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A Liberal Approach to Teaching Advanced Engineering Courses

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In this article, the authors elaborate on observations made and experiences gained from adopting a liberal approach to teaching advanced engineering courses offered either as electives to final year undergraduate students or as core in postgraduate coursework programmes at the University of South Australia (UniSA), Adelaide, Australia. The courses are aimed at giving students competences in applying advanced concepts to the solution of widely ranging engineering problems. The emphasis is on harnessing the creative potential of students in developing skills in a supportive environment that fosters interest, motivation and initiative. A number of such courses is delivered in intensive mode, during which a mixture of structured and non-structured tasks are tackled. This is followed by a period during which each student undertakes an advanced project.

INTRODUCTION

Much has been debated in recent times about the merits of a more liberal approach to education as opposed to a rigidly structured curriculum. Liberalism in this context has implied – among other things – shifting at least some of the responsibility for student's learning onto the student. This shift is made manifest by concepts like student-centred learning, project-based assessment and Problem-Based Learning (PBL), all of which emphasise the importance of experiential learning. These concepts have been further embellished with inclusiveness in curriculum design that recognises various learning skills and preferred modes of assessment, acknowledging the importance of experiential learning and student evaluation of teaching.

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The University of South Australia (UniSA), Adelaide, Australia, has embraced the notion of student-centred learning, characteristics of which are elucidated to be as follows:

- *Providing choices for students in relation to where, when and how they study;*
- *Fostering learning rather than teaching;*
- *Encouraging student responsibility and activity rather than teacher control and content delivery;*
- *Developing mutuality and interdependence in the teacher-learner relationship;*
- *Emphasising learning that is context-specific in which students build their own new understandings and skills through engagement with authentic problems based on* real world *experiences;*
- *Emphasising the need for expertise in the facilitation of learning: the role of learning expert to complement the role of subject expert;*
- *Responding to student evaluation to achieve continuous quality improvement* [1].

The School of Electrical and Information Engineering (EIE) at the UniSA has adopted a *liberal* approach in a number of advanced engineering courses with a specific focus on PBL, based on the notion of student-centred learning.

Liberal in this context signifies an approach that is designed to broaden the student's mind, be tolerant to differences in the learning styles of the individuals, and promotes creativity and entrepreneurship by providing a learning environment that is conducive to such.

PEDAGOGICAL CONSIDERATIONS

One of the most enduring models in education in the last half of the 20th Century has been what has come to be known as Bloom's Taxonomy [2]. It has been widely used to classify forms and levels of learning, as well as a planning tool, and continues to be one of the most universally applied models in education.

Table 1 lists the major tenets of Bloom's taxonomy (left column) comparing it with the more recent rendering of the same process by Anderson and Krathwohl [2]. In both cases, the progression of skills gained in the cognitive domain as educational outcomes proceeds from the basic general concepts to high level skills as indicated by the arrows.

At the risk of oversimplifying the underlying notions, Table 1 can be said to re-emphasise the common wisdom expressed in the words: *Give a man a fish and he eats for a day; teach him to fish and he eats forever*.

Bloom's Taxonomy and variations thereof have provided the inspiration for the development of the courses described in this article. The salient features are the student-centred approach, with the student assuming a major responsibility for the student's own learning and the challenge of solving problems, alluded to at the apex of the learning pyramid in the Anderson-Krathwohl model (see Table 1) [2].

Table 1: Bloom's Taxonomy contrasted with the Anderson-Krathwohl model.

Bloom's Taxonomy [1]	Anderson-Krathwohl Model [2]
Knowledge↓	Remember↓
Comprehension↓	Understand↓
Application↓	Apply↓
Analysis↓	Analyse↓
Synthesis↓	Evaluate↓
Evaluation	Create

FACTORS AFFECTING TEACHING AND LEARNING

A host of factors affect the processes of teaching and learning. Such factors include the individual's background, attributes and attitudes, as well as the mode of teaching that has been adopted. Within the Australian context, with the high influx of international students from non-English speaking background (NESB) concerns have been expressed as to how effective a learner, a student, can be if the mastery of the language is defective.

Some have even *seen and labelled as* rote *learners,* or as *otherwise lacking in appropriate study skills* the international students from south-east Asia studying at Australian universities. Such statements can best be described as unsubstantiated, as observation shows that *when teaching is aimed at actively engaging students in their learning, differences (such as* passivity*) between international and local students largely disappear* [3].

There is no denying that the internationalisation of education is proceeding at an unprecedented rate. Almost 25% of all students enrolled in Australian universities in 2004 were international students [4]. The School of Electrical and Information Engineering (EIE) at the UniSA has experienced a rapid increase in the number of international students at all levels (see Figure 1).

In Australia, a high percentage of university teachers are also from a non-English speaking background, whose English language skills may cause concerns to students whose native tongue is English. This could be construed as a handicap. But, combined with the substantial cohort of international students, it also presents a wonderful opportunity for rich experiences – both educational and cultural – at an international university where skills are acquired and positive attitudes are formed that make these graduates eminently qualified for work in a global environment. Being able to comprehend the countless variations in accent is undoubtedly an advantage, which also promotes tolerance and cooperation. The UniSA recognises the importance of having an international perspective by declaring it to be one of the seven graduate qualities it seeks to foster [5].

Cultural factors also play a role in teaching and learning. In some cultures, students are taught to learn by rote, which does not adequately equip the learner with the attributes of an effective problem-solver but, as stated before, this can be effectively addressed [3]. Another cultural factor is the notion that the *teacher is always right*. This statement can be again challenged as, for example in Japan, where one expects this to be

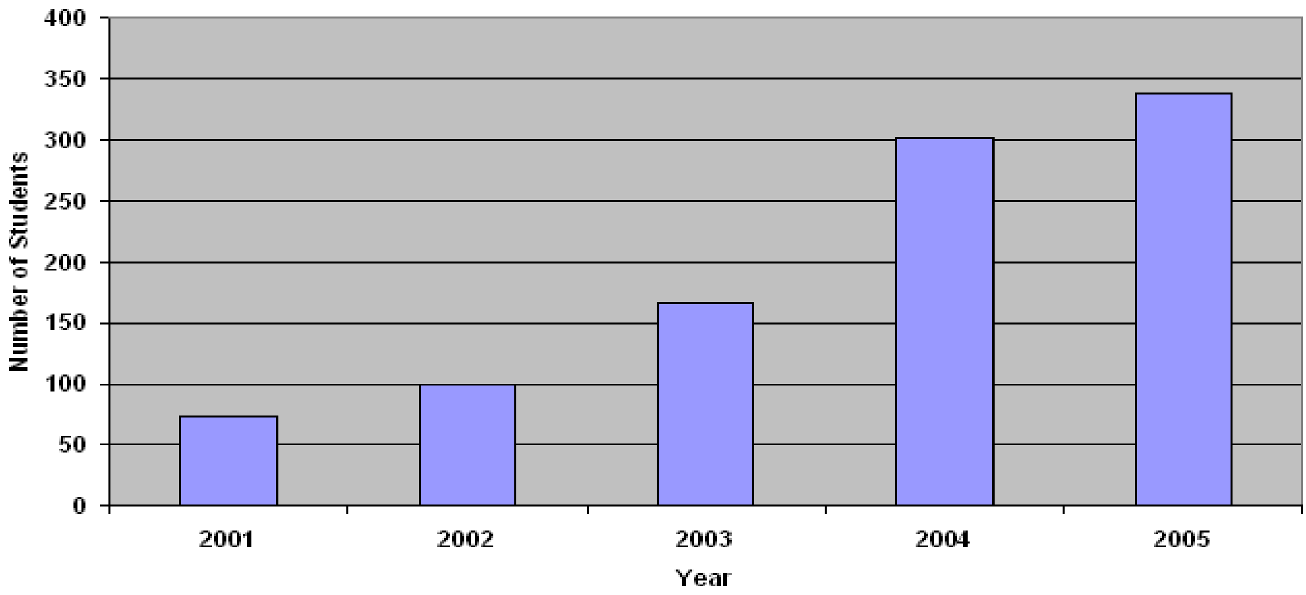

Figure 1: International students in EIE.

true, students are often quite active in the classroom debates with lecturers. Also, Japanese professors frequently and willingly assume a role of learner if they participate in a lecture or seminar conducted by others. Nevertheless, these cultural issues may be inhibitive factors when it comes to exploration, inquiry and deep learning.

Then there is the host of individual learning styles that affect study. The cohort of students at any time may comprise *active and reflective* learners, *sensing and intuitive* learners, *visual and verbal learners* as well as *sequential and global learners* [6]. *Surface learning* vis-à-vis *deep learning* constitutes another important factor affecting both the expediency and the efficiency of the learning outcomes [7].

COURSE STRUCTURES

Courses in engineering education at all levels need to be structured taking the above factors into account if effective teaching and learning is to be accomplished with lasting impact. In doing so, a course designer must have a clear picture of the aims and objectives of the course what graduate qualities the course is to reinforce and nurture. It is the authors' collective considered opinion that a student-centred and problem-based approach is far superior to the traditional monologue style lecture delivery via *chalk and talk*. Project work needs to be included if the knowledge acquired is to become *applied knowledge*, leading to the demonstration of competence in problem-solving.

The curriculum needs to be inclusive, making allowance for differences in background, culture and learning styles. It must offer challenges and rewards. The course must create opportunities for students to work on their own, as well as in groups. The authors next give some examples of courses that have been designed and successfully implemented at the UniSA.

Virtual Instrumentation Programming

Virtual Instrumentation Programming is a core course in the Master of Engineering programme in Electrical Power Engineering, which is also offered as an elective to postgraduate and advanced undergraduate students in other streams. The course is delivered in an intensive mode over three full days during a teaching break [8]. The course pedagogy makes use of both surface learning and deep learning concepts. Initially, students are led by the hand until they *remember* [2]. They are observed closely as they go through a set of exercises in order to establish a foundation on which to build.

They are given additional tasks that they must complete before the end of the intensive mode of delivery. These tasks are liberally specified, designed to assess the understanding and the level of competence that the student has reached, viz. *create a Virtual Instrument (VI) of your own choice to demonstrate your understanding of the concept.*

After completing the intensive mode of delivery, each student undertakes a project, which is to demonstrate the student's ability to use virtual instrumentation techniques to solve an engineering problem. The project topic is selected in consultation with the course coordinator and must be original in the sense that students conceive and produce it themselves, rather than merely copying or modifying an existing VI solution. Students are sternly advised that plagiarism will not be tolerated. A professionally written report, together with executable project files, must be submitted. Students appreciate this liberal approach and, by and large, live up to the expectations in terms of teaching and learning outcomes.

Figure 2 illustrates a creative project perceived and executed by an international postgraduate student. The inspiration for the project was provided by the student's own observation that first year engineering students have difficulty in grasping the concept of transients in electrical circuits. The project outcome is a practically useable electrical circuit simulator that can assist first year students in coming to grips with rather daunting invisible phenomena, an understanding of which is crucial to electrical and information engineering practice.

It is gratifying to observe that this successful project is not an isolated example, with a substantial number of students completing good projects for different applications. These experiences can not be taught in a traditional classroom setting.

Table 2 lists the extent to which the course strives to inculcate *graduate qualities* in students taking the course [5]. Evidently, a tangible success confirms the validity of the *qualities* striven for, and provides a fertile ground and motivation towards achieving the intended outcomes.

Table 2: Graduate qualities to be acquired by undertaking *Virtual Instrumentation Programming* [5].

Graduate Qualities	Point Weighting
Body of knowledge	1.6
Life-long learning	0.8
Effective problem solvers	0.6
Work alone and in teams	0.4
Ethical action	0.3
Communicate effectively	0.4
International perspective	0.3

This liberal student-centred and problem-based approach has been very well received by students. A recent survey conducted at the conclusion of the intensive delivery provides the justification for this perception.

In the survey students were requested to rate the course by responding to the following six questions:

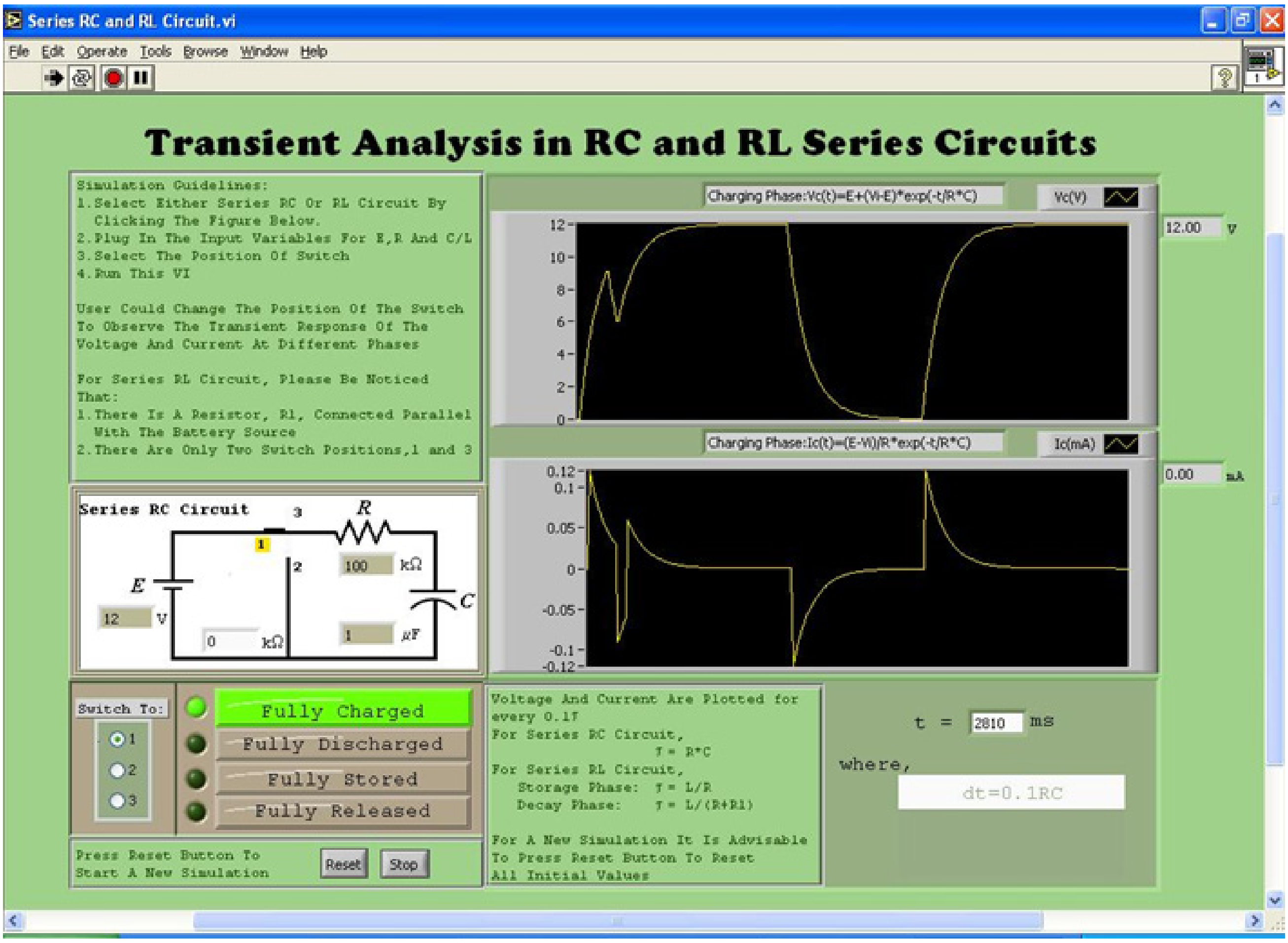

Figure 2: Electrical circuit simulator.

- *Question 1*: How would you rate this course compared to other University courses you have taken on campus and/or online?: (1)This course was one of my best learning experiences. (2) This course was better than most courses. (3) This course was about average. (4) This course was below average. (5) This course was one of my worst learning experiences.
- *Question 2*: When you compare your achievements in the course to the course outcomes, do you see that you have achieved: (1) All of the outcomes, (2) Most of the outcomes, (3) About half of the outcomes, (4) Only one or two outcomes, (5) None of the outcomes.
- *Question 3*: As a result of my experience in this class my interest in this subject area has: (1) Increased, (2) Remained about the same, (3) Decreased.
- *Question 4*: How would you compare the effort you put into this course with other University courses you have taken? (1) Much more effort than other courses, (2) A little bit more effort, (3) About the same effort, (4) Less effort.
- *Question 5*: Was the course assignment challenging enough for you to create a solution creatively from what has been taught to you?: (1) Excellent, (2) Good, (3) Average, (4) Below Average, (5) Poor.
- *Question 6*: Do you feel that the freedom to interpret the course project and come up with a solution that would showcase your ability of understanding: (1) Is good as it trains us to be competitive to present our skills for rewards, (2) Is a good idea as it gives us the freedom to explore what is taught to us and beyond, (3) Is good as long as the trainers explain what the marking scheme is, (4) Is too much of a hassle as we have other courses to worry about, (5) Not a good idea as we do not know what the markers expect.

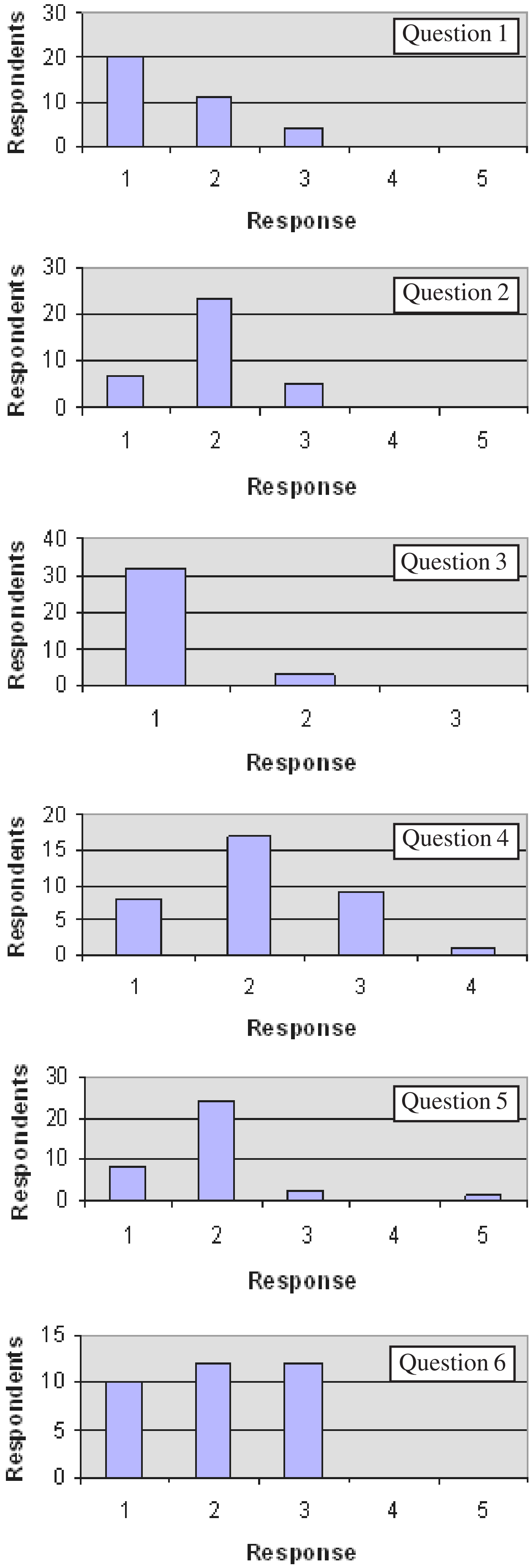

Figure 3: Student responses to the survey questions.

The responses to the student survey, presented in Figure 3, are rather pleasing by any standard, providing a level of reassurance that the liberal approach adopted in delivering the course is indeed effective.

Real Time Control

Until recently, the UniSA offered a common core course in classical and real-time control for students in electrical engineering (EE) and computer systems engineering (CSE). The content and manner of presentation of the real-time component in any particular year varied according to the professional interests of those entrusted with the responsibility to teach the topic. The differing, almost divergent orientations of the two cohorts, a highly variable level of academic and practical preparation, and significant cultural variations between students presented a significant pedagogic challenge.

One of the authors taught this topic. His interpretation of the syllabus, particularly of the generic skills supposed to be developed, led him to concentrate on the following aspects of the real-time control environment:

- Discretisation of a continuous system;
- Continuous design and discretisation of the compensation network;
- Direct design on the z-plane;
- Algorithm development through difference equations;
- Quantisation and its effects, eg dead-band and limit cycle;
- Sampling rate and its effects, eg roughness, dead-time and aliasing;
- A/D and D/A interfacing.

The CSE students' only prior exposure to control was lectures and tutorials in classical theory. They had little interest in non-computing applications or, indeed, in computing hardware and peripherals. The major challenge in teaching them was to stimulate interest in the wider engineering world. Their major strength lay in coding, and some were interested in and somewhat competent in program design and adaptation. Very many of them were culturally attuned to being spoon-fed information, an attitude which had to be changed if they were to graduate with the generic qualities demanded by the University and the profession [8].

A core group of the EE students had a trade/technician background. Once they grasped material, they were capable of stimulating and carrying along fellow students who had entered the degree programme directly from high school. None of the students could be said to be particularly adept at abstract thinking or readily linking mathematical operations to real-life applications. So, the common necessary element in teaching this mixed group was visualisation. CSE students had to be brought to see that even a mechanistic programming approach would yield control of an easily understood process before they could appreciate the concepts underlying the program design. The practically-experienced EE students had to see that the approach embodied and enhanced their existing knowledge of practical controllers, and that the effects were tangible. The rawer EE students had to see control in action, and to come to understand that it was they who could accomplish.

All of this was suggestive of using VI programming as a vehicle for control of an actual process that could be tuned (or mistuned) with the turn of a few *virtual* knobs to demonstrate the most important design constraints and effects. VI programming has advantages in visualisation because of its layered structure and flexible GUI, besides being intuitive in programming style. It also offers straightforward interfacing and, importantly in this context, simple, transparent control of such key factors as sampling time and word length.

Students were led by lectures and tutorials to the ultimate design of an appropriate digital PID controller. Concurrently, they were given rudimentary instruction in VI programming and sent off to work though example programs to gain fluency – and learn something about taking responsibility for their own learning. All were required to develop program segments used in the eventual simulation and real-time control.

The final design was finessed by the teacher. At the highest level, the VI comprised a representation of a three-term controller with variable sampling time and word length, with output and intermediate graphs and bar indicators for instantaneous values.

CSE students generally relished the opportunity to add a real-time programming language to their CV, although most had difficulty coming to terms with resource-based, self-directed learning, and not all saw the value of it. The experienced EE students regarded the insight into supposedly familiar PID control as a revelation, and the ease of varying parameter values encouraged extreme tests that demonstrated the adverse effects of PID settings when confronted by practical non-linearities.

The novice EE students were impressed that they could accomplish something tangible and visibly useful through their own efforts. It was possible to demonstrate good correlation with design values and with the predictions of limited sensitivity analysis. Altogether, the use of VI programming as a pedagogic tool was quite effective, not least in its influence on the acquisition of generic skills.

Electromagnetic Compatibility

Electromagnetic Compatibility (EMC), offered in a short-course mode, is a core course in the coursework Master of Engineering programmes, in both the Electrical Power Engineering and Telecommunications streams. It is also offered as an advanced elective in other streams of postgraduate coursework programmes and in the final year undergraduate programmes of the School of EIE. The core course position of EMC in postgraduate programmes is rightly justifiable, considering the growing proliferation of electromagnetic interference from human-made devices, increasingly causing problems of *emission* and *immunity*, in some instances being even considered to be hazardous to humans and other living organisms.

The course was introduced four years ago as a result of industry and student pressures to address an area of topical importance, at the time not covered in EIE programmes.

From the very beginning, the course has been a joint operation between the UniSA and the Defence and Technology Organisation (DSTO) – a major South Australian employer, sharing the delivery, with laboratory facilities initially offered by the DSTO alone (see Figure 4). In addition, an EMC laboratory with a screened room, established at the School of EIE, has been contributing further to the laboratory experience of students. Recently, two major industry organisations joined in, making the course a genuinely *industry-engaged* offering.

The field covered by EMC is extremely broad and, hence, impossible to comprehensively cover within the confines of an intensive mode delivery over five days. Therefore, a liberal approach is adopted, with the focus on giving students the fundamentals and allowing students to conduct their own inquiry for further learning. The course represents an advanced approach to learning at the postgraduate and final year undergraduate levels. As such, the expectations are for students to demonstrate analysis, design and synthesis skills in dealing with complex engineering systems. If they can persuasively demonstrate this by a well-executed report and assignments of good quality, the need for a conventional final examination disappears. Naturally, submissions by postgraduate students are expected to demonstrate intellectual and technical superiority compared with those of undergraduate students, thus addressing varied programme objectives.

Figure 4: Reverberating DSTO EMC chamber with a Black Hawk helicopter [9].

The growth in student numbers taking the course has been phenomenal, with international students in postgraduate coursework programmes being the main contributors to the growth (see Figure 1).

The liberal approach extends beyond the intensive mode of delivery over five days to include real-life demonstrations, tutorials on problem solving involving *screening*, teamwork, student inquiry and diversified assessment without examination. The industrial perspective that the three industry lecturers project and exposure to a real industrial testing environment play an important role in the development of understanding of the professional context of EMC issues.

Various assessment avenues have been trialled, including an open ended approach where students are required to assume the role of a team leader to design a new personal computer or a large variable-speed drive system, with all tasks to address EMC issues from component to system level. Even though this approach has been observed to develop substantial EMC knowledge and skills in the majority of students, it has also led to a large differentiation in submitted assessment reports from a mere 15 pages to over 200 pages (including attachments)! This has caused typical problems with tracing plagiarism, not to mention the marking load. When one considers that the student numbers have grown from initially 40 when the course was first introduced to a whopping 150 in 2005, one may sympathise with the plight of the course lecturers!

In 2005, a decision was made to base the assessment on electronic file submission via AssignIT – a Web-based assignment submission system. A limit of 30 pages was imposed on the total work submitted, including various assignments and a laboratory report. The software package TurnItIn has been adopted to detect and ward off plagiarism, which has, until recently, been the onerous task undertaken by the UniSA course coordinator and the three industrial lecturers.

CONCLUSION

It is both possible and desirable to treat advanced engineering courses liberally with quality outcomes in terms of teaching and learning. Rewards are the satisfaction on the part of students of knowing that they take on challenges associated with engineering problem solving and the gratification on the part of their teachers of knowing that they have somewhat contributed to their achievements.

ACKNOWLEDGEMENT

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a postgraduate student, whose work is alluded to in the text, with Figure 2 illustrating the outcome.

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BIOGRAPHIES

Özdemir Göl has had extensive experience as an engineering educator in addition to his substantial industrial experience. His academic career has included appointments in electrical engineering at universities in Turkey and Australia. He is the holder of MESc, ME and PhD degrees, all in electrical engineering. He is currently an Associate Professor and discipline head of Electrical Engineering at the University of South Australia, Adelaide, Australia.

His research interests have been focused on electrical machines and drives, and include modelling and simulation of electrical machines using numerical methods and the application of mathematical techniques to design optimisation of electromagnetic devices. He is particularly interested in the design and development of novel electromechanical energy conversion devices, which integrate emerging active materials and non-conventional topologies.

He has a strong interest in innovative approaches to engineering education and has published widely in this field. His teaching responsibilities have included courses in electrical machines, engineering design and virtual instrumentation. He is the author and co-author of some 150 publications.

Andrew Nafalski's career spans over 30 years in academic and research institutions in Poland, Austria, the United Kingdom, Germany, Japan and Australia. He holds BEng(Hons), MEng, GradDipEd, PhD and DSc degrees. He is a Chartered Professional Engineer and Fellow of the Institution of Engineers, Australia, Fellow of the Institution of Electrical Engineers (UK) and Senior Member of the Institute of Electrical and Electronic Engineers (USA). He is currently a Professor and Head of School of Electrical and Information Engineering at the University of South Australia in Adelaide, Australia.

His major research interests include: computer-aided analysis and design of electromagnetic devices, electromagnetic compatibility, low frequency noise, applications of modern magnetic materials and electromagnetic technologies, computer-aided testing of magnetic materials and magnetic measurements, and innovative methods in engineering education. His teaching areas cover: fundamental electrical engineering, network theory, electrical design, electromagnetic compatibility, information technology and programming techniques, numerical methods in electrical engineering and electromagnetic energy conversion. He has published some 170 articles, books, textbooks and software sets in these fields.

Kevin McDermott is a graduate of Adelaide University, Kettering University and the University of Southern Queensland. He is a Fellow of the Institution of Electrical Engineers, the Institution of Manufacturing Engineers and the Institution of Engineers, Australia. He worked in the electronics, telecommunications and automotive industries before being allured to academic life in 1973. Among other positions, he was Chair of the Curriculum Committee of the South Australian Institute of Technology from 1988 to 1990. In 1996, he resigned from his position as Head of the Engineering Discipline and Deputy Campus Director of the Whyalla Campus of the University of South Australia.

He is currently a company director, an education and engineering consultant, an arbitrator and mediator, and an Adjunct Associate Professor in the School of Electrical and Information Engineering at the University of South Australia, Adelaide, Australia.

His major research interests are in electrical machines and drives, and the education and formation of professional engineers. Most of his publications are in the area of engineering and university education. Active in professional society affairs, he is an International Membership Advisor of the Institution of Electrical Engineers.

Shivvaan Sathasilvam commenced his studies at the University of South Australia in 2001, undertaking the programme leading to the award of Bachelor of Electronics and Micro-engineering. During his studies, he spent one semester at Linköping University, Linköping, Sweden, as an exchange student, where he was exposed to experiential teaching methods. In 2004, he was admitted to the Dean's Merit List. He graduated in 2005 with First Class Honours.

Since 2005, he has been a part-time lecturer and tutor with the School of Electrical and Information Engineering at the University of South Australia. He has applied an experiential teaching approach to enhance students' learning experiences.

He is currently pursuing a Master of Engineering programme in Electrical Power Engineering at the School of Electrical and Information Engineering in the University of South Australia with the intention of continuing with a PhD pro-gramme.

David Chan graduated with a Diploma in Mechatronics Engineering from Nanyang Polytechnic, Singapore, in 1999. He proceeded with studies at the University of South Australia (UniSA), graduating with a Bachelor of Engineering in Electrical Engineering with honours in 2005.

He is currently pursuing a Master of Engineering programme in Electrical Power Engineering. He is planning to embark on a PhD research programme in electrical engineering in 2006.

He has been involved in teaching programmes, assisting with the delivery of a number of courses including that of the Virtual Instrumentation Programme. He is also actively involved in other initiatives of the School of Electrical and Information Engineering (EIE) at the UniSA, such as the Robotics Peer Mentoring (RPM) programme.

World Transactions on Engineering and Technology Education

A Call for Papers

Current events have impacted upon the arena of international conferences and academic travel, impinging on the freedom of intellectual movement to conferences and the like that are so important for the advancement of engineering education internationally and regionally and, indeed, the development of humankind now and into the future. To this end, the UNESCO International Centre for Engineering Education (UICEE) has established the *World Transactions on Engineering and Technology Education* (WTE&TE), which is open to everyone around the world who is interested in the progression of engineering and technology education. The *World Transactions* offers a safer and cost-effective alternative to conference participation.

So far, the first four volumes of the WTE&TE presented a range of papers from across the spectrum of engineering education and from around the world, including over 250 very interesting and insightful representations from many countries worldwide. From this, it can be seen that the WTE&TE contribute strongly to the publication of engineering and technology education papers globally.

Therefore, a call for papers is made for the next issue of the WTE&TE, **Vol.5, No.1**. The very nature of the *World Transactions* is open to every facet of engineering and technology education and is not confined to traditional views about science, engineering and technology. As such, there are no overriding engineering or technology themes, but rather the overarching principle of the globalised expansion of engineering and technology education that is not confined to borders or regions; instead the WTE&TE seeks to benefit all those involved in the engineering and technology through the wider dissemination of knowledge.

The deadline for this issue is **31 March 2006**. Authors should indicate their interest as soon as possible. Additional information can be found at the UICEE's homepage under *World Transactions* at http://www.eng.monash.edu.au/uicee/

Interested persons should submit their original, previously unpublished papers to the UICEE for consideration to be included in the WTE&TE. Authors should be aware of the standard formatting structure, which will essentially be the same as for other UICEE publications. Papers are to be submitted in MS Word format in 10pt font, single-spaced, double column, and a **maximum of 4 pages** in total, including abstract and figures (additional fees will apply for extra pages). Fees are based on cost recovery for editorial and publishing work, and every submitted paper will cost $A450. Also, within the cost structure is the delivery of one copy of the WTE&TE per paper submission by airmail postage to anywhere in the world. Please note that all Australian submissions are subject to 10% GST.

The electronic kit for authors, incorporating standard formatting details and submission forms, covering copyright, will be supplied on request. Potential authors should notify their intention of submitting a paper at their earliest convenience and earlier submissions than **31 March 2006** will be particularly welcome. Further correspondence via e-mail should be directed to Mr Marc Riemer on marc.riemer@eng.monash.edu.au