasons given by respondents had the same rank ordering and approximately the same response rate, again, confirming the importance of career-related reasons for studying engineering. However, there was a distinct and significant difference in the stated responses for electing to study engineering courses between students studying in on- and off-campus modes. On-campus students nominated principally career-related reasons for their choice of study (71 percent of responses). While career-related reasons were still important for off-campus students (36.7 percent of responses), the most frequent type of response from off-campus students were related to career upgrading (43.9 percent of responses). The differences between the two modes of study were not unexpected; on-campus students are principally directly from secondary school, coming to study for their first degree and aspiring to commence a career in their chosen profession; while off-campus students are typically mature aged, working at least part time and are using study to advance or change their existing career path. Being aware of the differences in the reasons for studying between these two student groups could help focus and differentiate recruitment efforts to attract the respective student cohorts, as well as providing valuable information to course designers and content developers so that the study programs can cater appropriately for the needs and aspirations of both student sub-groups who would normally study the same material 'together', though not in the same time or place.

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Gender Experiences in an Engineering Classroom

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Abstract: *There has been a significant amount of research into the culture of engineering faculties at Australian Universities and it is clear that it remains dominated by masculine values and attitudes. If this is the case in the environment of faculties then what is happening in the classroom? Engineering has been the domain of men since its inception and thus as would be expected their perspectives and paradigms have dominated its practices. Yet today even if unintentionally, the promotion of masculine values, experiences and interests within the engineering education system has left women feeling uncomfortable and different.*

This paper focuses on the gendered expectation and perceived advantages identify by both female and male students within an engineering classroom. It investigates the effect of the known faculty culture within the classroom environment and identifies some aspects of the classroom experience that needs to be taken into account when understanding the influences it has on students.

Keywords: *engineering classroom experiences, gender*

Introduction

There has been a significant amount of research into the culture of engineering faculties at Australian Universities and it is clear that it remains dominated by masculine values and attitudes (IEAust. Review, 1996; Tonso, 1996; Copland & Lewis, 1998; Johnson, 1999; Burrowes, 2001). If this is the case in the environment of faculties then what is happening in the classroom? What aspects of this faculty culture need to be taken into account when understanding the experiences of female and male students within an engineering classroom? Engineering has been the domain of men since its inception and thus as would be expected their perspectives and paradigms have dominated its practices. Yet today even if unintentionally, the promotion of masculine values, experiences and interests within the engineering education system continues to leave women feeling uncomfortable and different.

Tonso (1996) and others believe that it is the engineering education sector that must change first before inclusion of women can be realized within the engineering profession. Engineering remains largely (if unconsciously) defined by men, and can be an uncomfortable environment for women (Johnson, 1999). However, it is not only the way technology and engineering are defined but also how the profession is practised and taught that clearly discourages most women – and some men (Johnston, 1999).

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This paper presents some results of a broader study which focuses on the expectations and comfort levels of students from a gendered perspective within an engineering classroom. It has only investigated the student perspective of these aspects of the classroom and has not presented any other aspect related to the content and presentation of material of the course used in the study.

Literature

Gender difference and sex stereotyping within the classrooms of mathematics and science (and to a much lesser extent engineering) have been studied at secondary and tertiary levels. This research has shown that men and women often experience the classroom differently and that teachers have been shown to inadvertently treat genders differently.

A few of the studies which relate more closely to the areas presented in this paper include a study by Ware which highlighted that female students are "more likely to fix the blame internally - to cite their own inadequacies as the source of difficulty" (Ware, 1985, pg 73-84) when encountering problems within a program of study; whereas men tend "to place responsibility for difficulties outside themselves". For example, in response to a poor exam mark or failure in a subject, women tend to believe that it is their poor preparation or intelligence that is the cause and therefore are generally much less confident of their performance and will even transfer out of the course and career. A male student is more likely to blame the system whether it is the academic who has not helped them in their preparation or the examination, which was obviously a poor judge of their knowledge, and will therefore persist and re-sit exams and subjects if given the opportunity. In fact, Seymore (1992) identified that between 70 and 80% of females transferred out of science programs because they felt discouraged and even developed low self-esteem despite their grades being on par with the male students in the class. Improving self-esteem and expectation, particularly for first year university students, who are coping with a new learning environment, have been well documented across a broad range of discipline areas (DETYA, 2000b; Pfatteicher, S., 1999), however for women in sciences and non traditional areas in general there are additional, often unexpected, pressures which can further reduce their self confidence.

Seymore (1992) also discussed how women tend to place a higher value on what others in society think of them and were found to be more dependent on encouragement and personal feedback from teachers at High School. They have felt that learning is more difficult as a result of less close contact with their teachers at university. In a study, *Students' Perceptions of Problems in Undergraduate Teaching,* Hewitt (1991) found that 30% of women (0% of men) listed 'professors don't care about you' as a significant problem for them.

The Study

The results presented in this paper are a section of a much larger study performed to investigate the gender dynamics in an engineering classroom. To do this both the learning environment and social world of an engineering classroom was studied and the complex interactions between student behaviour, their knowledge, and learning experiences within that classroom was investigated (Burrowes, 2001). An ethnographic

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research methodology was used to obtain an understanding of the behaviours and socio-cultural activities and patterns of a group of engineering students, from their perspective, in a 'typical' engineering classroom setting. Ethnographic research is designed to present a dynamic picture of the student group and their interactions and provide an alternative, more humanistic research paradigm to the traditional empirical scientific method.

The process of ethnographic research is essentially to collect descriptive data as the basis for interpretation and analysis of the research questions. Data for this research study was obtained primarily through fieldwork, which involved both observations of the engineering classroom setting and interviews of participants within that setting. Surveys were also used and have provided some quantitative measures to increase the reliability of the results. Thus, three data collection techniques were used: observation, focus groups and surveys to produce the empirical findings.

The classroom used in this study was a second semester first year course, MECH 102, taken by students in the Mechanical, Environment, Surveying and Civil discipline areas. There were 136 students who participated in each of the two surveys conducted at the beginning and end of the semester, 122 male students and 14 female students (10.3%), which reflect the female average participation in engineering classrooms at the University. Three groups of 6 students participated in the focus groups sessions that were held twice during the semester. There were 12 male students and 6 female students in these focus group sessions. The researcher was also a second tutor in one of the large tutorial groups and so was able to make observations during class sessions as well as in assignment work.

Results

Expectations and General Experiences in Studying Engineering Courses

> "*Everyone says engineering is incredibly difficult, but I don't know. I don't want to do anything else, …..it becomes a time management problem, …. there is so much work and there is only so much you can fit in*" (Female Student, Focus Group).

Workload was a continual topic of discussion among students as they tried to rationalise and find the 'balance' of work/study and social activities. There was considerable frustration based on both male and female student inexperience in time management and a need to find someone/something to blame "*you've got these semester assignments, laboratories due all in the one week usually*" and that "*if it (course material) is not necessary then they shouldn't be teaching it*" (Male Student, Focus Group). In fact there was a feeling from one student that there should be *"more humanities in engineering programs"* (Male Student, Focus Group). However this raised concern among other students as to "*what is going to get the squeeze"*. A suggestion from a male student was "*series. Get rid of series"* (Male Student, Focus Group). 'Series' is a topic in mathematics for which this student had not yet found a use in his engineering courses.

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Students were asked at the beginning and end of the semester, what their expectation was of MECH102 and their rating of other courses which they had completed. The differences in female and male student expectations of MECH102 is interesting to compare. The survey results showed that women and men thought quite differently at the initial stages of the course yet ended the course with similar responses. This is despite the trepidation that accompanies the rumors that are passed down from year to year of the difficulty of MECH102 and the course, which follows MECH102 in the following year. Female students' expectation of MECH102 at the beginning of semester was that it was going to be 'difficult' (44%) or 'reasonably difficult' (50%), thus a total of 94% of female students were prepared for a difficult topic area. This compares to only 16% of male student indicating 'difficult' at this stage and 62% saying 'reasonably difficult', combining to a total of 78%. Only one female student felt that it was going to be 'relatively easy' compared with 21% (or 26) male students. By the end of the semester, 97% of male students indicated that the course was 'difficult' or 'reasonably difficult' which brings it in line with the female students. A total of only three male students indicating that it was 'relatively easy' or 'easy'. These figures are illustrated in Figure 1. The distribution between easy and difficult remained unchanged for the female students however, as with the male students there was a shift to 70% of both sexes indicating that the course was 'difficult'. The response to what their comfort level was in attempting MECH102, women generally felt uncomfortable in the initial stages of the course becoming more comfortable as the semester progressed. Male students however went in the other direction, with a transition from a comfortable position to an uncomfortable position.

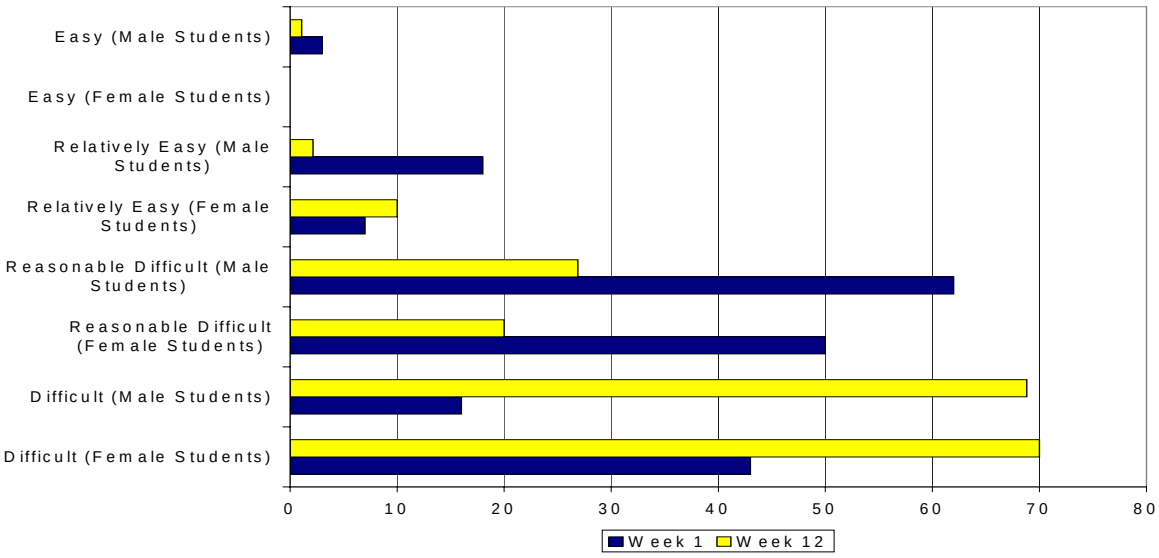


Figure 1: Comparison of Students Expectation of Difficulty of MECH102 by Gender and by Time of Semester

As a comparison, students clearly nominated MECH102, as the course considered most difficult in their program at this stage of their studies with other courses being rated generally between 'reasonably difficult' and 'relatively easy'. When discussing what is 'difficult' about the course a number of aspects of the learning environment were

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highlighted, however, the reputation of the course also appeared to have a strong influence deterring many students who were continually expecting the worst.

Student Perceptions Of Their Place Within The Classroom

Students' perception of lectures was that they were not an important part of the learning process in the course. A number of male students actually suggested "*lectures make the difficult courses harder*" (Male Student, Survey 2). They also felt very intimidated in asking questions or giving technical opinions during the lectures. Figure 2 provides the results of the confidence that each gender had in giving technical opinions in lectures and tutorials. Female and male students were approximately equally lacking in confidence in giving technical opinions in lectures with 70% of female and 75% of male students indicating this feeling of apprehension. For MECH102 the problem with lectures was compounded by the fact that the lecture basically followed the lecture notes given out to students and did not expand on these significantly. "*It is the tutorial where you learn everything*" (Male Student, Survey 2). "*I don't think they are tutorials, I think they are lifesavers*" (Female Student, Survey 2). Despite this, even the tutorials were not formats in which students felt confident to participate fully. This is illustrated in Figure 2 where 70% of female students and 48% of male students felt 'not very confident' to give a technical opinion during the tutorial session. A female student did say she felt that *"Help from tutors was always there when required. It was just a matter of overcoming an initial feeling of being stupid"* (Female Student, Survey 2). This was also illustrated during the observation sessions where it was often difficult to get students to explain what they had done because usually they did not appear confident to do so. Whether this was a result of not being confident in their solution or their approach was unclear. In many cases however by explaining what they had done so far was enough for them to work out where to go next and how to improve or solve the problem that they were working on. This was a positive process for many students, but a number of cases identified during observation showed that this did not follow through to the next time they were in trouble.

When investigating the similar percentage of female students feeling unconfident in both lectures and tutorials it was confirmed that it was the same group of female

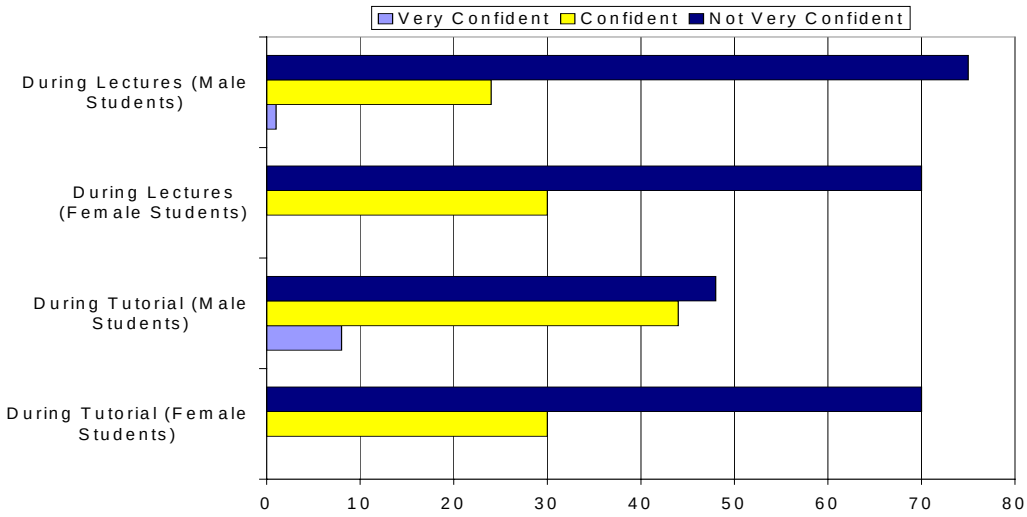


Figure 2: Confidence Level By Gender In Giving Opinions In Lectures And Tutorials

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students who felt unconfident in both environments. During the focus group discussion and tutorial observations the mature age women appeared to be more confident to speak up in general and felt confident to raise technical issues in a larger forum. The difference between the confidence level in the tutorials and lectures by male students was expected with higher confidence levels when speaking out in smaller groups. It is interesting to note also that it is only male students who felt 'very confident' in either environment with 8% being very confident in tutorials.

Students were also perplexed by the assumption that if students pass a course that they should know it. Mathematics was used as a typical example, although one, which had the worst repercussions. Mathematics courses *"create a lot of difficulties further on which reflect in a lot of other unhealthy situations and low marks. They assume that because we passed Maths we got 70 or 80 percent but we haven't"* (Male Student, Focus Group).

There was also a feeling that academics were not interested in students' progress and in fact suggested that *"the topic level is well above first year standard and the lecturer seems to have fun and enjoys exploiting this fact"* (Male Student, Survey 2)

Perceived Advantages Caused By Gender Within The Classroom

The general response from both female and male students was negative to whether they perceived that a particular group of students were more advantaged in various aspects of the classroom, Figure 3a & 3b. Students felt that they were on an '*equal footing*' had '*equal opportunity*', '*equal attention*', and '*everyone has a fair chance*'. Basically they '*can't see any bias*'.

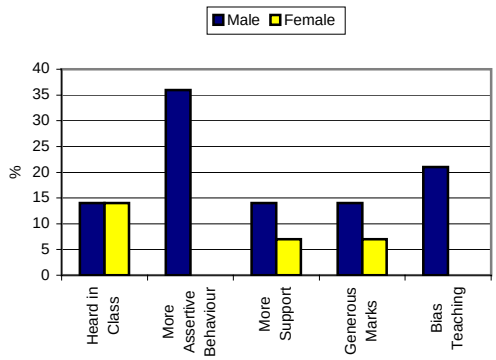


Figure 3a: Female Student Response to: Do you feel that a particular group of students is currently more advantaged through:

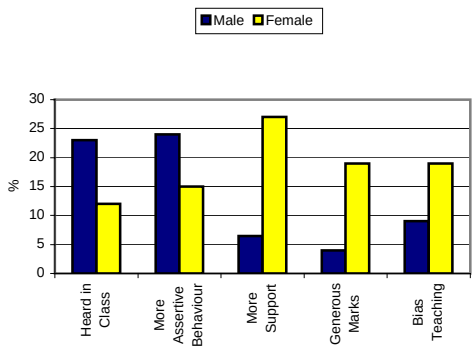


Figure 3b: Male Student Response to: Do you feel that a particular group of students is currently more advantaged through

Male student responses, however, showed that they felt somewhat advantaged by being heard in class and that they showed more assertive behaviour, whereas female students were given more support and were given more generous marks and that the teaching was biased for them.

All the female student indicated that they believed male students had much more assertive behaviour in the classroom which correlated with the male responses. Yet,

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contrary to the male student perception, female students felt that they were equally heard in class. Male students generally believed that they were heard in class above the female students. In addition female students felt that males were given more support and more generous marks than they were given which was in direct disagreement with the male students. As with assertive behaviour, all female responses said that the teaching was biased towards the male students.

> *"…male students do not want to put their hand up because they are too macho. If you're female you can ask anything. They don't expect you to know it, they have this low picture of your intelligence level so you can ask anything and they just go yeah, yeah, really condescending of course, but you just use it to your advantage. Which is bad and I mean, I'm sure all the males do get annoyed about that but it is what you do"* (Female Student, Focus Group)

A female student recited a story in the focus group session of a male student upset at her for getting a higher mark. She asked him how long had he spent on the assignment and his answer was 'a couple of hours not much', although she believed that he had spent more time on it than he admitted. She declared that she had worked solidly for two weeks on it and had enjoyed understanding it. The male student's response was that she must be unintelligent to have to spend so much time on it.

Female students did feel that the male students would try and find other ways of getting around their studies and assessment tasks and believed that *"advantage is only gained by students working hard on the course"*. A supportive male student admitted that *"occasionally a female will be given greater attention but they usually work harder in any case."*

A number of male students recalled stories and situation where female students used their gender advantage.

> "*It may seem sexist, but as most lecturers are male, female students are generally treated better*' and "*the lecturer was present in the tutorials and these two young ladies were very attractive so I mean he's only human so he is going to hang around isn't he. We got a bit cheesed off, but I thought well he's doing his job and he's letting his personal feelings come into it a bit and they were using their gender to their advantage. That's life."* (Male Student, Focus Group)

A male student also suggested that it was worth giving female students a bit of a helping hand; " *Well I think that the guys in mechanical think that (because) there are so few women doing the program that they like to give them a bit of extra chance so (that) they keep hanging around, and (also that) they are easy on the eye*" (Male Student, Focus Group).

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Discussion

It is interesting to note the clarity with which both female and male students did not want to engage in the discussion of gender in an engineering classroom. In fact it was clear that both genders remain unable to comfortably engage with the topic to the extent of often denying that there is a problem. This is has been shown to be true in other research that has focused on gender in engineering (Jolly, 96; Stonyer, 99). It is thus difficult to unravel some of the different and contradicting comments in this research area and why it is important to use more than one method of data collection. However, it does identify the very important need that the barriers to discussion on gender must be the first to break down.

Generally, students would stress the opinion that there were no inequalities between genders yet contradictions within the results gave the impression that this was simply a result of not wanting to engage in the discussion. There were however high ideals espoused relating to 'fairness' when it affected them personally but this did not emerge in terms of gender 'fairness'. Students were unable to challenge paradigms, which reflected the gender topics and attitudes because they simply could not or would not see them. This was particularly due to individuals feeling unable to speak up in the group situations due to fear of being laughed at or put down. This was also what was felt when having to ask teaching staff for help.

Often students, and in particular male students, took on a negative approach to their studies. They felt that they would achieve in spite of the teaching staff and the system. There was no theme of a 'working together' relationship but instead an 'us against them' mentality. The educational environment was a battle to be fought and won. This combined with the competitive atmosphere of the classroom blended to enhance a military attitude. A male student felt that, "*Everyone should look after themselves and not whinge*". It was therefore surprising to hear so much 'whingeing' about the poor teaching environment and staff. In an unusual twist these factors actually emerge as a positive environment for male students, as men were able to motivate themselves within this framework.

The study found that workload and the reputation for the difficulty of the program was an issue for potential students. It also identified that there was a perspective from some students that the program was a set of disjointed courses, where individual courses were not connected in any way. The system thus expected students to negotiate their own way through the system with the guidance given by the teaching staff only being within the boundaries of the course and not across the program. Despite this issue being raised by a male student there was more agreement among the female students that this did not create a positive learning environment for all students. As educational literature has suggested, female students prefer to understand the broader context of the course material and therefore are at more of a disadvantage in this disjointed course/program structure.

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Conclusion

This paper presents some results of students perspective of their expectations and comfort level when working within an engineering classroom. It shows how the masculine values and culture of an engineering faculty are reinforced in the classroom and how both genders attempt to work within it.

The environment of a classroom however is a place where individual values and belief systems can be influenced and therefore stereotypes can be broken down. This is where individuals are at their most vulnerable, and students need to prove their academic ability. This means for women that they need to prove in most instances to a male academic in a male system. Also, it suggested that students through their interaction with a 'male' academic come to understand his actions as part of being an engineer, which sent narrow messages about who engineers are and what engineers might be. Unsurprisingly the classroom met the male student's expectation of the world whereas women's viewpoints could only be injected under certain rarely existing conditions.

For these reasons among others illustrated in this paper, academics have a very important role to play in the environment. Their understanding of the gender dynamics and interactions that are happening in the educational environments in engineering faculties is critical in supporting cultural change and ensuring that female students have the same opportunities as their male peers.

Finally, from a broader perspective, if in the engineering classroom the presentation of a set of values which include the feminine as well as the masculine were presented, then it is likely that this will lead to a more humane and balanced engineering profession and society.

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Teaching engineering management in a flexible learning environment

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***Abstract**: The University of Southern Queensland (USQ) has a very distinctive educational offering especially with respect to learning modes. Along with the traditional on campus mode it has external and on line modes of learning. The Faculty of Engineering and Surveying mirrors these offerings. Furthermore its zero departmental structure allows significant cross teaching within its four disciplines of agricultural, civil and environmental (ACE), electrical, electronic and computer (EEC), mechanical and mechatronic (MM) and surveying and land information (SLI). No more is this evident than in the teaching of engineering management and communication studies. According to Institution of Engineers, Australia guidelines 10% of all programs must cover this area of study. This paper focuses specifically on the course ENG3003 Engineering Management. It describes how this course began and continues to evolve as well as the factors that have influenced this evolution. A short survey of different University engineering programs with respect to their management and communication content is made. USQ programs are placed at the higher end of the survey. Speculation is made on ENG3003's future. Being created in and for a flexible learning environment allows this course to develop many possible modes of offering depending on student demand as well as adding supplementary material to incorporate international students. Further development for a course work masters offering of an advanced engineering management course is being considered. The engineering profession has learnt that being flexible and adapting to change is the key to success in the 21st century and ENG3003 is no exception.*

***Keywords**: engineering management, professional practice, flexible learning.*

Introduction

The University of Southern Queensland (USQ) is a major provider of tertiary courses by distance education, with 75% of its 26,000 students studying in external or "off-campus" mode. The Faculty of Engineering and Surveying, a foundation faculty of USQ's predecessor Darling Downs Institute of Advanced Education (DDIAE) in 1967, shows a similar distribution of on-campus (day) and external enrolments in its 2400 students.
The Faculty has a strong commitment to providing quality higher education opportunities to as broad a cross-section of the Australian community as possible. The Faculty offers engineering and surveying courses that meet the needs of industry and the wider community for associate, paraprofessional and professional staff. In addition, a number of coursework and research postgraduate courses are also available.

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The Faculty of Engineering and Surveying has a special academic structure with overall financial and academic control vested in the Dean and Associate Dean portfolios. There is no separate departmental structure; instead academic staff are grouped into related disciplines under the direction of an appointed Head of Discipline. Currently academic staff are grouped under the four discipline sections of agricultural, civil and environmental (ACE), electrical, electronic and computer (EEC), mechanical and mechatronic (MM) and surveying and land information (SLI) (Baker 2002). The Faculty offers about 130 courses and this paper will concentrate on those involved with what is generally describe as management and communication studies.

Management and communication studies

Per Institution of Engineers, Australia accreditation manual (section 5.2 - integrated exposure to professional practice, including management and business ethics; should be about 10% of the total program), between 10 to 12.5% of most USQ engineering programs are dedicated to teaching management, communication and professional practice principles. This is embodied in the academic courses of ENG1001 Principles of Engineering & Surveying (first level course on communication skills), ENG2002 Technology & Society (second level course dealing with a range of social, environmental and economic aspects of engineering and surveying), ENG3003 Engineering Management (third or fourth level course on management and professional practice) and ENG4004 Engineering Management Science (fourth level course covering operational research management tools for engineers) as well as the practice courses of Professional practice 1 and 2. This paper will mainly focus on the top level courses as these are the capstone courses for the Institution of Engineers, Australia graduate generic attributes (IE Aust 1999):-

- Ability to communicate effectively, not only with engineers but also with the community at large
- Ability to function effectively as an individual and in a 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 professional and ethical responsibilities and commitment to them

ENG1001 Principles of Engineering & Surveying covers the roles of engineers and surveyors in society as well as the principles of communications using engineering and surveying case studies as a contextual methodology. It uses the textbook, *Technically Write* by Blicq, R. S. & Moretto, L. 1998, 5th edition, Prentice-Hall, Ontario to support the communications section.

ENG2002 Technology & Society has the objective of preparing students for their engineering role as developers, users and transferors of technology for society. It raises the issues of ethical and legal constraints as well as the social, economic and environmental effects of technological progress. It is offered in all modes in semester 1 and external mode in semester 3. It uses the textbook by Johnston, S, Gostelow, P & Jones, E 1999, *Engineering and Society: an Australian Perspective*, 2nd edition, Longman, Melbourne. This course is a core course in all programs offer by the Faculty and thus has the largest enrolment of all Faculty offerings.

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ENG3003 Engineering Management is a corporate course within the Faculty of engineering and surveying offering at USQ. It introduces, reviews and analyses the role of engineers as managers and practicing professionals. It is divided into two sections; the first section deals with management principles in today's business environment while section two covers the topics of law, engineering contracts, ethics, product liability, intellectual property, industrial relations, the structure of the engineering profession, risk management, and workplace health and safety. It is presented in both on campus and by distance education mode. On campus mode consists of two hours of lectures and one hour of tutorial work per week. The eight modules of content are presented to external students in the standard study book form and on campus students may also purchase these materials. Both modes are supported via the internet by WebCT discussion groups and electronic material as well as the textbook website. Note WebCT is the software USQ uses for on line, student communication including discussion groups and course homepages. The course is assessed by two assignments worth 20% and 30% respectively and a final examination carrying 50% of marks. This course is also a nominated benchmark communication course and as such dedicates about 20% of the assessment marks to written communication. These marks are allocated to the assignment assessment and students not meeting the required standard are given make up work to achieve set standards. Textbook is *Management: an Australasian Perspective*, second edition, by Paul Davidson and Ricky Griffin (2002).

ENG4004 Engineering Management Science is a core course for most bachelor of engineering programs but is not used in the bachelor of engineering technology programs. It covers the topics of micro economics, critical path analysis, statistical quality control, simulation, linear and dynamic programming. It is offered in semester 2 in on campus and external modes and recently has had some offerings in semester 3, externally. It has the same assessment format as ENG3003 and as will be seen later, was once part of the same course as ENG3003. It has stand alone study and problem solution books used in all modes. It is also supported by the WebCT interface system.

Who does ENG3003?

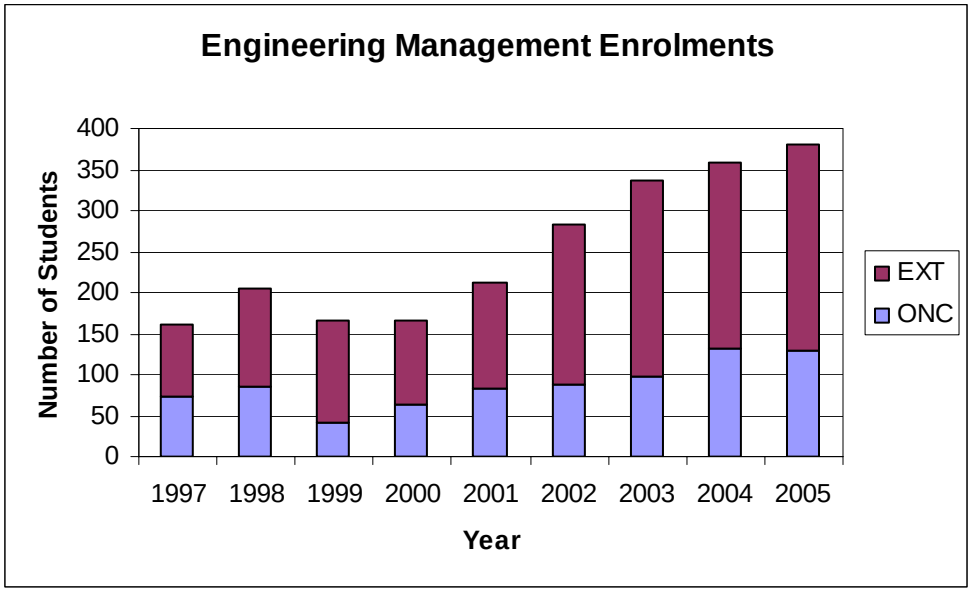


Figure 1: ENG3003 Enrolments

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This section focuses specifically on ENG3003 as it is the capstone course for management studies in the Faculty. Each discipline has a number of programs which use a common course of instruction in management principles and professional practice called ENG3003 Engineering Management. Each of the engineering discipline has ENG3003 at final level in their bachelor of engineering technology and bachelor of engineering programs and as a core course in their master of engineering technology course work postgraduate program. Surveying uses it as an elective.

Figure 1 depicts the total student enrolments by mode since 1997. In 1997 there was about equal percentages of each mode. Currently there is about 37% on campus and 63% external enrolments. Of these external enrolments, about 50% are from overseas locations such as Singapore, Malaysia and Hong Kong. Recently a small enrolment of students has been forthcoming from South Africa and the Middle East.

According to DEST Research Note No. 2 May 2004, the total higher education student enrolment in Australia has increased by almost 20% from 1997 to 2002. While the rate of increase for domestic students was 8% that of overseas students was 123%. ENG3003 enrolments have mirrored this trend. Due to English language difficulties, different styles of learning and cultural differences overseas student pass rates are generally lower than domestic students. This coupled with full fee paying system applied to overseas students has caused significant stress in the teaching and learning process. Special overseas teaching schools in Singapore and supplementary study booklets for New Zealand students have been used to alleviate this stress with some success. But basically this is a Faculty, if not University wide problem, which can only be ameliorated at a course level.

How do students react to ENG3003?

The course has had an average pass rate of about 90% since 1997 but there has been a distinct difference between the pass rates in each mode. While on campus students pass rate is about 95% the external mode pass rate is about 85%. In most cases this has been due to about 10% of external students not participating in course assessment. Generally as this course is in the final level of respective programs a high pass rate is expected.

Student evaluation surveys have not had sufficient feedback to be statistically significant (6 from 79 in 2003) but the following comments have been made:-

- WebCT discussion groups were very useful.
- Textbook was excellent.
- Course was enjoyable but as an overseas student I found the Australian case studies difficult.
- Self assessment questions at the end of each module were very helpful.
- Course material was relevant to my work situation.

How was ENG3003 developed?

70710 Engineering management and practice was the forerunner of both ENG3003 and ENG4004. After the 1996 I E Australia review, it was recommended that 70710 be divided equally into Engineering Management and Engineering Management Science. With an extra credit point for project this gave the bachelor of engineering program a total of 32 credit points for completion, thus creating eight equal four credit point semesters.

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After the I E Aust review in 2001, with its focus on the outcome of generic attributes, further changes were made due to the introduction of the Technology and Society course. Economics and environmental issues being transferred to this new course while risk management and workplace health and safety were added (IE Aust 2001}.

The Open Polytechnic of New Zealand (TOPNZ) agreement introduced in 2001 meant that New Zealand students via the bachelor of engineering technology were undertaking this course. This required the introduction of supplementary material specific to the differences in the New Zealand context. This included such areas as law, contract standards and New Zealand case studies and is presented as a supplementary booklet.

What next for ENG3003?

As the enrolments in ENG3003 increase, there continues to build demand for a Semester 3 offering and possibly an on-line offering depending on specific student demand. What level of demand to initiate this is still to be determined but there has been at least a 100 student enrolment demand for semester 3 course offering in engineering management science. Engineering management demand would, I believe, be somewhat greater as it is used in more programs. This will probably be introduced in 2005.

Recently the Faculty has introduction a course work masters called master of technology management (MTM). It has been proposed to develop an advanced engineering management course for the MTM. This would allow further in depth development of the materials from ENG3003 especially in professional engineering practice.

How do USQ engineering management studies compare with other University?

Proportion of Management and Communications Courses in B Eng Mechanical Programs from Selected Australian Universities				
University	**Number of Compulsory Courses in Management & Communications**	**Credit points**	**Program Credit Points**	**% Management & Communications**
Curtin	3	62.5	400	15.63
UTS	5*	30	204	14.70
USQ	4*	4	32	12.50
Deakin	4	4	32	12.50
Newcastle	4*	40	320	12.50
Wollongong	4*	4	32	12.50
JCU	3	3	32	9.38
Swinburne	3*	37.5	400	9.38
Sydney	4	18	192	9.38
Monash	4	16	192	8.33
Victoria	4*	40	480	8.33
CQU	2*	12	192	6.25
UNSW	3*	12	192	6.25
Queensland	2*	4	64	6.25
QUT	2*	24	384	6.25
RMIT	2	24	384	6.25
Adelaide	3*	6	96	6.25
Melbourne	2	25	400	6.25

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Table 1: Proportion of Management Studies in Mechanical Engineering Programs

A short survey of internet sites of eighteen Australian university programs was made to view the proportion of compulsory management and communication courses there in. Nominally the bachelor of mechanical engineering program was selected as it is a standard offering at most institutions and well known to the author.

Table 1 depicts the results noting that courses containing minor sections in said studies were not counted in the survey. It is also noted that problem solving (engineering skills) type courses were also excluded.

The USQ program (12.5%) was amongst the programs that exceeded the nominal I E Australia 10% guideline but not the highest which was Curtin at about 16%. There has certainly been a trend towards increasing the proportion of management type courses over time; with many Universities now exceeding I E Aust guidelines. Problem based learning courses have been introduced at USQ and CQU which require management and communications objectives so it can be argued that their respective programs are allocating even higher proportion of time to said studies.

Programs with the asterisk in Table 1 have a specific course called Engineering Management. A review of these specific courses indicates that they are mainly at level 3 or 4 of their respective programs and have a wide range of content such as management principles, project management, communications, contract law, environment, economics, finances, innovation & society and a general area called professional practice. This professional practice deals with a whole spectrum of topics such as industrial relations, safety, quality, ethics, intellectual property and so on. ENG3003 covers a few of these topics with the notable exceptions of project management, communications, technology & society, economics, environment and finances which are presented in ENG1001, ENG2002 and ENG4004. Hence there is a significant variation in what is covered by an engineering management course and thus this area is best viewed by considering a management stream in specific programs where there is better commonality of content over several courses. Swinburne best depicts this by having engineering management 1, 2 and 3 series of courses.

Conclusion

All engineering programs now include a proportion of studies for engineering management, communications and technology study objectives. The amount of credit points allocated to these studies varies from University to University but all have shown an increasing proportion of credit points to this area. Each program now contains a management stream of several courses covering the full range of topics. The recent advent of problem based learning courses has further increased this aspect of said programs. At USQ this has certainly been the case. The course ENG3003 Engineering Management and its companion courses have evolved over time as a response to a flexible learning environment defined by several modes of study and continuous development due to a changing student profile, especially overseas enrolments, and distance education enhancements via I E Aust accreditation reviews. Obviously some technical content has made way for this development but in a world that demands flexibility and adaptation, this area of study has become crucial for engineering students to perform well in the 21st century corporate environment.

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The evolution of an Engineering Communication subject - learning theory through practice

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Abstract*: The increasing recognition of the complex communication challenges facing engineering practitioners has meant that although the subject Engineering Communication has run at the University of Technology Sydney for many years it has continued to evolve. The current change, outlined in this paper describes our move from teaching the students to use a variety of communication genres while learning* ***about*** *human communication issues, to learning about communication issues through communicating and reflecting on that communication behaviour . Changes have been made in subject outcomes, the lecture component, the teaching strategies to support facilitation rather than transmission models of teaching, the assessment scenario, the teaching and assessment of processes for effective collaborative group work, the number of formative assessment tasks, the support of and opportunities for reflection on learning, and the inclusion of a technical sketching component. These changes are described in terms of the pedagogical issues underpinning them, and a number of examples are given.*

Keywords: *learner centric education, engineering communication skills, group work*

Introduction

Engineers need to communicate effectively with their colleagues, competitors, clients, managers, workshop and site workers, the public, in multi-disciplinary teams (Engineers Australia 1999) and to advocate engineering as a viable profession. To develop such skills in our undergraduate engineers at the University of Technology Sydney (UTS), the six credit point core subject Engineering Communication has run for many years. It covers basic communication skills for engineers but also grounds these skills in an engineering workplace setting (McGregor *et al.* 2000). Undergraduate subjects evolve as a result of staff changes and pedagogical research. In autumn semester 2004, this subject has been restructured to explicitly address a number of pedagogical issues that have previously been implicit in the teaching activities but often not transformed into student learning.

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Pedagogical Changes

In line with current research, the practice-based approach at UTS is grounded in the recognition that vocational and professional skills are best learnt through contextualised, meaningful participation. Research on the social construction of knowledge, communities of practice and situated learning (Lave & Wenger 1991) that allows for experiential learning in the context of use, states that a deep approach to learning will result if accompanied by reflection. Kolb's experiential learning cycle (as cited in Jaques 1984 p.xii) suggests that we learn best when we are personally and actively involved in the learning process and that reflection is integral to this process. Brockbank and McGill (1998 p. 85) agree but suggest that using an 'internal' dialogue to aid reflection is no more than a preliminary step, for this reflective thinking to be of use and for deep learning to take place, they propose that a reflective dialogue with others is also necessary.

How can these theoretical underpinnings shape a pedagogical approach to curriculum re-development of a communication skills subject that will enhance student learning and the transfer of knowledge and skills? The emphasis on a learner-centred mode of teaching requires a shift from a transmission model of subject delivery to one that may result in transformational learning - learning which involves changes in communication behaviour. If learning requires a participatory framework (Hanks as cited in Lave & Wenger 1991 p. 15) then a communication skills subject requires an emphasis on interaction, on learning through doing, on teaching content through process. In other words, communication achieved through the real need to communicate. Our pedagogical approach was determined by this rationale and we decided to focus on team-based learning, a contextualised 'client-focussed' assignment scenario, a reframing of the teacher's role, and, more explicit assessment procedures with formative feedback and reflective practice tasks.

"Team-based learning programs provide the learning environment that is most similar to the evolving work environments that students are likely to experience." (Gordon & Connor cited in Boud, Cohen & Sampson 2001 p. 81). Collaborating in group work processes emphasises interaction and simulates an engineering *community of practice*. Requiring the students to form multi-disciplinary teams further establishes this link to the 'real world' and engenders motivation and a sense of engagement. Furthermore, using a series of sequenced tasks to provide students with group work skills and to review group management processes shows students that this aspect is important and enables them to review and reflect on group behaviour (IML 2002). "In one sense the task is the means to the end of group process aims; in another the group process helps the completion of the task" (Jaques 1984 p. 67).

Although the assessment tasks for this subject have been scenario-based for many years, this year we have linked the scenario to a professional engineer in a real engineering environment. To encourage motivation within group work situations it is important that this scenario is:

- meaningful e.g. 'client-focussed'
- easily allocated into sub-tasks
- relevant to the learning needs of each student
- achievable (IML 2002 p. 11).

For experiential learning in the context of use to occur the role of the teacher changes to facilitator and monitor. "While experience may be the foundation of learning, it does not necessarily lead to it: there needs to be active engagement with it" (Boud *et al*. 1997 p. 9). To

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generate this active engagement and motivation we have to consider the factors that not only make students want to learn but also the teaching styles adopted. The teacher's function is to guide, to demonstrate, and to teach content through process. An understanding of students' learning styles and what motivates them is essential. The procedural and logically-sequenced tasks that we have incorporated reflect what engineering students encounter in other subjects and suit their generally analytical and logical approach to learning. Motivation is particularly challenging in a Communications skills subject for engineering students who may be passively resistant to writing and speaking in public. However, as Biggs asserts, if teachers can "teach in such a way that students build up a good knowledge base, achieve success in problems that are significant and build up a feeling of 'ownership' over their learning, motivation follows good learning as night follows day" (1999 p. 61).

A further aspect of motivation is ensuring that the students understand the learning goals of the assessment tasks. The assessment procedures and criteria must be explicit, the tasks must be do-able, and the feedback formative. Students should not be asked to perform in a vacuum, the teachers must clearly state their expectations and prepare the students for the tasks. The assignment outcomes should be included in the assessment marking sheets and available in the subject guide for students to use as a guideline. The feedback given in formative assessment is vital to instil a sense of progress in and sustain the engagement of the students. Contextualised, open-ended activities in which students negotiate, articulate and discover lead to enhanced learning situations. By facilitating these in an atmosphere in which reflection is a valued part of the learning experience, students are more likely to develop life-long learning skills.

Changes in subject structure and delivery

In the restructuring of the subject we have attempted to incorporate strategies that more explicitly support the pedagogical issues discussed above.

The major changes include:

- describing clear **subject outcomes** in terms of five simple communication concepts
- distilling the **lecture component**
- supporting **tutors as facilitators** of learning for learner-centred workshop approach for tutorial sessions
- providing a **scenario based** on a real engineering situation meaningful to all Fields of Practice with an engineer in that situation acting as consultant to the students
- embedding **collaborative group work** theories more explicitly in practice
- developing opportunities for more **formative assessment** strategies
- incorporating a series of **reflection** tasks
- providing a **technical sketching** component.

In the following section we describe each change in terms of the pedagogical issues and give examples.

Subject outcomes

The Subject Outline describes the subject outcomes in the following terms:

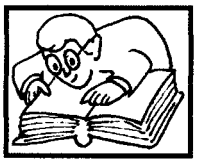
> "In very general terms this subject is about communicating as an engineer. There are five very simple 'four-letter-words' that encompass the scope of communication covered: we would expect you to

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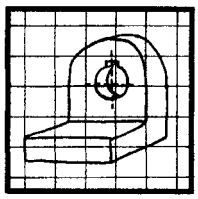
improve and demonstrate your ability to **find, read, write, draw** and **talk** in engineering fields. Of course these five simple focus areas have very complex hidden depths in terms of the theory and practice of human communication" (University of Technology Sydney 2004).

Figure 1 (from the same Subject Outline) represents these five simple terms graphically as five logos that are used to identify all subject documents and web materials, thus making communication a more concrete, explicit, simple and cross-cultural concept. The inherent complexity of such seemingly simple terms is then elaborated upon. By couching all objectives, outcomes and learning activities in this way, students can better understand the reasons for many of their class activities and assessment tasks.











Key words	What this means in terms of developing your engineering communication skills
Find Search Access Source Evaluate Research	You will need expertise in finding information about a particular topic from a wide variety of sources - books, journals, magazines, web, experts, clients, the engineering workplace and many more. You will also need to demonstrate that you can evaluate the information you find in terms of its credibility and depth.
Read Research Understand Paraphrase Summarise Analyse Synthesise Reference	You will need to be able to read English and make sense of it. More importantly you will need to read critically to inform your secondary research (research of work done by others) - analyse the information you read, paraphrase it, synthesise ideas from a number of sources... Your work in Engineering for Sustainability will have given you a starting point for developing your skills in this area. You will also need to 'read' technical drawings and other forms of visual communication including tables, charts, diagrams, and many more.
Write Structure Genres Audience Collaborate	You will need to write effectively in English. This means your writing must be easily read and understood by the audience for whom it was intended. It also means that you can write to demonstrate your ability to analyse and synthesise the writing of others as well as data generated from your own primary research (raw data found by you). You will need to develop writing skills in a number of genre and for a variety of different audiences.
Draw Plan Sketch Present Integrate Design	You must be able to represent your ideas and plans visually in many engineering contexts. These contexts might range from sketching ideas on a bus ticket or serviette whilst meeting informally with colleagues or clients, to representing data in tables, diagrams, plans and graphs in formal engineering reports and presentations. You should also develop your ability to create meaningful visuals that include appropriate labels, captions and titles and are correctly integrated into your written work.
Talk Listen Discuss Present Collaborate Manage Body-Language Groupwork Negotiation	This is perhaps the broadest of the five focus areas. You will need to be able to discuss ideas with clients and colleagues, present ideas in formal presentations and play an active role in work teams. To do all this effectively you will need to use theories of human communication to inform and improve your interpersonal communication style. Some of the human communication issues might include cultural understandings, body language clues, negotiation skills, communication management and many more. Listening to others and understanding their issues will mean you will need to develop your thinking skills to be able to develop creative ideas and accept the ideas of others.

Figure 1. Complexities that arise from the five simple logos. (University of Technology Sydney 2004)

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Lecture component

In previous years, much of the subject content has been presented in lecture mode followed by a tutorial. In general, attendance at lectures has been poor and interest superficial. It is believed that the students found this teacher-focussed transmission model of transferring/ presenting knowledge both uninteresting and demotivating. The subject teachers recognised that a 'surface' rather than 'deep' learning approach to the lecture material was the result for most students. This concurs with the issues raised in an RMIT survey of second year Chemical Engineering students' attitudes towards lectures and tutorials. The survey concluded that most students were dissatisfied with the traditional model (Jollands *et al*. 2003 p. 200). The most popular tutorial style was one in which the "development of skills was augmented by engaging with relevant questions and getting one-to-one help" (p. 197). This tutorial style also enables the tutor to assess individual learning styles and needs (p. 200). Consequently, we have significantly reduced the number of lectures and content is now presented in tutorials based on a student-focussed workshop approach with tutors as facilitators of learning.

Although this is a more expensive format for the faculty it is justified by being a more appropriate model for a 'communication' subject. The lectures that have been retained are those for which we have a guest practitioner with expertise in a field of communication and who is able to demonstrate communication skills in action through, for example, presentations on visual and group communication.

Tutors as facilitators

Moving to a more student-focussed model requires that tutors are supported in moving from "Sage on the stage to guide on the side" (New Scientist 1994). To this end the workbook now has more explicit rationales and guidance, and is accompanied by a tutor's manual. This manual and the weekly tutor meetings further explain the more learner-centred pedagogy and provide information on effective facilitation skills. To further enhance tutor awareness and encourage discussion, the tutors are rostered to present a workshop module in the weekly meetings. This input and feedback from the tutors is invaluable not only as a teaching tool but also to aid in improving the subject.

The new workbook is designed to allow for flexibility in the choice and order of module completion depending on the tutor's understanding of the students' learning styles and needs. This ensures that students are able to work at their own pace, allowing for a building of knowledge and skills onto those previously learned.

One important aspect of providing formative learning strategies is that students are facilitated to 'see their mistakes as learning opportunities'. Progress must also be continuously monitored and feedback strategies employed to ensure that progress is achieved. To further enable students to work from their own communicative capabilities, they can choose to join the tutorial groups run by tutors from the English Language Study Skills Assistance (ELSSA) Centre. Although these groups, which tend to be selected by Non-English speaking background students, are presented with the same subject content, there is a stronger focus on the development of academic writing and oral communication skills and a more detailed drafting and feedback system is used.

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Assignment Scenario

Motivation to learn is increased when students see a need beyond merely passing the next exam. If students see the learning situation as intrinsically important to them in real life their learning is less likely to be surface and short term (Biggs 1999 p. 60) and more likely to lead to life-long learning (Jaques 1984 p. 64). Thus the "situation" for learning should be perceived as truly real-life and not just devised to seem so. Biggs describes this as *expectancy-value* motivation because a learning task must be:

- important; i.e. it must have some *value* to the learner
- possible to do; i.e. the learner has to *expect success* (1999 p. 56).

Our current scenario is 'Engineering in Antarctica'. Links have been established so that students can communicate with an engineer from UTS who is a resident at the South Pole for 12 months. Her diary and photo album are maintained at www.eng.uts.edu.au/links and she has access to our online learning platform for the subject. The ultimate task for the students is to produce a feasibility study of the issues that would need to be addressed if building a new Antarctic base. We feel this is more achievable by 2nd year engineering students than a more technical design report. They should find motivation for learning in being able to explore, develop hypotheses, test and retest at their own level. Moreover, this scenario simulates the engineering workplace by having students work in multi-disciplinary teams called Engineering Consultancy Groups.

In addition to writing an individual paper and a group work report using the scenario, the students give an oral presentation to the scenario 'client'. As with the writing assignments the students are prepared for this through being prepared for and participating in a series of lead-up tasks. These mini-presentations, for which they receive peer and tutor feedback, further support the idea of learning communication skills communicatively.

Assessment

After considering the communication skills of the students (both the average and extremes) that enrol in our 2nd year Engineering Communication subject, assignments have been modified to an appropriate level for these students in terms of:

- **length** – a reduced word count means a need for more precise and concise writing. This is harder for students and an important lesson in communication. Limiting the word count also has the added benefit for tutors of less time spent reading, allowing more time to be spent giving meaningful feedback.
- **genre** – by including 'summary' or 'précis' as a genre, tutors are able to support learning of critical reading skills. A series of written activities sequenced in terms of difficulty early in the semester also better equips students to develop their skill in writing a synthesis.
- **technical knowledge required** – most students enrolling in this subject have limited technical knowledge in their engineering field and most have not yet experienced the engineering workplace. It is important that the content of their reading and subsequent communication about their reading is at a level that does not require a high degree of technical knowledge.
- **audience needs** – communicating to non-technical audiences about technical matters requires a much higher standard of communication skills than communicating with an audience of peers or tutors. The scenario has allowed us to focus on both types of audiences by including funding bodies, developers and users as the audiences for various tasks.

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While marking sheets with explicit assessment criteria have been used for many years for assessment tasks in this subject, the criteria have often been interpreted differently by each tutor and student. While open-ended criteria allow for greater scope, students also need explicit information to inform them of the standards expected. These assessment criteria sheets reflect assessment of learning in the five focus areas outlined at the beginning of this paper as well as the product and process required to achieve it. This then allows for feedback and formative assessment of the skills and development issues that we feel are important rather than simply on how well the students write English.

Collaborative group work theory made explicit

Educational research as summarised in *Enhancing Experiences of Group Work* (IML 2002) shows that self-directed learning, peer learning, interpersonal skills and autonomy are fostered through team-based tasks. Collaborative learning occurs when students work in small groups towards a common goal using the qualities of the individuals within the group to achieve that goal. In collaborative learning there is an opportunity for the discussion of problems enabling students to communicate their learning and experience with peers. This "Formulating and articulating experience transforms it in ways that can allow us to see it anew" (Boud *et al.* 1997 p. 10) and leads to deeper learning as students view their knowledge and skills through the perspective of others.

There are five issues that may cause the failure of group work activities:

- The composition of the group is important so that a truly co-operative grouping of students is achieved and workload division is equitable.
- Students bring their previous group work experience with them. Unsatisfactory group work experiences may result in a negative approach and hamper learning. These experiences must be overcome for group work to be truly effective.
- Students are rarely given the appropriate tools to work effectively in groups.
- Unless group work skills are assessed students may consider them to be of little importance.
- "No understanding of group behaviour is sufficient for successful participation in groups unless each person in the group has the capacity to communicate effectively" (Jaques 1984 p. 45).

In the restructuring of the subject, group work theories are presented and practised throughout the semester in two different working groups. The ECG (Engineering Consultancy Group) and FPG (Field of Practice Group) are central to the scenario and provide a practice-based 'jig-saw' learning opportunity. Assessment has also been modified to include marks for group working processes. "By using questions that focus on teaming issues, the instructor also makes it clear that the course is as much about helping students learn about effective teaming as it is about producing a good final product" (Lewis *et al.* 1998 p. 151). As communication skills are learned very effectively through communicating and reflecting in groups, activities are presented that provide scaffolds for analysis of individuals and how they can best support the group. Students learn how to identify their individual team roles, their strengths and weaknesses and also those of the groups in which they work. They also learn strategies to address these issues, for example, they participate in activities designed to achieve the 'forming', 'storming' and 'norming' stages of group work (so often ignored when group work tasks are expected of students). They also learn how to manage their groups by completing:

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- a Team Charter-including ground rules at the beginning of semester and a review half way through
- checklists for meetings
- meeting agendas
- sequenced reflection activities.

Reflection on learning

Reflective practice and life-long learning skills are promoted through reflection on practice and formative assessment procedures. "Making reflective practice accessible to student learners, enables the latter to become more conscious of their own approach to their learning and thereby promote critically reflective learning via reflection on their practice and learning about their learning" (Brockbank & McGill 1998 p. 73). However, for this to succeed the teacher needs to be explicit about the intention of any reflective task and be able to recognise the process of reflection, relate to it and model it (Brockbank & McGill 1998 p. 73). This focus of reflection on the process and learning strategies involves helping students to develop a metacognitive awareness, an ability to think about the strategies they use to complete a task (Johns 1997 p. 13). Metacognition (thinking about thinking and learning processes) is the ultimate learning goal because it is transferable. It is achieved by developing the ability to evaluate learning situations and the learning achieved, then reflecting on how this learning will direct future activities and finally articulating this learning. It enables students to answer the 'So what?' question about the relevance of learning experiences and how they affect them as individuals.

This subject has previously had a summative examination or quiz to test material presented in lectures and texts. However, in the light of assessment of both product and process and in an attempt to develop metacognition in our students we have introduced a summative reflective task. Marks are awarded for breadth and depth of reflection rather than on positive and negative comments. It is important that there are no marks for the 'correct answer' but marks for the depth of the answer given. By developing reflection scaffolds through mini-reflection exercises in class throughout the semester students are expected to be able to provide a deeper reflective writing task at the end of the semester.

In the introduction to this task students are given the following information in the Student Outline: "Assessment of reflections is made on how you have reflected rather than what you have said. Therefore it is important that you reflect on:

- your progress and your past and current level of development of your engineering communication skills
- the positives and negatives of the process of your development both as an individual and as a member of a variety of groups
- your strengths and weaknesses
- the opportunities and trade-offs you had to face in the process
- the objectives of the course as stated in this Subject Outline and how you have developed outcomes that demonstrate your success in these areas
- the issues of human communication that you have addressed and will need to remember when working as an engineer and working with others." (University of Technology Sydney 2004).

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Technical sketching component

Within the faculty there has been much debate over the years about whether the subject Engineering Communication should cover any visual communication skills. It was decided that it was 'inappropriate ... to teach sketching and drawing skills' that were specific to any one field of practice (McGregor *et al.* 2002). In other words, students should learn **about** visual literacy rather than how to **do** specific graphic communication tasks. However, after much consideration, input from other staff, and research into the graphic communication skills of our 1st Year students, we are now trialling a technical sketching component within the subject. More details of this component are published in Jacobs & Brown (2004).

Conclusions

While at the time of writing this paper the restructured version of the Engineering Communication subject has been operating for only four weeks, it is felt that the focus of the subject is successfully changing from teacher-focussed to student-focussed. The understanding of the breadth of communication and the focus areas presented via the five logos is developing well. The students have formed their FPGs and ECGs and generally seem to be benefitting from the tools they are being equipped with. The students' levels of maturity, motivation and commitment vary, and, as is to be expected, some are approaching the reflective practice activities more seriously than others. It is also too early to gauge the opinions of the tutors most of whom are new to the subject. We will be asking both the students and the tutors for quantitative and qualitative feedback at the end of the semester. Although it is impossible for any one student to compare the 'new' version with the 'old' version of the subject, as no student who understands communication has experienced both, students who have passed the subject previously and seen the redeveloped subject materials have commented positively on the changes.

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Chartered Engineering Executive
Engineers Australia implementation status as at June 2004

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Abstract: *The Council of Engineers Australia established the Centre for Engineering Leadership and Management (CELM) in 2002 with a charter which includes the definition of mid-career leadership, management and business competencies that engineers should acquire as they move into mid-career. Further, the Centre should ensure that engineers who can demonstrate achievement in these competencies have a suitable form of professional recognition that has strong credibility in the wider market. Through the efforts of a Competencies Working Group, established under the auspices of the national CELM Board, an overall framework for implementation of suitable arrangements has been endorsed in principle by Engineers Australia. A set of competency units and elements, with nearly 200 defining activities, have been identified, and an implementation strategy established. An initial trial process for assessing attainment of these competencies has been undertaken in the Canberra Division of Engineers Australia. The overall framework is to be disseminated widely in the form of an exposure draft, in parallel with the conduct of further trial assessments in other Divisions around the country. This paper sets out the background to the current state of play, and describes the six major elements of the policy and implementation framework accepted in principle by the Council of Engineers Australia – the list of competencies, eligibility for assessment and recognition, assessment arrangements, background to the selection of the Chartered Engineering Executive form of post-nominal, initial considerations for a marketing and communications strategy, and a broad timetable including resource demands and transitional demand from the membership for assessment and recognition.*

Keywords: *Chartered, engineering, executive*

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Introduction

Through the work of the Centre for Engineering Leadership and Management (CELM), Engineers Australia will offer a special form of Chartered Status recognition to members who have attained advanced leadership, management and business competencies – Chartered Engineering Executive.

This paper describes the state of implementation planning for the associated competency framework as at June 2004.

Background

The members of Engineers Australia have been advised progressively over the last 12 months of this development activity, which is being undertaken by a Competencies Working Group under the auspices of the national CELM Board.

In accordance with the approved objectives for CELM, the CELM Board has approached the issue of development of these advanced competencies with two mutually supporting key elements in mind:

To provide a framework for the further professional development of mid-career engineers by defining the leadership, management and business competencies they should acquire as they move into the next stages of their careers.
To provide a suitable form of professional recognition for those who are deemed to have attained those competencies – such as a post-nominal.

The Working Group is chaired by Air Vice-Marshal Julie Hammer, and includes:

The past and current Chairs of the National Committee for Quality in Engineering – NCQE – Mr Mike Evans and Mr John Anderson.
The Directors of Engineering Practice and Education and Assessment in the National Office of Engineers Australia (Mr Martin Dwyer and Dr Maurice Allen respectively).
Other National Office staff at various times.

Definitions of appropriate leadership, management and business competencies were completed in large part by around mid-2003. Work since then has been directed mainly at:

Developing and trialling an assessment framework.
Determining a preferred form of post-nominal recognition.
Examining the policy and implementation issues which need to be settled before formal adoption of the full framework could be considered.

On 2-3 March 2004, NCQE members and CELM Chapter Chairs from the regional Divisions of Engineers Australia were briefed on progress, and provided with a copy of the latest guidelines being used for the trial assessments. Several valuable suggestions were taken up from those briefings.

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Policy and implementation framework

Set out below are the six major elements of the policy and implementation framework now approved in principle by the Council of Engineers Australia:

The context and coverage of the competency units.
The form of post-nominal being recommended (and requiring a change in the Bye-laws of Engineers Australia).
The eligibility of members for assessment and recognition – including the approach to subsequent ongoing CPD requirements for successful applicants.
The proposed assessment arrangements, including accreditation of panel members, avenues for appeal, and fees for assessment.
A marketing and communication strategy for launch and promotion of the new framework, including promulgation of an 'exposure draft' based on the framework underpinning the current trial assessments.
A broad timetable and costs to complete the trial phase and to handle the transitional issue of the level of potential applicant demand from among the existing membership cadre.

Some implementation issues – including transitional issues – will require further consideration in the light of lessons from the trial process.

Competencies

An early priority in Council's business plan for the CELM Board was to develop a set of competencies for leadership, business and management with particular (but not exclusive) reference to an engineering setting.

The Advanced (Stage 3) Competency Definitions now recommended as part of the initial implementation framework have been reviewed by the NCQE, the CELM Board, and key National Office Directors.

The 10 Competency Units listed below draw on recognised principles such as AS/NZS ISO 9000:2000, and are supported by 47 Elements, with 197 Indicative Defining Activities. It is expected that applicants demonstrate achievement of a substantial depth and range of these competencies, but not necessarily a high level of competency across all 47 Elements.

Leadership
Leadership
Strategic Direction and Entrepreneurship
Management
Planning
Change and Improvement
Customer Focus
Processes, Products and Services
People/Human Resources
Business
Supplier Relationships
Information
Finance Accounting and Administration

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Progression Through Career Stages 1-4

The requirements to demonstrate 'non-technical' competencies already exist for Stage 1 (tertiary qualification) and Stage 2 (Chartered Status) – as per the applicants handbook. This paper addresses the implementation issues at the 'advanced' or Stage 3 level.

It is felt there is presently a sufficiently evident ramp-up in significance of competencies in leadership, business and management skills from Stages 1 to 3. Subject to periodic review of the competency elements, and the broader framework described in such as the National Generic Competency Standards for professional engineers, technologists and associates, the CELM Board has endorsed that leadership, business and management competencies remain embedded in Stage 1 and 2 standards.

Indeed, the CELM Board is interested in further consideration of the 'expected graduate attributes' in leadership and management at Stage 1 – with communication and presentation skills of particular interest, along with basic financial skills.

The CELM Board has noted also that the recent current review of Stage 2 documentation combined the competencies for all three grades of engineer into one set, with the assessment process required to ensure the differentiation between engineering professionals, technologists, and officers.

The approach to core competencies and 'electives' in the form adopted for Stage 2 is not seen as appropriate to the leadership, business and management competencies for Stage 3. The Competencies Working Group has addressed the recent review of Stage 2 competencies and is comfortable that a suitable relationship exists between the relevant Stage 2 competencies and Stage 3.

While the CELM Board does not have the charter to address advanced technical competencies in engineering, it should be noted that Engineers Australia is to address advanced technical engineering competencies in the same context as CELM is addressing the non-technical Stage 3 competencies (ie. leadership, management, and business).

Similarly, it was noted that there is work to be done in relation to the concept of Stage 4 competencies, and in the light of Council's deliberations on governance and related issues early in 2004, there is a need to undertake further discussion on the way forward.

Form of post-nominal

A form of post-nominal, recognisable for its engineering origins, and granted after a rigorous and transparent process for assessment, has always been the aim.

Following many discussions in various guises during 2003, the rationale for the form of recognition had been largely explored. During September-November 2003, steps were taken with the 'branding' team involved in the Engineers Australia campaign known as 'Raising Our Professional Standing' to market test a suitable post-nominal with a couple of focus groups.

Some key points in respect of the survey:

> Any chosen post-nominal should allow for possible future added forms of recognition, and retain an 'EA family' flavour.

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Six options were presented for consideration, using a mix of the terms "Chartered", "Engineer/Engineering", "Business", "Master", and "Executive" – suggestions for others were sought.
Some 30 individuals from the National Industry Liaison Board, employer representatives from the Excellence Awards nominees, and CELM Chapter Chairs were approached – eventually, 17 formal responses were received.
The result demonstrated a clear preference for a post-nominal combining "Chartered", "Engineer/Engineering", and "Executive" for Stage 3.
Overall, the Competencies Working Group members were quite pleased with the quality of the resulting report (one respondent registered considerable disquiet at the survey method and conduct, and took the position that no post-nominal was necessary).

The Competencies Working Group considered the survey report in December and agreed that the form of post-nominal to be recommended would be "*Chartered Engineering Executive*" - short form "*CEngExec*". This has been accepted by Council, and appropriate amendments to the Bye-laws for Engineers Australia are in train.

Eligibility

Recognition for attainment of these 'advanced' competencies will be open to professional engineers, engineering technologists, and engineering associates who are eligible for membership of Engineers Australia, and who are members.

Eligibility will not be limited to members with Stage 2 *Chartered Status*.

As an indication only, it is considered that in most instances a period in the order of 10 years will be necessary before candidates who have achieved Member status are likely to be in a position to demonstrate a sufficient breadth and depth of competencies for consideration for 'advanced' recognition.

Transition Phase

There are in the order of 20,000 members who have gained 'Member' status since 1990. It is not clear how many of these members can be expected to consider applying for early recognition of competency attainment at Stage 3 level, and therefore whether and to what extent this is likely to generate a 'bulge' of early demand for assessments.

As assessment resources are expected to be limited, the Working Group will be looking to the next phase of the trial assessment process in the Divisions for indications of the size and timing of any such bulge in demand.

The overriding consideration from the CELM Board is that recognition for achievement of Stage 3 competency must not be given lightly. Attainment of the right to use the post-nominal must be aspired to and earned on merit, on the basis of documented evidence, rather than through a trivial 'transition' process.

The preferred approach at this stage is to require a full form of written application from all applicants, with perhaps a truncated form of panel assessment based on the written applications rather than a formal interview. Here the Working Group will look to the trial assessments in Divisions to provide further insights.

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A method based on 'invitation', or deliberate staging to smoothe out demand may be suitable options also.

Ongoing CPD Obligations

The Working Group and the CELM Board have discussed various approaches as to whether there should be any ongoing CPD obligation as a requirement for the retention of the Stage 3 badge, once attained.

Considerations have included:

> Leadership skills, once acquired, are more enduring than technical skills and may not warrant the same degree of ongoing refreshment.
> The commercial and regulatory environment within which business operates can change frequently, so maintaining currency is an important consideration.
> The ethos of a learned society such as Engineers Australia embodies continual learning – Tenet 8 of the Code of Ethics refers (published, among others, as Appendix E to the Chartered Status applicant's handbook, 2004).

Accordingly, an ongoing CPD obligation will apply. The Working Group has yet to formulate the form of CPD requirement, and the method of monitoring compliance. An honour system based on undertakings by the member at the time of annual membership renewal is preferred at this stage, rather than a directly reportable or auditable system, or a system of periodic full assessment.

Assessment

The 'practice report' assessor and 'expert panellists' approach presently being used for the Stage 2 (*Chartered Status*) assessment regime is a proven and rigorous basis for application for *Chartered Engineering Executive.*

The assessment will be practice-based. The combination of *Chartered Status* and (for example) an MBA is not in itself sufficient to grant recognition of attainment of 'advanced' competency to a member. Competencies must be displayed through demonstration of achievements in the workplace – see Bowen-Clewley, Section 5, discussion 'The nature of professional competence'.

Formal tertiary studies leading to a degree or post-graduate diploma may be seen in the assessment process as reinforcing an applicant's claims, but will not of themselves constitute evidence that competencies have been achieved. This applies equally to applicants who have acquired knowledge through non-formal learning (eg in-house training or private reading).

Once adopted formally, applicants for *CEngExec* status must have confidence that Engineers Australia has developed a sound merit-based assessment process, which is applied with reasonable consistency across all Divisions.

Before full-scale roll-out to the membership, a two-phase trial is being undertaken to road-test the assessment framework and help gauge the demand for assessment resources. The first phase of the trial – based on assessment of four invited applications in Canberra – has been completed, with valuable lessons learned for fine-tuning the Competency Definitions and for the format of applications.

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An 'exposure draft' Initial Handbook for Applicants is being produced for the Phase 2 trials, taking into account lessons learned during Phase 1.

In the light of the first phase trial assessments, the CELM Board has accepted that concurrent roll-out in all Divisions with interview panels who do not have the in-depth background knowledge of the core members of the Working Group is not desirable. A timetable is being developed which will provide for direct involvement in each Division, at least initially, of the National Assessor Mr Doug Tompsitt MIEAust CPEng, together with one of the three core members of the Working Group:

AVM Julie Hammer FIEAust CPEng
Mr Mike Evans FIEAust CPEng
Mr John Anderson FIEAust CPEng.

The over-riding considerations for the conduct of the Phase 2 trials are to prove the framework, to establish some guide as to likely demand, and to be assured that an adequate knowledge-transfer process exists.

Further guidance was sought during discussions with National Assessors on 30 April in Canberra. Assessors raised a number of practical issues for consideration during the Phase 2 trial process, and in the ongoing framework once formally adopted.

The Formative Panels

Panels for Stage 3 assessment must have appropriate standing.

To cover the initial trial phases, it is intended that relevant CELM Board members, Working Group members, and CELM Chapter Chairs be certified by the Chair of the Education and Assessment Board of Engineers Australia as 'expert panellists' for the purposes of assessing the merits of Stage 3 competency applications.

Applicants for the trial phases in all Divisions are expected to be chosen largely by invitation. A condition for these applications will be that successful applicants undertake to act as 'expert panellists' for subsequent rounds over, say, two to three years in their respective Divisions. For this reason, assessment fees for trial applicants will be waived.

Appeals

No detailed appeals process is prescribed at this stage. Any form of appeal or grievance over the standing, conduct or outcome of an assessment process will be referred to the Chair of the Education and Assessment Board in the first instance to determine a suitable review mechanism.

Marketing

It will be vital to inform and manage expectations for the introduction of the framework for *Chartered Engineering Executive.*

A low-key approach has been used to date, and until the lessons from the Phase 2 trials are evaluated, this general approach should continue to apply. However, some expectations will be raised simply by virtue of the trials. A low-key education and awareness strategy, comprising progress articles in such vehicles as Engineers Australia Magazine and e-News, and update briefings for CELM Chapter Chairs, Division Executive Directors and their relevant staff, will be used.

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Given that attainment of Stage 2 *Chartered Status* is not to be an essential prerequisite for eligibility for *CEngExec*, it will be of particular importance to reinforce this new form of recognition as a different and advanced form of *Chartered Status*.
Beyond internal EA stakeholders, it is now timely to start preliminary briefings of external stakeholders. An exposure draft on the framework, based on relevant material from the Initial Handbook for Applicants prepared for Phase 2 trial applicants, is being compiled for this purpose.

Promulgation of an exposure draft in this way should have the benefit also of reinforcing the intellectual value for Engineers Australia which is embedded in the Competency Definitions and in the wider *CEngExec* recognition framework.

The CELM Board and National Office staff, and CELM Chapter Chairs and Division Offices, will be invited to act as spokespersons with employers, potential applicants, and mentors, with other professions, associations, and with industry and the education sector more broadly.

A further marketing and communication plan will be developed in conjunction with the final implementation package to be brought forward later in 2004 for approval. This will need to cover the concept of career 'stages', the overall *CEngExec* framework, and the roll-out sequence including timing of calls for applicants.

The final form of the Handbook will then provide also a template to assist less-experienced aspirants target their own personal development needs.

Timetable and costs

Implementation is being addressed in 5 distinct phases, with timings as indicated:

Phase 1 – initial trial assessments in Canberra Division, completed April 2004.
Phase 2 – initial trial assessments in other Divisions, and review of the framework based on lessons learned, through end-2004.
Phase 3 – formal adoption by Council and Congress of the Stage 3 competency framework – November 2004.
Phase 4 – initial roll-out for transition demand, through end-2005.
Phase 5 – move to long term steady state from start-2006.

Accurate scoping of ongoing costs and other resource demands would rely on lessons learned in the initial trial phases (and fee strategies developed accordingly).

Some one-time additional costs are likely to be incurred during the Phase 2 trial assessments. Once some estimates for the Phase 4 transition period demand can be established, and for the Phase 5 'steady state', fee strategies can be developed to offset assessment and other costs.

Conclusion

Introduction of the framework for recognition of *Chartered Engineering Executive* is planned to continue in accordance with the above timetable.

The current intention is that final agreement to the new competency framework be sought by end-2004. By this time, it is expected that the benefit of the lessons learned during the staged trial assessments will result in a smooth and successful introduction.

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Using simulation as a learning tool in Civil Engineering: The Dam Game or learning to be real engineers

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Abstract: *A pilot study to evaluate the effectiveness of using a dam construction simulation in the Civil Engineering course at Curtin University of Technology has been conducted. In particular the development of professional skills and other qualitative learning outcomes were assessed. The study used a variety of methods (observations, student assessment tasks, and questionnaires) to gather information and revealed, in the main, that students believed that the simulation was an effective learning tool for them. Students recognised that the simulation helped them to develop skills in applying their fundamental engineering knowledge to a civil engineering construction project. They also came to understand how their engineering decisions affect the workplace, people, and the environment. Students were confident that the simulation taught them much about working as part of a professional team. The simulation exercise was run with third year engineering students. They had to plan, monitor, control and report on a civil engineering project (dam construction). In this paper the different perspectives and observations of the teaching team, [of an engineer and a teacher] and the students on the teaching and learning process is discussed. While the simulation is an effective learning tool, we believe that it must be used in conjunction with supportive face-to-face teaching practices.*

Keywords: Simulation, Civil Engineering, Professional Practice

Introduction

During semester two 2003 a preliminary evaluation was undertaken to make judgements about the effectiveness of using the simulation "Dam Construction Game" in the Civil and Construction Engineering course at Curtin University of Technology. The simulation was used as a learning exercise with third year engineering students with the purpose of providing

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them with a vicarious experience of project management. Students "were appointed" as engineers in charge of a dam construction project and were required to plan, monitor, control, and report on the project. Students' development of engineering knowledge and professional practice, such as presenting a plan to a Board of Directors and compiling written reports, were specifically assessed. Based on lecture observations, students' achievement in their assessments, and a survey of students' opinions, judgements were made about:

- the learning outcomes that students had achieved by engaging with the simulation; and
- the effectiveness of the simulation in developing students' engineering fundamental knowledge and professional practice.

In this paper the overall purpose of the evaluation, the way in which the evaluation was conducted, and the outcomes of the evaluation are documented. Teaching and learning implications are highlighted to ensure that the potential is realised for the simulation in the common first year engineering course in 2004.

The purpose of the evaluation

The purpose of the evaluation was to make judgements about the effectiveness of the simulation in developing students' engineering fundamental knowledge and professional practice in relation to project management. By using the simulation as a pivotal learning exercise, the students were expected to:

- plan for the construction, rate of construction, equipment requirements and income and expenditure for the project by preparing appropriate charts and information sheets of planned productivity, cash flow and equipment/plant use;
- gain approval for their plans from a "Board of Directors" (the two-discipline teaching team comprising of an engineer and teacher); and
- undertake, monitor and control the [simulated] construction of the dam by keeping a record of production, income, expenditure, plant/equipment utilisation and productivity, and in particular, record any changes to their original plans and the reasons for these changes.

The extent to which the simulation was a way to represent an authentic work context requiring students to engage in "real world" engineering tasks in project management was central to the evaluation process.

The simulation

The idea of using a computer simulation or management game to help students learn about complex issues is not new. Gilgeous and D'Cruz (1996) describe simulations stretching back over many years. The use of management games for teaching and learning about project planning and control is also not new and was described by Scott and Cullingford in 1973. Further, Au and Parti (1969) described the use of a game using a project with a significant amount of earthmoving as a basis. Not all games have to be complex and computer based and Tommelein et al. (1999) describe one which can be run either manually or on a computer to illustrate the interaction of parties on a project. More recently, the Internet has featured with games as part of the learning environment (Sawhney et al., 2001).

Despite all these developments, simulations are still little used in teaching, perhaps because of their inability to capture the attention of people brought up with computer games as a major form of entertainment. Whilst not competing with the leisure games, this simulation combines the experience of players and traditional teachers and engineers to provide a user interface and style of play that is both interesting and informative. The detailed objectives of the game are:

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- To provide a 'realistic' model of a construction project which will react in physical and financial terms to the decisions made and actions taken by the player.
- To provide reports as might be expected on a real project.
- To include uncertainty but to control it in such a manner as not to hide the effects of control actions.
- To be suitable for use by both undergraduates and practicing engineers.

The simulation is based on a project to construct a rock-fill dam with a clay core. The finished dam is 30m high and 300m wide at the top. Figure 1 shows a general arrangement of the site. It indicates some of the features to be considered by the player including the design and maintenance of temporary haul roads; the environmental impact of the work; and the effect of the work on neighbours. This is in addition to the normal planning and control considerations present on an isolated site.

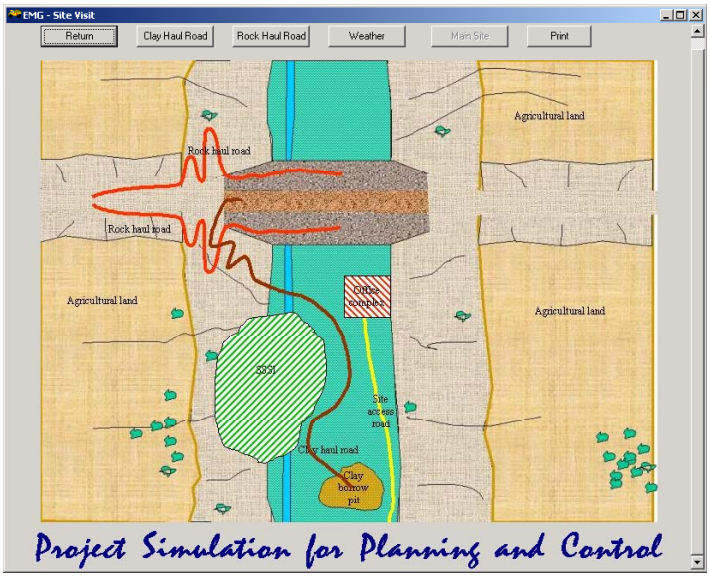
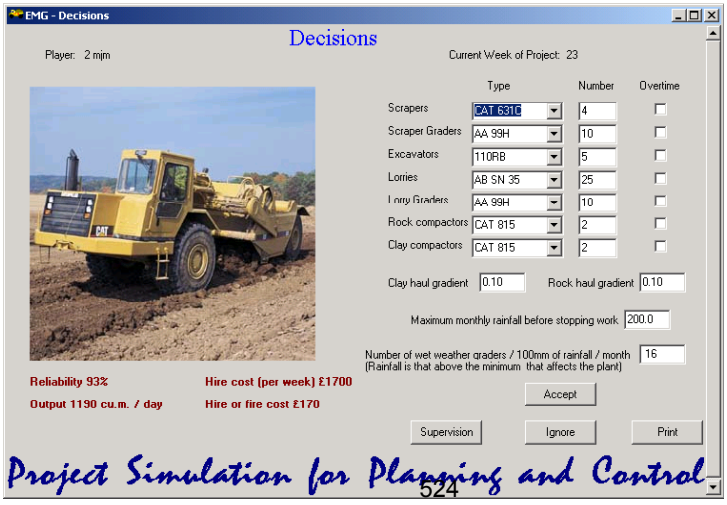


Figure 1. General arrangement of the site

The player takes the part of the contractor's project manager and is responsible for the planning, resource selection and use, the control and the reporting to the company management. Planning is required for both the physical and financial aspects of the project. It must be carried out and the project plan input to the computer before work can start on the actual construction. The plan can be amended at any time but the system remembers all plans and reports against the agreed one. Resources are required to excavate, transport and place the rock and clay and to maintain the haul roads. A typical screen for the choice of plant is shown in Figure 2.



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Figure 2. A typical decision screen

Basic information on the equipment is provided on this screen but it is usually insufficient to make effective decisions. To aid the player and to increase the verisimilitude of the simulation various resources are provided. These include links to:

- web sites of equipment companies such as Komatsu and Caterpillar;
- web sites of contracting organisations;
- notes and PowerPoint presentations on equipment selection and use; and
- notes on the operation and use of teams of equipment.

Management resources are also required and have to be selected by the player. For example, the number of engineers to supervise the rock excavation, transport and placing must be considered together with the amount of money to be spent on training them in the quality, safety and environmental matters. All the most common control charts are available from the system and players can choose which they want to use to help them make decisions.

The player receives reports from the simulation in many formats as would happen on a real project. There are some aspects which would be picked up from meetings and mail. These are reported as text and are illustrated in Figure 3. It can be seen that these refer to a large range of aspects including work quality, environmental impact, training issues and problems with progress. This type of information would be obtained from many sources in reality and would depend on the staff and reporting mechanisms on the project. In the simulation, the amount of this material also depends to some extent on the staff and its training.

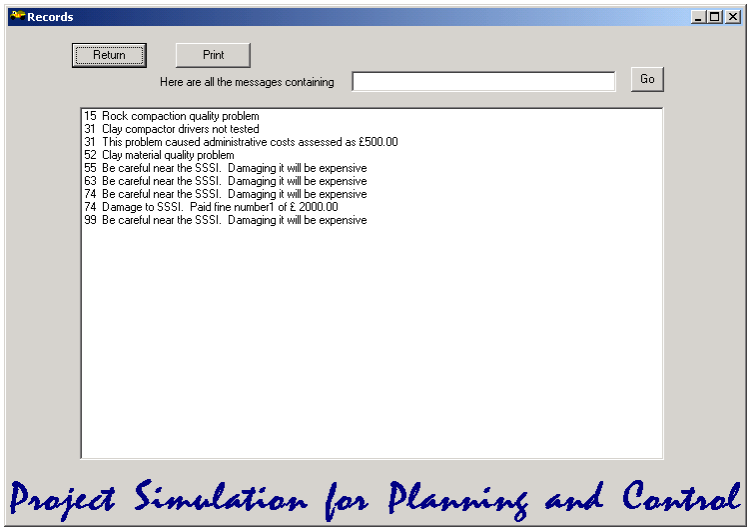


Figure 3. A typical text report screen

The more formal control information can also be provided by the system although its availability depends directly on the staff employed. If few staff are employed, few reports will be produced. The information is available in numerical form or graphs. Figure 4 shows a graph of performance variance during construction. All the most common control charts are made available.

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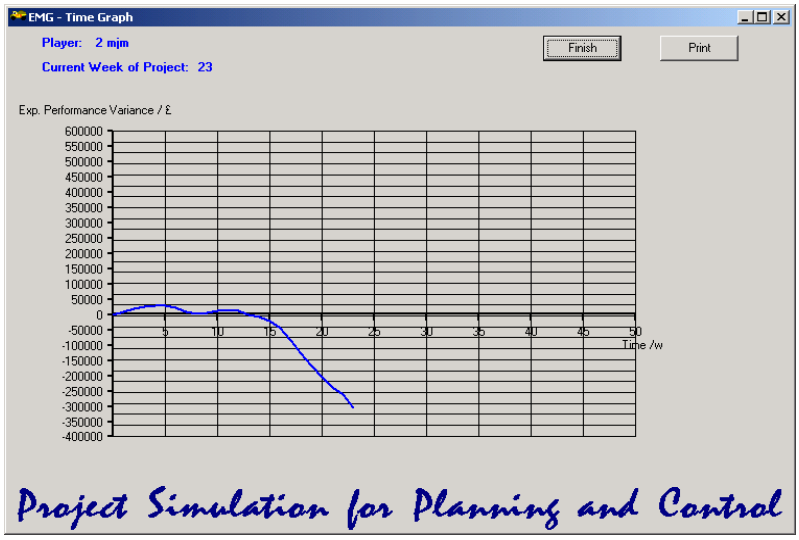


Figure 4. A typical variance graph

Methods of evaluation of the Simulation

Several methods (observations, student achievement of assessment tasks, and student questionnaires) were used during the evaluation process to gather information about the effectiveness of the simulation in developing students' knowledge and professional practices. The two-discipline team teaching approach was used to collect the information to allow interpretations to be made about the teaching and learning processes involved in using the simulation. The strength of these interpretations was that shared understandings about students' learning converged from different perspectives (of an engineer, the engineering content expert, the teacher, the curriculum expert; and the students themselves). Students' learning outcomes for the unit, which were tightly linked to the generic skill statements for their overall engineering course, included:

- demonstrating and articulating an understanding of professional engineering, its structure, workings and relationships with society;
- applying scientific/mathematical and technical theory to engineering problems;
- identifying, defining and providing solutions to engineering problems;
- producing engineering style reports;
- using engineering judgement in both quantification and elementary modelling;
- structuring engineering problems into a sequence comprising identification, formulation, solution and impact;
- demonstrating a range of effective engineering communication skills;
- collaborating effectively in, and identifying the working-benefits of, a multidisciplinary and multi-cultural teams; and
- showing an appreciation of the role and responsibilities of professional engineers

There were 53 students in the group who organised themselves into project teams of three (or two). These groups were given guidance about working as teams and the types of roles they might adopt within the project team.

The two-discipline team approach to observations

Observations and team debriefings were conducted for each of the 12-week lectures. The lectures were the main avenue to provide information to students at the appropriate stages of planning, controlling, and monitoring the project. Student questions during lectures were of interest in relation to their ability to apply their learning to achieve the objectives.

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The two-discipline team approach to assessment tasks

There were two main assessment points during the semester. The first was associated with the simulation and the second built on the skills gained from the exercise to enable students to develop feasibility plans for an urban development project. The teaching team acted a pseudo Board of Directors in both of these assessments.

The assessment associated with the simulation involved three tasks; an initial set of project plans were displayed for assessment, an oral presentation of the plans showing any adjustments based on feedback from the Board of Directors, and a written project report. Each task in the assessment was a project team effort and assessed as such.

A questionnaire was designed specifically for the evaluation of the simulation.

Outcomes of the evaluation

Students understanding of engineering fundamentals

Overall, students had a positive response about the effectiveness of the simulation in terms of understanding the basic principles of the design and construction process and believed that they could apply these to other situations in a practical world (see Items 1 and 2 in Figure 5). Students indicated that they had gained a greater awareness of the planning and economics aspects of civil engineering.

> The game helped us to experience the practical knowledge of civil engineering and gain a better understanding of practical engineering. It allowed us to think of a whole project as one item instead of one part of it only.

Students also were positive about their new learning about the "plan-monitor-control" cycle in project management (see Item 4 in Figure 5). The development of this knowledge was significant and was also evident from the observations made during lecture sessions, the ways in which students tackled their assessment tasks, and the positive manner in which students responded to feedback from the Board of Directors.

> It has taught me that in engineering original plans don't always go the way one originally thought. This was the first exercise in our course that gave me variable and unexpected outcomes (and problems).

However, there was a range of responses from students about whether the simulation improved their ability to structure engineering problems into a sequence (see Item 5 Figure 5). Some students commented positively about their improved problem solving.

> We have learnt to identify problems and improve our problem solving abilities. The game made us realise how one decision will affect others and that there isn't one correct answer; there are many ways to solve problems. The game has aided in improving our ability to work under pressure.

Other students were less confidant about any improvement in their problem solving abilities as noted by one student.

> I don't think it helped too much. The principle behind it was good and the ideas it brought up were important but I think the game was hard to function and we were

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unable to correctly identify and solve problems. More background information is needed.

In addition, it appears that engagement with the simulation did not necessarily allay several students' concerns about whether they were able to make engineering judgments concerning quantifiable activities in project management (see Item 3 Figure 5). Some students considered that the simulation "assisted them in a better understanding of how to use our engineering judgement" but others, as demonstrated in their assessment tasks, grappled with the challenges embed in quantifiable data associate with project management.

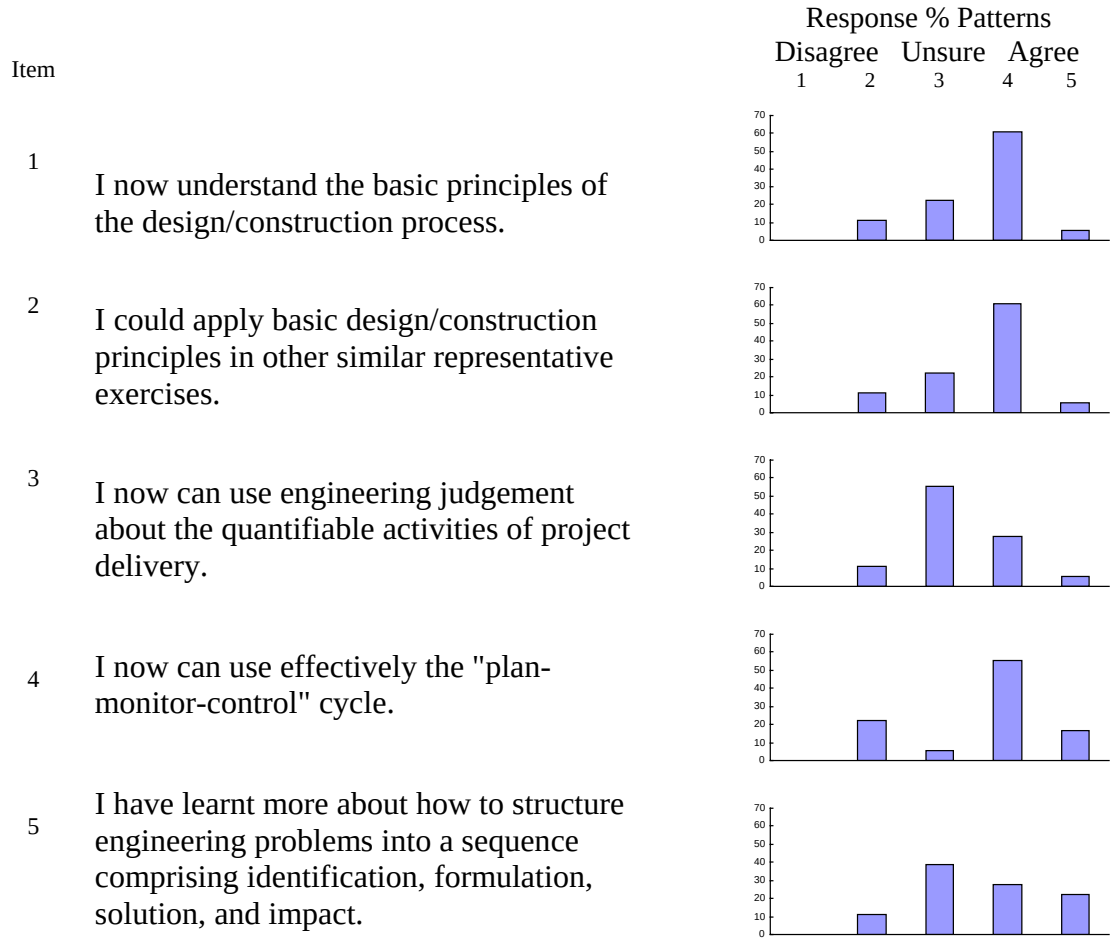


Figure 5. Learning outcomes about engineering fundamentals

Students understanding of professional practice

The simulation had a positive effect on students in relation to organising a group to work as a team (see Item 3 Figure 6). Many comments by the students about the simulation were along these lines.

> It has provided us with the opportunity to work in a team and come to a common goal in a short period of time. It made us think through problems and make judgements as a group. We became more aware of different people types; how some are aggressive leaders and other submissive followers. The choice of group is very important and the ability to communicate as a unity is a must.

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Also, students gained an awareness of their future professional responsibilities and the impact of proper engineering procedures on the workplace, people, and the environment (see Items 4 and 5 Figure 6).

> To work in a group and accept decisions of others is a real learning experience. The game has definitely made us more aware of the responsibilities of an engineer and how our engineering decisions affect a broad range of people. It has contributed in understanding the basic work environment.

While many students believed that they were more able to communicate in a professional engineering capacity (see Item 1 Figure 6), others were unsure about their own competency with communicative skills. Because the assessment of the initial oral presentation of the plans and written reports were conducted as a group assessment, it is probable that students could not gauge their individual performance as a contribution to the group. There was a range of student responses about their abilities to communicate effectively within their project team during the simulation exercise (See Item 2 Figure 6).

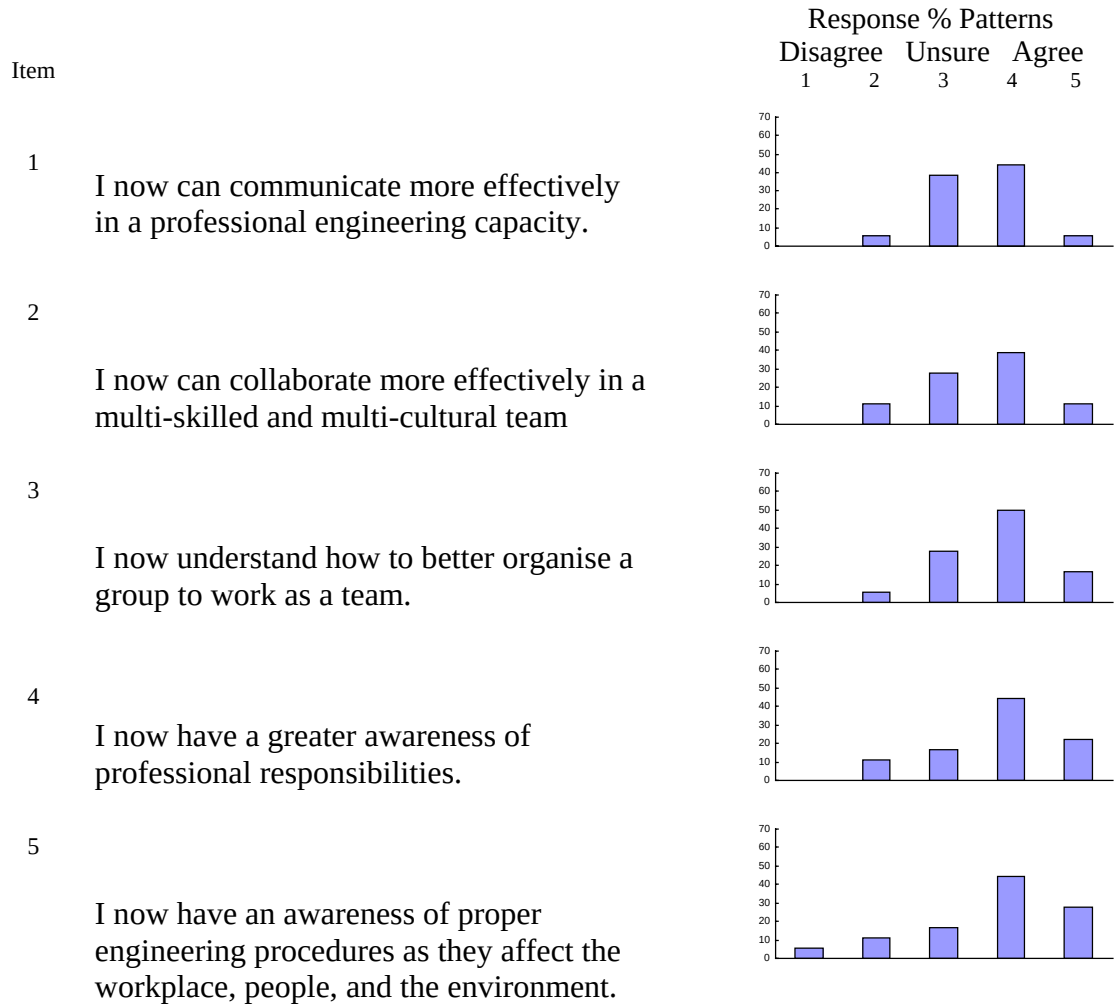


Figure 6. Learning Outcomes about Professional Practice

Teaching and learning implications for the first year common course

Students working with the simulation

An important finding from the evaluation was that students required more time to find out how to manipulate the workings of the computer simulation. One student made this clear.

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> I think the DAM idea was good but I found it difficult to see how it allowed us to better understand problems. We were not using the program properly because we didn't understand it and as a result we lost patience with it. The game provided much stress for little return. We need to try the game beforehand to understand the value (engineering) of numbers shown so problems are not tackled blindly. We need something like a practice game with warnings or a tutorial in the simulation which will inform the user what to expect.

Not all students had difficulty working the simulation as one student said "the game itself is good and relatively easy to understand" but most students needed to know what the computer program required them to do in order to carry out planning, monitoring and controlling the production of the dam.

It became clear that the simulation does not replace the teaching of essential information required for project management; it is a learning tool which must be used in conjunction with formative and iterative teaching strategies. Once students can master the mechanics of engaging in the simulation, their learning from the simulation will be heightened.

Students working with uncertainty and making informed judgements

Importantly, the evaluation of the simulation showed that many students were frustrated because "it was impossible to win the game, that is, make a profit!" This issue also is tied to providing more information to students about the principles of costing and making equipment and contract estimates in terms of an appropriate cost-benefit timeframe for production rather than ‘winning’. It is envisaged that more information provided to students in the supporting lectures in future will overcome this problem.

Students working in groups

The simulation evaluation clearly demonstrated that the third year students had little prior experience in working in groups as part of a learning experience. Indeed, the students commented that the team approach to learning was novel for them.

While the team experience was effective for third year students, they were still keen to know about their individual performance with their group. Some students suggested that part of the assessments could include a brief report on group efficiency in their capacity to plan, monitor, and control their projects. This suggestion is worthwhile for further consideration because the strategy will assist future students to monitor and reflect upon their own and others’ learning.

Students learning with additional resources

The evaluation of the simulation revealed some inadequacies in the level of resources in the students' learning environment. Students required more time, and more computers running the simulation, to allow them greater access to both independent and group learning. Pin-up space is essential for students to adequately display their original plans (on the poster-like charts) for the review process to be conduct by either the Board of Directors or the students themselves. Students learn from their peers and the display of students work is an essential part of a rich learning experience for all students.

A valuable teaching and learning resource emerged from the evaluation of the simulation. Photographs were included in the formative evaluation feedback that the Board of Directors provided to the third year students and signalled to students a clear rubric for the way in which their work was assessed.

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Making modifications to the evaluation process

The two-discipline team approach to the formative and summative evaluation of the simulation was valuable. The continual discussions about the simulation and students' progress were both a powerful teaching and learning experience and revealed the way in which reflective practice could enhanced students' learning experiences. Furthermore, the validity of the judgements made about the effectiveness of the simulation was strengthened because of the methods used in the evaluation process. However, of necessity, the student questionnaire instrument used in the evaluation will require modification. The learning outcomes expected of future students undertaking the exercise will be tailored to their developmental discovery experiences with civil engineering and project management. There will be a greater emphasis on assessing students' specific learning outcomes, outcome statements that will be finer iterations of the generic skills for their overall engineering course.

Conclusion

The observations of students, the progressive improvement of their performance in assessments, and their general positive response to the simulation, indicated that students has gained learning momentum in their engineering knowledge and professional practice skills. It was rewarding for the two-discipline team teachers to observe students:

- reach a high professional level of delivery in their oral presentations;
- grow in confidence with making and supporting engineering judgements; and
- improve in their abilities to write engineering project management reports that were analytical rather than descriptive.

In the main, students believed that the simulation was an effective learning tool for them and recognised that the simulation helped them to develop skills in applying their fundamental engineering knowledge to a civil engineering construction project. They also came to understand how their engineering decisions affect the workplace, people, and the environment. Students were confident that the simulation taught them much about working as part of a professional team.

While the simulation is an effective learning tool, it must be used in conjunction with a repertoire of face-to-face teaching practices. Continued evaluation of the use of the simulation in first year studies will take place during 2004. This will help the teaching team to understand how the learning and assessment approaches used with first year students based on the simulation can be embedded into an enriched teaching context to maximise students' learning about civil and construction engineering and professional practice.

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The Animation of Simulations and Tutorial Clients for On-line Teaching

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***Abstract**: The underlying structure of web pages can allow them to contain images that are moved by software algorithms. With little effort, simulations can be animated by software that is on open view to the student and that will be modified 'there and then' as part of the learning exercise. The JavaScript environment allows instant execution of code with visualisations unsurpassed by many massive and expensive packages. Examples are given of dynamic demonstrations and the simple means of achieving them. With a little more effort, graphical clients can be written and embedded into web pages which allow students to try tutorial exercises, interacting with the exercise in a diagrammatic form. Examples are given of applet and XML techniques that can make these graphical components interact with the page they are embedded in and also with the server.*

***Keywords**: JavaScript, XML, Jollies*

Introduction

Without simulation, any attempt to describe a dynamic system's behaviour to a student is dry and arid. To bring simulation to life, however, it is necessary to generate an animated visualisation. Many would regard this as the realm of the media graphics professional. As web pages become more sophisticated, however, the tools originally created to add life to advertising material lend themselves readily to move images in response to 'serious' differential equations.

For some years now, the web site www.jollies.com has shown the simple use of JavaScript for animating simulations ranging from Billiards games to Butterfly populations. As new and ever-changing protocols are introduced for web documents, it is necessary to revisit the principles behind the methods and revise the skeleton pages that the teachers can embellish.

This paper is enlivened by contrasting opinions. One author is convinced that a 'fundamentalist' approach will be of the greatest value, where each feature is presented in its simplest embodiment, while the other is a proponent of the latest methodology and eager to take advantage of new features at the expense of a steeper learning curve.

The aim of the paper is to impart enthusiasm in the reader, while giving some helpful steps towards getting started on creating new examples.

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The original Jollies site

Creation of the site was stimulated by a number of needs. Its full title is "Javascript On-Line Learning Interactive Environment for Simulation". An educational site for Victoria schoolchildren (www.GoAmazing.com) was seeking scientific 'novelties' and the butterfly and billiards examples lent eye-catching colour and activity. At a more prosaic level, the simulation aspects for a course in mechatronics were most easily presented in 'jollies' form.

All the relevant code was visible in a code window and could be edited by the student. When a button was clicked, the simulation would run, drawing a graph in an applet, while allowing real-time disturbances to be injected by the student by clicking other buttons.

Applications fell into two categories, although these could readily be combined. In one, the simulation resulted in a drawn graph, as described. In the other, however, the computation variables determined the positions to which objects were moved on the screen, for example the billiard balls.

The 'board' on which graphs are drawn is a simple Java applet that 'instantiates' a powerful library of graphics routines and allows them to be used in JavaScript. So far, the drawing applet has been 'stable' across the platforms of Internet Explorer and Netscape and their evolving versions. The 'moving objects' paradigm has presented problems from the outset.

In Netscape 4, there is a method MoveTo(x, y) that can be used for positioning objects on the screen. Internet Explorer has no such method. Instead the 'properties' style.pixelLeft and style.pixelTop had to be given the desired values. 'Browser sniffing' had to be used to detect which technique would be valid in the user's browser.

To complicate matters, the existence of code for one browser when viewed by the competing browser would cause an error to be flagged and execution would stop. The commands had to be constructed using the 'eval' command, where a text string is treated as software and then executed or 'evaluated'. Unless subjected to the 'eval' command, the alternative code is mere text and therefore safe from the complaints of the rival browser.

To avoid a build-up of conditional code, the choice was contained within a single function MoveLayer defined at the top of the document.

The term 'layer' arose in early versions of Netscape, where page elements could be formatted in a layer similar to that of many graphics packages. This layer could be moved in the ways described above. Microsoft – and perhaps the W3C committee that rules over the definitions of web standards – preferred the tag <DIV> to the tag <LAYER>, so the latter name has remained while the former tag is common to both browsers in old and newer forms.

IE6 has continued to execute the original code with few protests. But a newer version of Netscape, NS 6 and an improved and simplified version NS 7 have moved to the new document object model, with disastrous results for the original code.

A link on the Jollies page leads users of the newer browsers aside to pages that are gradually being brought up to date. These can also be viewed with IE 6 and it is hoped that the platforms will remain stable for some time to come. Do not dare to think, however, that the platforms are in agreement. For IE 6 and NS 7, the same document is likely to be mapped as different 'object trees' and some ingenuity at the page-design stage is needed to avoid pitfalls.

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Visitors to the Jollies site have consistently been in excess of one hundred per week. It must be admitted that many will not have found what they expected from the site name, but half stayed on to browse the examples.

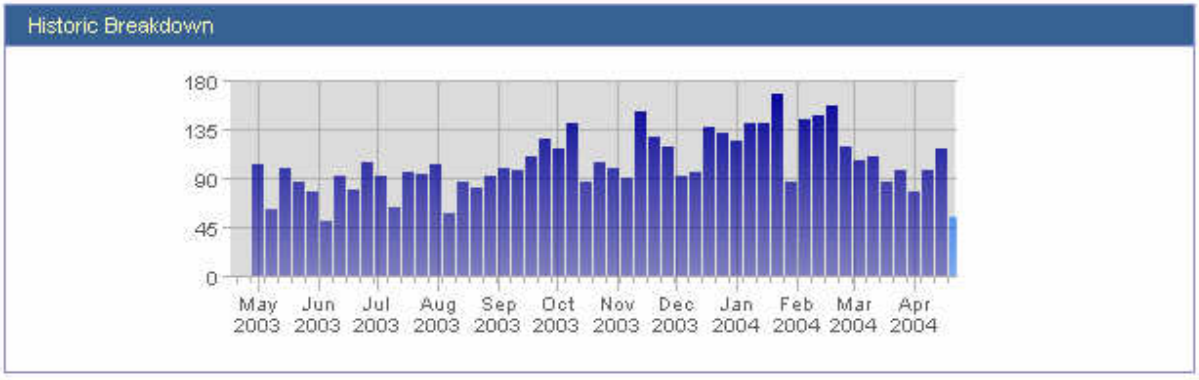


Figure 1. Visitors to www.jollies.com

A Jollies example

There is a vast difference between the requirements of a position controller for industrial purposes and one that will produce a 'pretty' response for a scientific paper. The industrial system has a motor chosen for economy, one that can give sufficient but not excessive acceleration to the load. The motor must almost certainly use full torque to resist a very small disturbance of the load position. Damping, the addition of velocity feedback, is more likely to be determined by its effect in causing the load to start decelerating when halfway to the target than by the placement of poles or zeros in the complex frequency plane.

A simple Jollies example allows the student to verify the authenticity of the nonlinear simulation, 'nothing up my sleeve', while choosing values for the feedback parameters and 'prodding' the load with the aid of disturbance buttons.

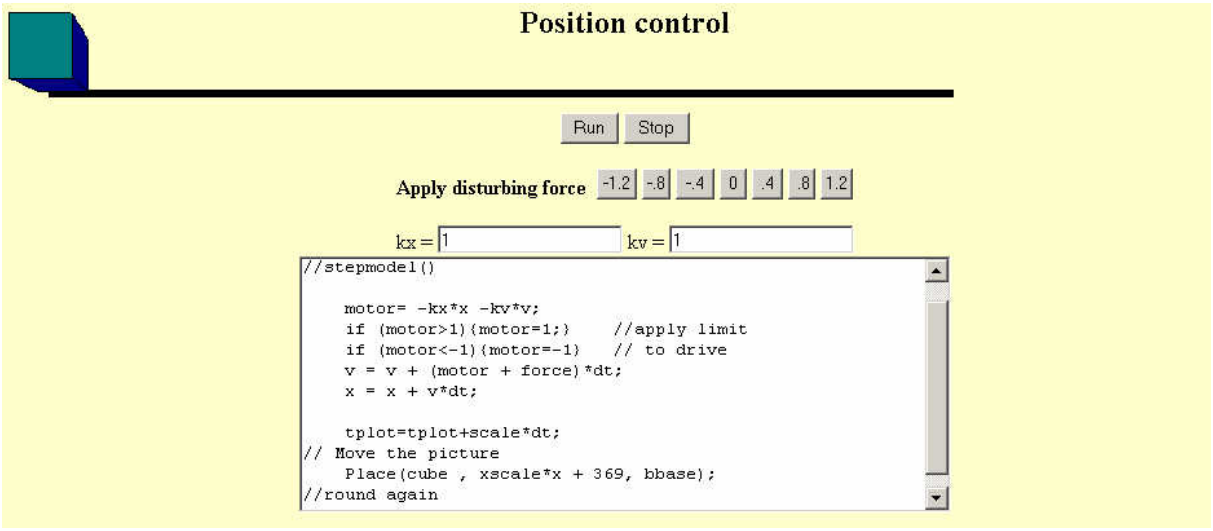


Figure 2. Position control demonstration

Simulation is, of course, equally easy in a package such as Matlab, but it is more difficult to achieve the 'instant response' to user interaction. There is also the small matter of the price tag and the more important matter of availability to the student.

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Embedding Graphical Editing Clients in Web Pages

Simulations are not the only circumstance where it is useful to embed graphical scripted components into web pages. Consider, for example, a web page designed to teach students electronics or mathematics. It may be useful to place some exercises or example problems on the page, and have the students try them online. Traditional HTML forms only provide good support for option selection and text entry, so if the student is required to enter a response in the form of an electronic circuit or a maths equation in mathematical notation, something more is needed – a tutorial client that can allow the student to edit content graphically. Ideally, the editing component should be self-contained so that it can be easily deployed into any web page, scriptable so that other teaching materials on the page or on a server can interact with it, and small so the page does not take too long to download.

One place where graphical editing components like these are used extensively is in the Intelligent Book project. This is a joint project between the University of Cambridge and MIT to develop web-based teaching systems that can use AI techniques to help the student work through exercises, and that can adapt their HTML teaching content to suit individual students. So, for example in the Intelligent Book Circuit Tutor, shown in Figure 2, the student needs to be able to edit the electronic circuit in the browser. In the Maths Tutor, the student must be given the means to build maths expressions. In both cases, the editing component has to fit into a web page so that it can be included in other HTML teaching materials, and it has to be possible for the teaching server to edit and correct the student's work co-operatively in the component. Although it is not obvious in the black and white screenshot, the Circuit Tutor is highlighting relevant parts of the circuit in colour in Figure 3.

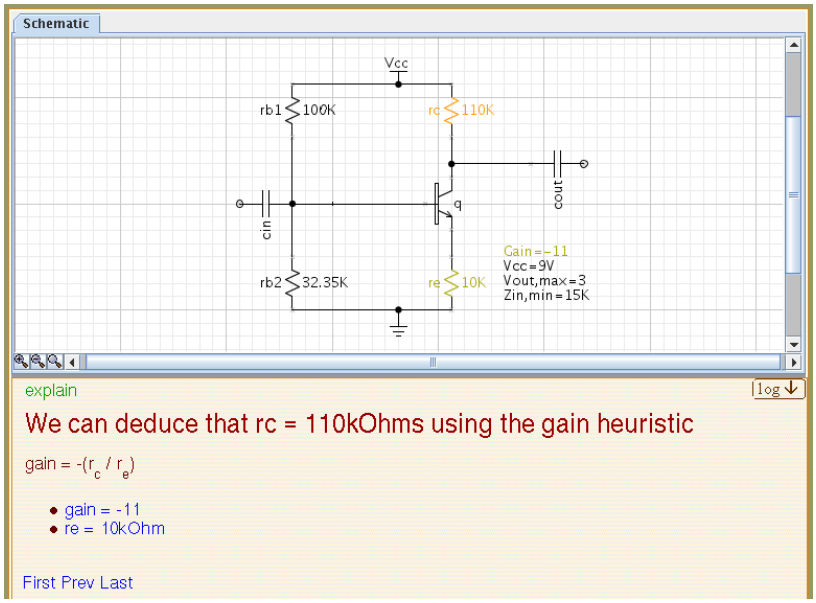
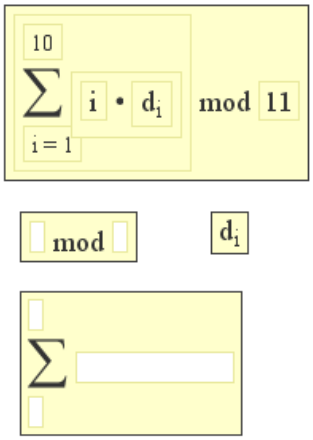


Figure 3: A screenshot of the Intelligent Book Circuit Tutor explaining one of its deductions

It would be possible to use the Jollies JavaScript techniques to build a graphical editor. However, these techniques tend to involve altering the shapes in the diagram on screen directly in a low level way. For tutorial clients where the interaction is more extensive or more complicated, it can be worthwhile adding an extra layer of abstraction and defining an XML format that just represents the data you are really interested in: the current state of the simulation or the answer the student is putting together in the tutorial client. This is the approach taken by the Intelligent Book tutors. Small Java applets are used to render this XML on the screen, deal with mouse interaction, and present scriptable APIs so that other

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applets or JavaScript on the page can interact with them. A screenshot of some maths tiles from the Maths Tutor's editing applet, and the XML of those tiles, is shown in Figure 4.




```
<tileSet name="tileSetOne">
 <tile x="20" y="20" name="mod" definition="mod">
  <socket name="first">
   <tile name="sum_1" definition="sum">
    <socket name="socket_top"><tile name="10" definition="10_sm" /></socket>
    <socket name="socket_bottom"><tile name="i1" definition="i=1_sm"/></socket>
    <socket name="to_sum">
     <tile name="dot_1" definition="dot" >
      <socket name="first"><tile name="i_1" definition="i" /></socket>
      <socket name="second"><tile name="di_1" definition="di" /></socket>
     </tile>
    </socket>
   </tile>
  </socket>
  <socket name="second"><tile x="0" y="0" name="11" definition="11" /></socket>
 </tile>

 <tile x="30" y="150" name="mod_2" definition="mod">
  <socket name="first" /><socket name="second" />
 </tile>
 <tile x="150" y="150" name="di_2" definition="di" />
 <tile x="30" y="200" name="sum_2" definition="sum">
  <socket name="to_sum" /><socket name="socket_top" />
  <socket name="socket_bottom" />
 </tile>
</tileSet>
```

Figure 4: A set of maths tiles in the maths editing applet, and the XML that describes them. Separate XML (not shown) defines the text, symbols, and sockets of each kind of tile.

Graphical Editing Applet APIs: DOM and SCFX

DOM, the Document Object Model (World Wide Web Consortium, 2004), is the W3C's standard set of interfaces for making alterations to an XML or HTML document when it has been loaded and parsed into a data tree in a program's memory. In DOM, the document is represented as a tree of nodes that matches the XML or HTML tree. Each node publishes functions that allow you to navigate to its children, parents, or siblings, and other functions that can be used to make changes to the node itself. So, an obvious argument could be made that since this is the standard API for the HTML in the browser, it should also be the standard API that the graphical content applets present.

However, this is not a very convenient API to call remotely, say from a tutorial server. Separate methods are provided for navigating from node to node, and for making changes to nodes. Suppose in the Maths Tutor, the tutorial server wishes to change all the colours of all the tiles in the maths editing applet to blue. Using DOM, the server would have to make a number of calls to the applet to step through the document to get a reference to each tile node, and then a number more calls to make the change on each tile node. This could be a dozen or more calls. What is really wanted is a way that the server can make a single call to the client to change all of the nodes at once.

SCFX (Simple Change Format for XML) is an API designed for the Intelligent Book project that answers this need. It is based around describing a change to make to an XML document in a single call. The methods in this interface are shown in Figure 5. The SCFX call to turn all the tiles blue is shown in Figure 6. SCFX is based on XPaths (World Wide Web Consortium, 1999), a standard way of representing a "path" to a set of document elements as

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a string. As can be seen from Figure 5, XPaths look a little like UNIX or Windows directory pathnames, but they can also contain conditionals and can resolve to a set of nodes rather than just one node. In SCFX, the change is made to every node the XPath resolves to.

```
public void addXmlFragment(String xpath, String xml, int childIndex)
public void moveSubTree(String xpathA, String xpathB, int childIndex)
public void removeSingle(String xpath)
public void removeSubTree(String xpath)
public void replaceSingle(String xpath, String xml)
public void replaceSubTree(String xpath, String xml)
public void setAttribute(String xpath, String attrName, String value)
public vod setValue(String xpath, String value)
```

Figure 5: The SCFX API Functions

```
setAttribute("tileSet[@name='tileSetOne']/tile", "colour", "0000FF");
```

Figure 6: The SCFX call to change all the colour attributes of all the tiles in tileSetOne to blue.

Because SCFX each SCFX call maps to an obvious set of DOM calls, and since the Java Runtime Environment provides built-in support for both XPaths and DOM for XML documents, the code that implements SCFX is small and easily reusable. It is essentially a set of convenience methods for DOM.

It would also be possible to create a small applet that provides an SCFX interface to the HTML DOM of the web browser, so that the APIs of the graphical content applets and the web page itself would be the same. In practice, though, small differences between browsers and the components they use to connect to Java can make this tricky to get working reliably across all browsers with a very generic API like SCFX. The "Common DOM API" (Sun Microsystems 2004) in Java 2 version 5.0 is intended to standardise access to the browser's DOM from Java, but does not yet support every browser. For the moment if wide cross-browser support is needed, it is still easier to have the tutorial applets call JavaScript functions on the page to make more specific updates to the HTML.

Rendering Custom XML Diagram Formats using Behaviour Factories

The XML data describes the state of the maths applet, what maths tiles are on the canvas and how they are connected, but it does not describe anything about how that data behaves once it is loaded into the applet. It is a representation of the data object's fields without any information on those object's methods and implementation. At some point during the loading process, the object methods need to be reunited with the data. The maths tiles need to be able to appear as components on the screen and interact with the student.

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The usual way of doing this is for the applet to have its own set of classes to represent the data, and for those classes to implement the DOM interfaces to provide a consistent API for the outside world. The XML is parsed and the correct custom classes are instantiated. But implementing this would be arduous. Not only would you have to implement the behaviour you want for your classes, but you would also have to write implementations of the DOM interfaces, and subclass the XML parser so that it would correctly instantiate your classes rather than its own default classes. The Maths Tutor applet uses a different method which only requires writing the application-specific behaviour.

At load time, the XML is parsed into a DOM tree using only the parser that is built into the Java Runtime Environment. This creates a generic document tree with no specific behaviour. This tree is passed to a behaviour factory, which runs through it and creates a Java behaviour object for each element in the tree, and attaches it to the DOM node as "user data". A picture of this is shown in Figure 7. The behaviour objects are the graphical appearance of the tiles on the screen – UI components which can be dragged around on the screen and keep their on screen appearance in sync with their data in the DOM tree.

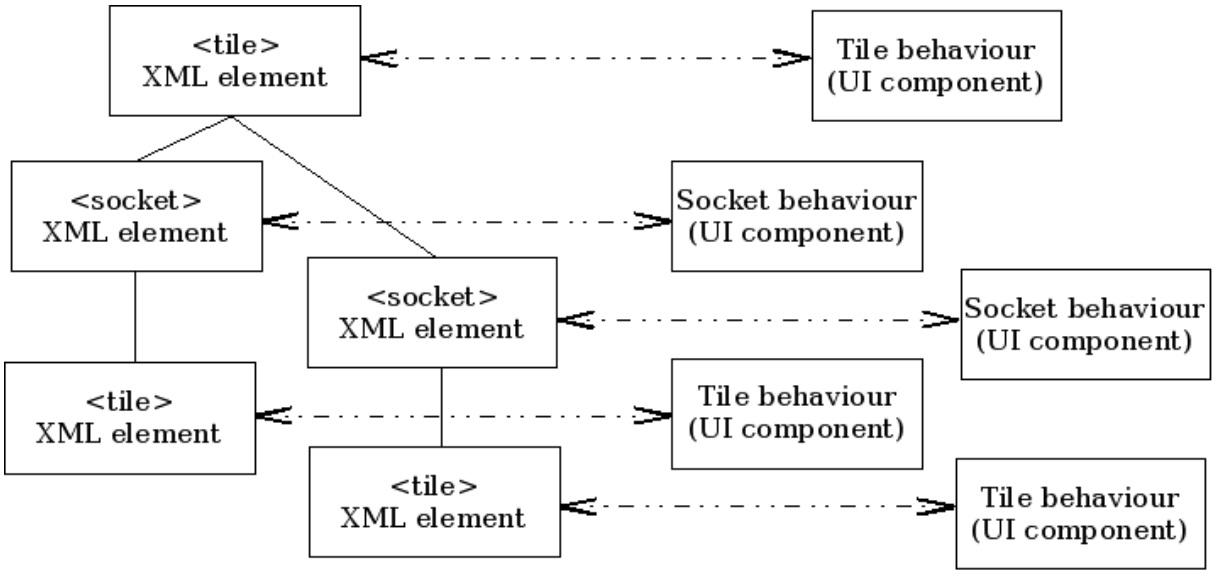


Figure 7: The XML elements in the DOM tree are linked to custom behaviour objects, which display the elements on the screen.

Using this method does mean that the tiles' fields and methods are split across two classes, but this fits in quite well with the Model View Controller design pattern that is often used for building user interfaces. The DOM tree is the data model, the behaviour objects are the view (UI components which reflect and update that data model), and a UI controller co-ordinates interactions between the user and the UI components.

To make matters simpler, in the maths applet the behaviour objects use Swing, a rendering and GUI framework that is built into the Java Runtime Environment.

A Limitation With Events

A limitation comes with notifying the UI when a change has been made to the document using the DOM interfaces. DOM Level 3 (the version of DOM that the latest Java version supports) does allow a “user data handler” to be attached to nodes in the document. These handlers are notified whenever certain changes are made to the node, so that the application can make any internal updates it needs to. Unfortunately though, the handlers are only

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notified for renames, imports and deletes, and not for simple things like an update to a data value. So the problem remains that a DOM call could turn a Maths tile blue in the document tree, but since no application object would be notified of this change, the tile would not turn blue on the screen until the next time the user manipulated that tile.

Fortunately, in the Maths Tutor this is not very limiting at all. As discussed earlier, SCFX (or another small wrapper interface) is a more appropriate interface than DOM for tutorial clients to expose to their servers and to other components on the page. The implementation of SCFX uses the DOM interfaces internally, making it small and simple, but implementing it also allows us to add a call to refresh the client display whenever a change is made via the SCFX API.

DomEditor Package

The basic structure of the maths applet is made available as an abstract package called DomEditor. This includes the set of classes that provide the basic framework for a GUI that makes live updates to an XML document and provides SCFX support. All that needs to be added is the factory to decide which behaviour object to create based on the current XML element, the controller which defines how the user can interact with the elements, and the behaviour objects themselves.

In terms of size, the JAR file for the current version of the maths applet weighs in at approximately 100kB, small enough for use by students over the slowest web connections.

Putting Stateful Java Applets and HTML Forms on the Same Page

In basic usage, HTML forms work by the user clicking ‘submit’ on the form, data being sent to the server, and a new page being sent in response. If a Java applet with a lot of state information occupies the same page as the form, this can be problematic. Even if the new page also contains the applet, the applet will still need to set up its state again because the page load will have reinitialised the applet. Even if that state data is kept in a cookie on the client, the reinitialisation process could make the applet seem slow and unresponsive. If a stateful applet and changeable HTML are on the same page, it seems better to change the HTML dynamically.

There are a number of common ways the HTML can be changed using only JavaScript. However, if the graphical editing applet is already communicating with the server, it may be cleaner to use Java for this communication with the server also. A Java applet can be called by the HTML form to perform the submit and receive the response from the server. The applet can then update the HTML dynamically using the DOM and other browser methods, either via the Common DOM API (Sun Microsystems 2004) or by calling into JavaScript functions using LiveConnect (Netscape 1998).

Conclusions

Whether the task of interacting with the student is approached from the simplistic direction, using JavaScript alone, or whether it employs more sophisticated concepts, there are remarkable advances that can be made with a relatively modest investment in infrastructure and author training.

The convergence between professional and games application of computers has seen the latter stimulating the greatest advances in computing power and speed. Development of the Internet is responding to the needs of a vast market of ‘surfers’ who demand dynamic

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entertainment. This has a comparable result in advances that can be of inestimable use for educational purposes.

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Use of an interactive computer-based instruction package to teach water quality modelling

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Abstract: *This paper explores an innovative teaching module to introduce inexperienced final year engineering students to water quality modelling as part of a core subject. The water quality teaching module consisted of an interactive computer-based instruction (CBI) package in assisting students to set up and run a commercially available water quality computer model (WQMAP) for a hypothetical raw sewage spill. The CBI package comprised of numerous HTML pages with links to on-screen recorded Lotus ScreenCam movie clips. A formal class survey was undertaken which showed the teaching module was highly beneficial.*

Keywords: modelling, simulations, computer-based instruction

Introduction

The use of computers in undergraduate education is now widespread, both in the form of computer-based learning (CBL) or in the use of generic software tools in support of students' research, writing and presentation activities (Dewhurst et al., 2000). CBL learning has a number of potential advantages over more traditional methods of teaching: it may promote independent learning, give students some control over when and where they learn and the pace of their learning, and ensure quality and consistency of delivery. If it can be demonstrated that CBL can replace conventional teaching methods and achieve similar objectives then it may also save staff time (Dewhurst and Williams 1998). The purpose of the study reported here was to develop a practical and effective teaching strategy to give students an introduction and basic training in water quality modelling as part of a final year core subject. This would not only improve students understanding of water quality through the engagement of specialized software, but expose them to issues faced in the actual workplace environment.

A paper by Zigic & Lemckert (2001) first described the water quality modelling activity and the teaching module used to educate inexperienced undergraduate students in using and understanding a commercial water quality model. An informal class survey had found that the combination of the module and water quality model itself was a valid and worthwhile teaching and learning strategy, to assist in introducing water quality modelling to undergraduate engineering students with minimal supervision and at a pace that they can

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control. The following paper is an extension on that work, and presents results of a formal class survey to gauge the students perceptions of the activity.

Methodology

The water quality modelling activity was first introduced in Semester II, 2000, as part of a final year core course, Water and Wastewater Engineering, offered within the Griffith University Bachelor of Engineering in Civil Engineering degree (Gold Coast Campus). The course aimed to introduce civil engineering students to important concepts relating to water and wastewater (Lemckert 1999). Therefore, a computer-based water quality modelling activity was introduced to complement the theory-based component.

The water quality modelling activity began with a two hour lecture that was delivered in Week 7 of semester II. The lecture covered the basic concepts and principle of water quality modelling, a brief overview of the actual water quality software, how to use the teaching aids, and the expected outcomes as part of the activity requirements. Over the following three weeks, only 1-hour computing sessions were scheduled with an instructor. For the next 4 weeks of the semester the students continued working through the project unsupervised. As part of the activity assessment the students were required to submit a written assignment at the completion of the activity. The learning outcomes expressed for the activity were practical: (1) set up and run a commercial water quality model (WQMAP) for a hypothetical sewer overflow with minimal supervision and at a pace that the students could control; (2) interpret and report the model results as a professional document.

Application

In this study, the students were required to examine the implications of a hypothetical overflow of untreated wastewater from a nearby pump station into the Nerang River estuary, Gold Coast, Queensland, Australia, following a major rainfall event. The assignment brief supplied enough information for the students to carry out water quality modelling of the spill event, including:

1. *Time and date of the spill;*
2. *Location of the spill;*
3. *Volume of untreated sewage; and*
4. *Analysis of the e-coli counts on day-1 and day-3 of the spill.*

The students were also supplied with a tested model grid of the Nerang River estuary.

Specifically, the students were required to run the hydrodynamic model to generate reliable currents through the estuary for a five-day period. This required the student to create a new simulation to produce a current (velocity) file, using the relevant data inputs i.e. linking of wind, ocean forcing and river flow information to drive the model and adding time series points to observe and compare the water elevations and speed along the estuary.

Once the current file had been created, the students used it as input into the mass transport model to predict the distance and decay of the faecal coliform levels in the receiving waters.

The students than had to write a detailed report using the various output options from each of the models, in the form of figures and graphs. As well as, provide an estimate of the anticipated length of time before receiving waters would be safe for primary (swimming,

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fishing) and secondary (boating) contact based on ANZECC (Australian & New Zealand Environment & Conservation Committee) water quality guidelines.

Water Quality Model

The water quality modelling was carried out using the commercially available software, WQMAP (Water Quality Mapping Analysis Package), developed by Applied Science Associates, Inc. It is the latest in decision-support technology and uses information technology to combine hydrodynamic and pollutant transport models with GIS (Geographical Information System) and data management tools (Howlett et al., 1996). Thus, the WQMAP program combines modelling and mapping capabilities through an intuitive graphical user interface that runs under Microsoft Windows™. Also WQMAP drag-and-drop environment allowing the students to setup, run and play simulations without needing any programming experience or formal training. Figure 1 shows a snapshot of the WQMAP interface.

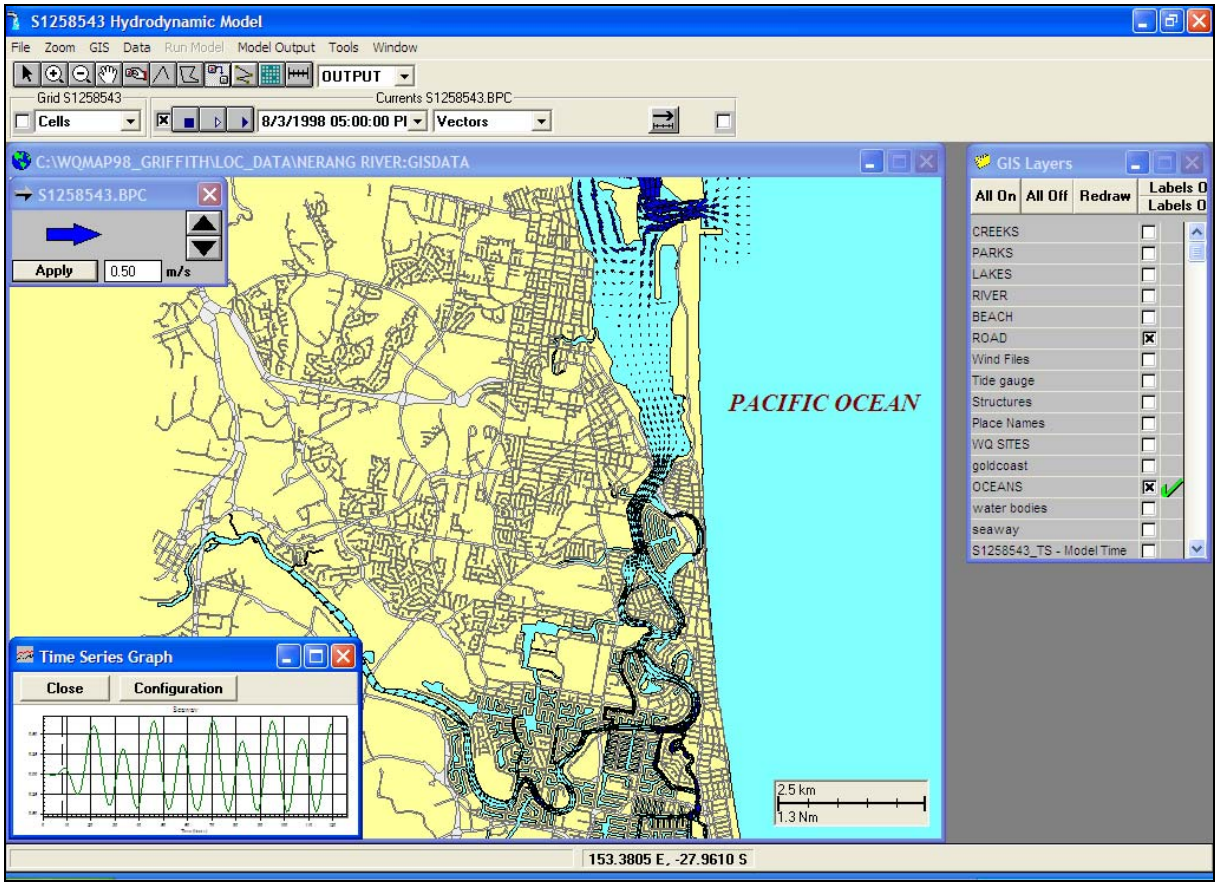


Figure 1: A snapshot of the water quality model (WQMAP) interface.

Although, WQMAP includes a detailed manual and example applications for an estuary in the United States, the authors' belief was that using only these resources to become familiar with and setting up the water quality model would be too time-consuming and allow room for error and confusion. To this end, the authors' specifically developed a focused water quality teaching module for the local environment.

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Water Quality Teaching Module

The teaching module was presented in the form of an interactive computer-based instruction package. The module consisted of 43 HTML pages, with a step-by-step guide on how to set up and run a water quality simulation using the WQMAP system, with necessary basic background information to the aspects of water quality modelling.

Once the program is initiated, the first HTML page appears welcoming the students and explaining how to use the CBI. The students are then capable of working through the module by clicking on the links located on each of the HTML pages, describing the hypothetical spill event, objectives the assigned activity, a description of the water quality model, and a step-by-step guide to running the hydrodynamic and mass transport models. Each page contains text and pictures of various form cards and typical model output. The level of information was intentionally kept to a minimum and relatively basic, since the activity was only intended as an introduction to water quality modelling and its potential uses and benefits. At any time the student is able to go forwards or backwards through the module. Each HTML page includes either links or buttons to direct the student to the next, previous or home page. The pages were progressively ordered to restrict the students from skipping relevant pages and steps, thus missing important information. Figure 2 shows the opening hydrodynamic HTML page.

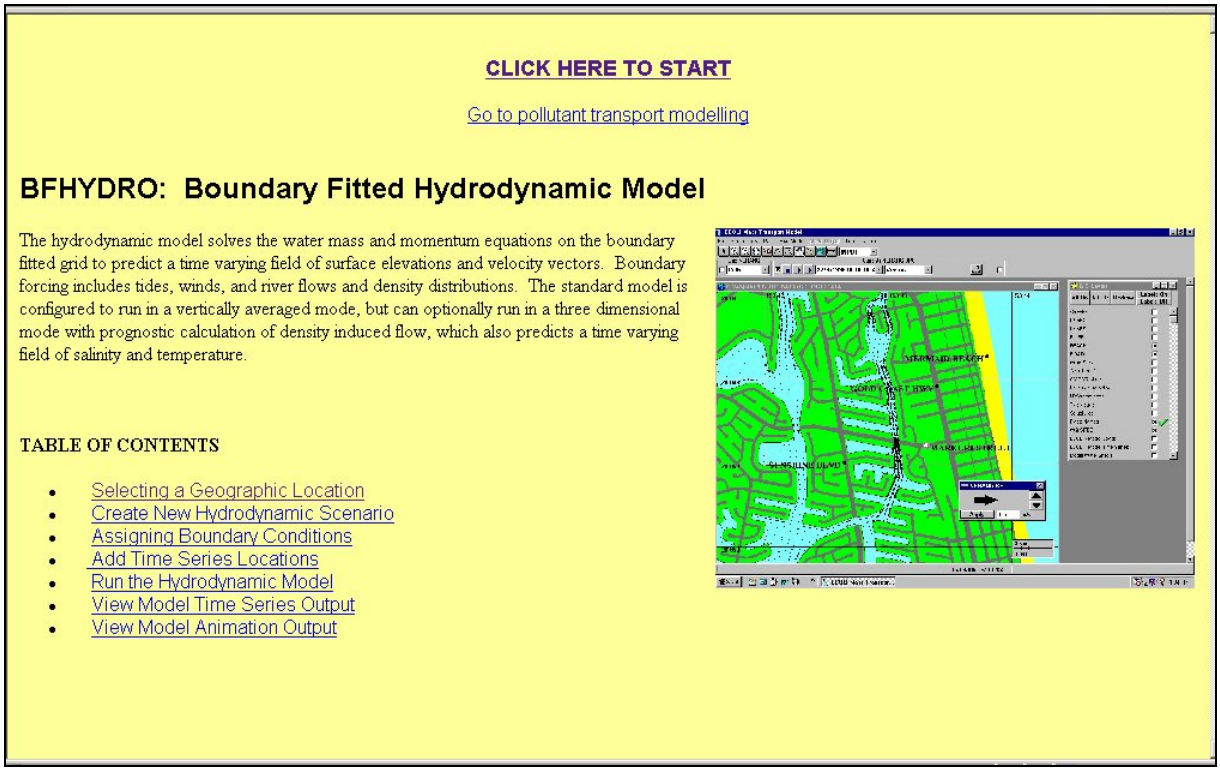


Figure 2: Opening hydrodynamic HTML page and the various links incorporated as part of the water quality teaching module.

The hydrodynamic and mass transport modelling components were split into simple step-by-step instructions aimed at supplying the students with sufficient information to learn about some aspects of water quality modelling and to complete the prescribed task. Linked to particular HTML pages were pre-recorded Lotus ScreenCam movie clips. By clicking on the ScreenCam icon on the HTML pages, the students are able to see all mouse pointer movements and on-screen actions, as well as listen to the voice over narrations as

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demonstrated by the instructor to successfully run the water quality model (Zigic and Lemckert 2001).

This allowed the students to watch and listen to the clips without the presence of the instructor and at any time stop, play, rewind or pause, allowing them to toggle to the model and apply the directions learnt. Figure 3 shows an example of the Screen cam movie clip to set-up the hydrodynamic run card. Note the Screen cam play-back icons and status are shown in the bottom right corner.

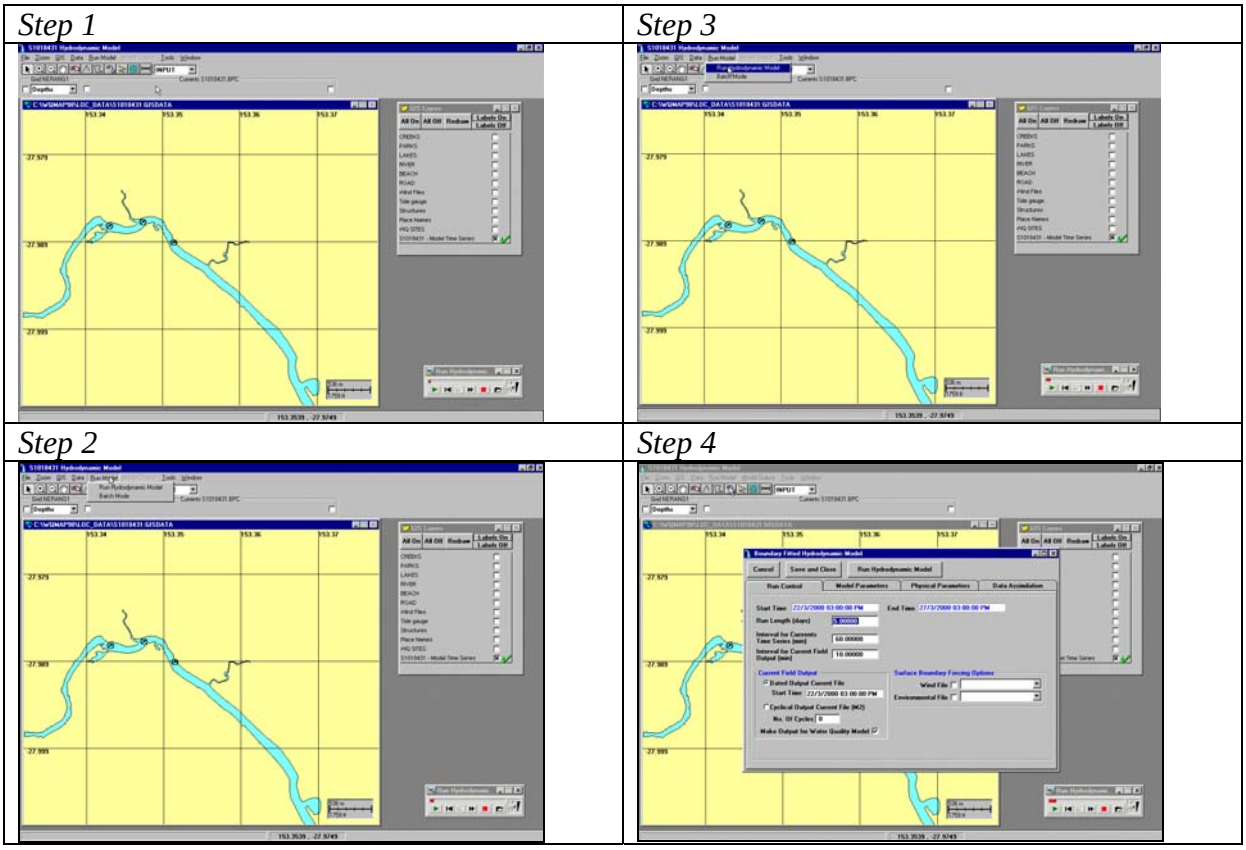


Figure 3: An example of the Lotus ScreenCam recorded movie clip showing the sequence of on-screen events to set-up the hydrodynamic run card.

Results

Nearing the completion of the activity, students were asked to complete an anonymous questionnaire designed to gain details on student perceptions of the teaching/learning strategy. The questionnaire consisted of two components. The first part addressed specific aspects of the general issues and the trainers/students overall effectiveness (refer to Table 1), whilst, the second part addressed the teaching module (Table 2). The activity itself was taken by 29 students with 21 completing the evaluation sheet. The students were asked to rate various statements on a “Strongly agree” to “Strongly disagree” scale. The survey questions are presented in Tables 1 & 2. The results of the survey are presented in Figures 4 & 5 following Hussman and Smaill (2003) methodology.

Overall, the survey results were very encouraging. With regards to the general issues and trainers/students overall effectiveness, 76.2% and 71.4% agreed or strongly agreed that the project objectives and deliverables were clear, respectfully. The majority (95.2%) of the

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students felt that they now have a basic understanding of water quality modelling. While 61.9% agreed that there was enough time with the instructor, the same percentage agreed that they were able to complete the project with minimum supervision.

With regards to the water quality module, 95.2% of students strongly agreed or agreed that the html was helpful and easy to follow. Finally, all (100%) of the students agreed that the ScreenCam on-screen demonstrations and voice narrations made it simple for the students to setup and run the water quality model. From observations made during the classes, and from the final reports, it was clear that the students certainly learnt from the experience and at a level beyond that would have been achieved through formal lectures. While a control group was not used (due to equity reasons) it was felt (and shown in the results) that the developed teaching module had learning benefits that warrant its further use and expansion into other areas.

Questions
(1). The objectives of the project were clear
(2). The project deliverable's were clear
(3). It was helpful having a instructor present
(4). There was enough time with the trainer
(5). I was able to complete the project with minimal supervision
(6). I have a basic understanding of water quality modelling
(7). The trainer was more useful than the html package

Table 1: Final survey questions which address general issues and the trainers/students overall effectiveness.

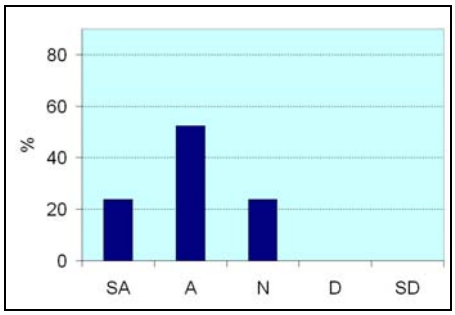
Questions
(1). The html module was helpful
(2). The html module was easy to follow
(3). The content was basic enough for me to follow without getting to confused
(4). The screen cam recordings were helpful
(5). The on screen demonstrations made the project easier
(6). The voice narration was more useful than the on-screen demonstration
(7). The combination of the on-screen demonstrations and voice narrations made it simple to follow

Table 2: Final survey questions which address specific aspects of the teaching module

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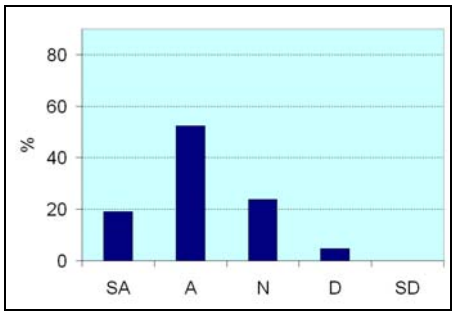
Q1

SA=23.8
A=52.4
N=23.8
D=0
SD=0



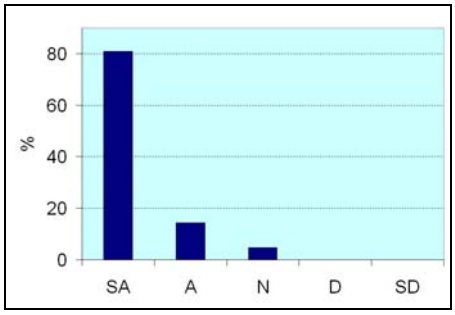
Q2

SA=19.0
A=52.4
N=23.8
D=4.8
SD=0



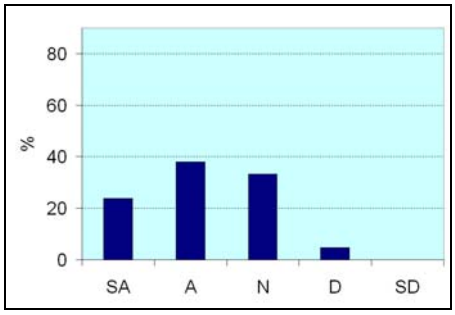
Q3

SA=81.0
A=14.3
N=4.8
D=0
SD=0



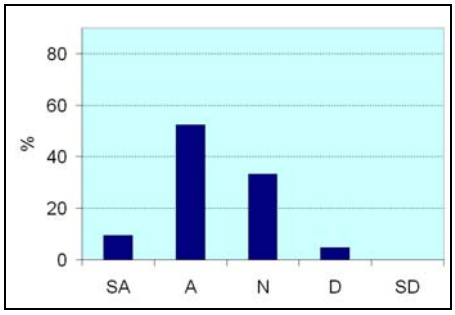
Q4

SA=23.8
A=38.1
N=33.3
D=4.8
SD=0



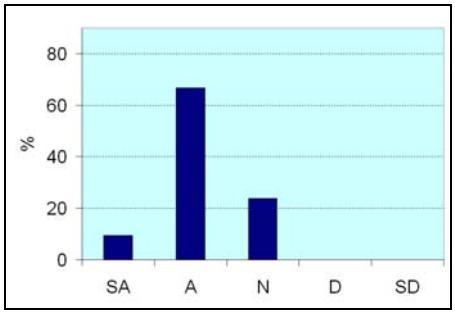
Q5

SA=9.5
A=52.4
N=33.3
D=4.8
SD=0



Q6

SA=9.5
A=66.7
N=23.8
D=0
SD=0



Q7

SA=28.6
A=23.8
N=38.1
D=9.5
SD=0

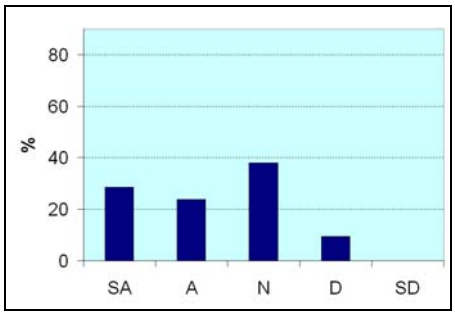


Figure 4: Results of the students feedback on the general issues and the trainers/students overall effectiveness. Note the abbreviations used are: SA: Strongly Agree; A: Agree; N: Neutral; D: Disagree; SD: Strongly Disagree.

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Q1

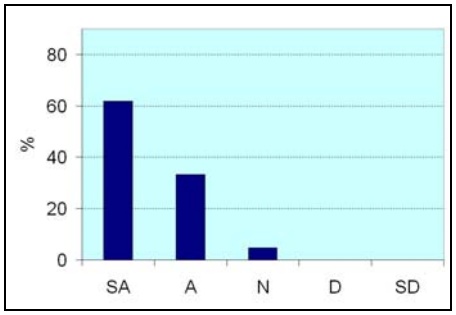
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A=33.3

N=4.8

D=0

SD=0



Q2

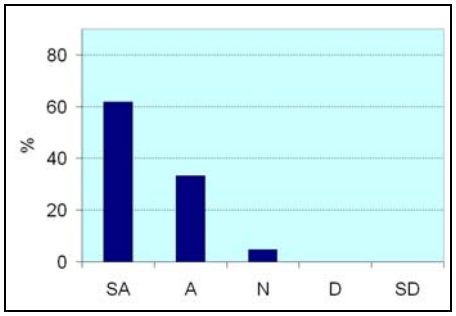
SA=61.0

A=33.3

N=4.8

D0

SD=0



Q3

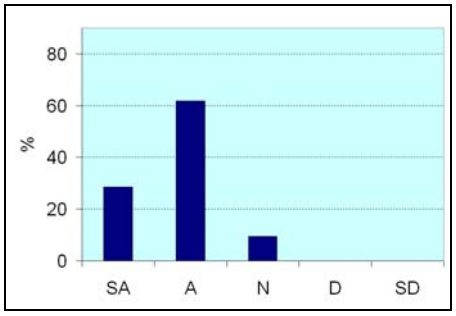
SA=28.6

A=61.9

A=9.5

D=0

SD=0



Q4

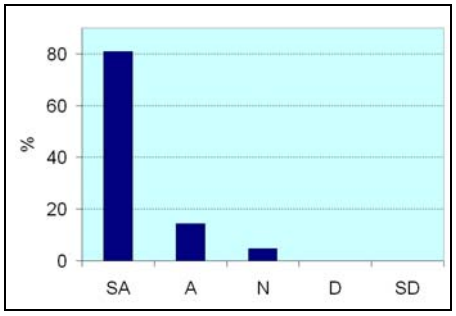
SA=81.0

A=14.3

N=4.8

D=0

SD=0



Q5

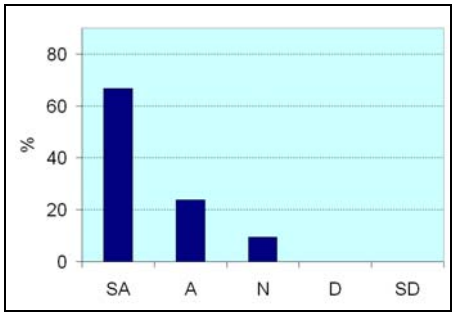
SA=66.7

A=23.8

N=9.5

D=0

SD=0



Q6

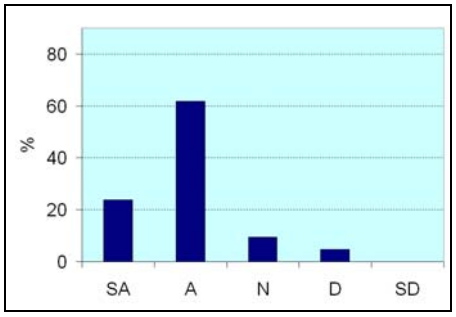
SA=23.8

A=61.9

N=9.5

D=4.8

SD=0



Q7

SA=57.1

A=42.9

N=0

D=0

SD=0

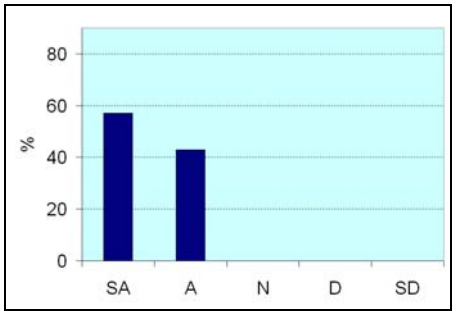


Figure 5: Results of the students feedback on the specific aspects on the teaching module. Note the abbreviations used are: SA: Strongly Agree; A: Agree; N: Neutral; D: Disagree; SD: Strongly Disagree.

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Conclusion

This paper looked at the use of an interactive computer-based instruction package to teach water quality modelling. The formal class survey verified that the teaching module was received well by the students and was highly beneficial to completing the assigned tasks at their own pace and with minimum supervision. Thus, proving that teaching module developed is a very useful tool in teaching aspects of water quality modelling. The students' feedback will be further analysed to find ways of improving the activity and the water quality teaching module.

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