The Teaching Philosophy of the REAL units of a Mechatronic Engineering Degree Program*

GRAHAM G. ROGERS
Curtin University of Technology, Perth, Australia. E-mail: graham@vesta.curtin.edu.au

The paper outlines the teaching philosophy underlying the Real-world Engineering And Learning (REAL) units that provide the integrating core of the mechatronics engineering degree program at Curtin University of Technology. These units are based on the problem-based learning (PBL) pedagogy and teach, in addition to technical knowledge, essential generic skills such as problem solving, communication and teamwork. The paper details how this approach is implemented in one of the second-year units. The paper concludes by outlining the experiences in implementing this educational approach and describes the perceived benefits.

INTRODUCTION

FUNDAMENTAL CHANGES in the nature of work have led to a recognition for the need to shift the focus of education towards developing life-long learning skills [1], including communication, time management, teamwork and fostering creativity. These trends are particularly evident in manufacturing companies where the role, knowledge and skills of engineers is rapidly changing because:

- Modern work structures and methods are changing from sequential (functional) to concurrent (team-centred) methods [2]
- Rapid advances in computing is radically altering the manner in which engineering work is undertaken—in particular, detailed design and analysis issues are increasingly addressed by use of advanced CAD and CAE tools.

Such workplace changes have led to numerous calls in recent years for the focus of engineering education to change so as to better develop students' communication skills, teamwork, initiative and sense of responsibility, including an appreciation of the concepts of 'the customer' and 'quality' [3]. In particular, the increasing adoption of mechatronic methods of artefact design has resulted in calls for the creation of new engineering degree programs which are multi-disciplinary and emphasise real-world hands-on experience [4].

THE MECHATRONIC ENGINEERING PROGRAM AT CURTIN

The Mechatronic Engineering degree at Curtin University of Technology was introduced in 1995

and is structured around two distinct types of units, namely:

- Traditional single domain topics, such as mechanics, digital electronics, mathematics, dynamics etc. These units form 75% of the degree program and are common to degree programs in electronic and electrical engineering and mechanical engineering.
- Real-world Engineering And Learning (REAL) topics which form the remaining 25% of the degree program. These units focus on developing the application oriented knowledge and skills necessary for solving open-ended mechatronic design problems.

The REAL units are based upon the problem-based learning (PBL) pedagogy. This approach to learning is noted for:

- developing self-directed learning and problem-solving skills [5];
- aiding students in their conceptual understanding [6];
- promoting deep rather than surface learning [7];
- provide learning in a 'real-world' context which helps in future recall and developing lifelong learning skills [8];
- increasing students' curiosity, physical understanding and insight [9].

Currently there are four REAL units that operate in years 1–3 of the Mechatronic Engineering program. The first-year unit addresses mechatronics modelling and experimental methods. In the second year there are two such units that introduce the principles of electronics, control and software systems design. The third-year REAL unit addresses issues in the area of mechatronic control system design. The remainder of this

---

paper outlines the teaching philosophy, operation and educational outcomes of the REAL units.

THE REAL UNITS

Each REAL unit is centred around one overall design oriented task that has both practical and theoretical elements. The task is chosen so that students:

- use knowledge gained in the traditional single domain topics;
- are not confronted with issues too far removed from their current knowledge;
- build on knowledge and skills gained in the previous REAL unit;
- are actively involved in problem analysis, problem solving, written and oral communications, time management and teamwork.

Students are informed of the overall task in the first lecture class of the 15-week teaching semester. There are two 1-hour lecture classes per week for the first 7 weeks reducing to one 1-hour lecture for the reminder of the semester. These classes outline how the unit is structured and taught, develop technical understanding in topics specific to the task and detail the requirements for the assessment. In addition to lecture classes students spend 4–6 hours per week in the mechatronics studio. This facility provides the support equipment, components and tutoring support to help students address any specific problems they are experiencing.

For example, unit Mechatronics 223 requires students to design and build a DC motor voltage control system with an accuracy of 0.1 V over a range of ±12 V. The hardware provided includes a geared DC motor, a PC with a digital interface card and a breadboard for development and implementation of all the electronics. A 'budget' of $50 (Australian) is provided to cover the cost of the electronic components. The 'budget' is a paper budget since no money is transferred and all parts are 'bought' from the technical officer operating the mechatronics studio. The range of components available is purposely limited so as to constraint the design alternatives. This also has the advantage that many components can be recycled at the end of the project and the logistics of handling the hardware is neither too difficult or time consuming to manage with a large number of students.

The technical topics addressed in Mechatronics unit 223 include both theoretical and practical issues relating to:

- design and construction of a PWM voltage control circuit;
- role and use of schematic, circuit and layout design diagrams;
- use and role of feedback in electronic system design;
- computer input-output using a commercial interface card;
- software for user interface and real-time control.

As with real-world engineering, the REAL units are split into a number of distinct phases. Each phase corresponds to a design sub-problem, typically involving aspects of analysis, synthesis, implementation and testing. Assessments are an integral part of each phase and provide students regular feedback on their progress. For example, in mechatronics unit 233 there are four phases and associated assessments:

- Phase 1: Build and performance testing of a simple transistor push-pull power amplifier. Assessment: week 2: Lab book assessment of results of push-pull transistor operation (10%).
- Phase 2: Design and build of the PWM signal generator circuit for driving the power transistors. Assessment: week 5: Demonstration of prototype motor voltage control circuit (15%).
- Phase 3: Integration and testing of the entire motor voltage control circuit. Assessment: week 10: Design report detailing the design of the entire motor control system (25%).
- Phase 4: Design and implementation of a software user interface to control the motor over ±12 V range. Assessment: week 14: Demonstration and evaluation of the complete control system performance (25%).
- Final assessment: week 15: Final report (25%).

DISCUSSION

As both the designer and teacher of the REAL units I have had the opportunity to see first hand and reflect on what was for me previously uncharted waters. In particular, prior to developing these units I had not appreciated:

- *The difficulty involved in relating theory taught in the traditional lecture classes to the 'real world' problems.* For example, virtually all students find it difficult to know how to make appropriate simplifying assumptions in order to be able to apply analysis techniques taught in traditional classes.
- *The intellectual skills and demands of applying the top-down engineering design method.* In particular, students generally have no prior understanding of how to identify and split a design task into sub-tasks which can each be individually analysed, built and tested.
- *The 'common sense' mechanical knowledge necessary to design mechatronic systems.* For example, most students have little prior understanding or qualitative 'feel' of the concepts of precision, gear efficiency, power and torque and the relevance of design parameters, such as DC motor characteristics.

Through teaching these units I have also become increasingly aware of the significant differences

and implications of PBL teaching methods on staff-teaching skills. My experiences reflect those of Aldred [10] who notes: 'teachers and tutors are no longer the transmitter of facts, delivering a body of knowledge. Rather, the role of the PBL tutor is that of a facilitator. The tutor must be prepared to ask leading and open-ended questions, monitor progress, help students to reflect and create a positive team atmosphere, all of which require a high level of interpersonal skill'.

On a personal level I found developing these units has been a significant 'voyage of discovery'. In particular, my experience with these units has convinced me:

- it is possible to achieve a level of student learning and interest which cannot readily be achieved via traditional lecture and laboratory classes;
- virtually all students, irrespective of their academic abilities, relish the challenge of these units;
- design oriented units provide significant intellectual stimulus and challenge, even to the most able students;
- these teaching methods provide a true multi-dimensional learning experience developing students' knowledge and skills in a deeper and more meaningful way than conventional classes.

The following excerpts, taken from students' final reports on REAL units 102 and 223, are further testimony to the above:

'By the end of this unit we have gained valuable experiences. . . . we were encouraged to develop our method of solving each problem, either in modelling or establishing an experiment. This wasn't easy but we realize that this is how engineers solve problems in real-life situations. Apart from that, we also learned about the characteristics of a DC motor, functionality of a gearbox and how to apply theories and knowledge that we have learnt previously. . . we learned to analyse a system first and then make the right assumptions. This unit helped us in learning how to face and solve problems in real life situations.'

' As far as the entire class was concerned, the project seemed to capture interest like few (if any) other subjects have managed to. The variety of designs and concepts that were produced was amazing, and I think that the rate and enjoyment of learning in the laboratory certainly far outstrips anything that has been produced in the lecture theatre in a year and a half. Obviously, many of the designers would perhaps regret some of the design decisions that they made,

however, I don't think anybody could say they had not learned a huge amount from the project.'

CONCLUSIONS

With over 10 years experience with such teaching methods it is perhaps useful to finish by conveying some of the major lessons and pitfalls to avoid when designing and implementing such units.

At the outset one of my principal concerns was that the hands-on element would be fraught with practical difficulties, including both expensive in money and staff time. However, rather surprisingly, these concerns have proved unfounded, although, as with all new education developments, much thought and effort has gone into unit design, producing support material and adjusting to this new style of teaching.

Without doubt the most important factor when developing a REAL unit is the choice of the task and restricting the scope of the design domain. This is vital both to prevent students becoming confused and ensuring the tutoring work is not significantly more demanding than traditional laboratory classes. The use of systems technologies, such as Meccano and integrated circuits, has proved invaluable in this regard because it:

- develops the students' understanding of the systems philosophy underlying mechatronics.
- is a relatively low cost hardware that does not require workshop time or equipment for purposes of shaping materials
- is able to be dismantled and reused once the project is completed.

My only note of caution to staff considering such teaching developments is that the work needed to design, introduce and refine such units can be significant. For new untenured academics the decision to introduce such styles of teaching should not be considered lightly since trends in most Western universities is for tenure and promotion to be based on research rather than teaching quality or introducing novel teaching developments.

Despite this concern, my overwhelming belief is that problem-based teaching methods provide an important means of developing the knowledge and intellectual skills required for 21st century engineering.

REFERENCES

1. T. Heath, Education for the professions: contemplations and reflections, in *Higher Education in the Late Twentieth Century—Reflections on a Changing System*, I. Moses, (ed.), University of Queensland Press, Saint Lucia (1990).
2. G. Shina, Special report: concurrent engineering, *IEEE Spectrum*, July 1991, pp. 22–37.
3. D. Christiansen, New curricula, *IEEE Spectrum*, **29**(7), 1992, p. 25.
4. M. L. Dertouzos, *Made in America—Regaining the Productive Edge*, New York: Harper Perennial (1989).

5. G. Ryan, Student perceptions about self-directed learning in a professional course implementing problem-based learning, *Studies in Higher Education*, **18**, 1993, pp. 53–63.
6. H. Barrows, A taxonomy of problem-based learning methods, *Medical Education*, **20**, 1996, pp. 481–486.
7. F. Marton, and R. Saljo, On qualitative differences in learning: I—Outcome and process, *British Journal of Educational Psychology*, **46**, 1996, pp. 4–11.
8. S. Glen, Towards a new model of education, *Nurse Education Today*, **15**, 1990, pp. 9–95.
9. R. G. Carter, Engineers as problem solvers, in *Fifth Conference on the Teaching of Electronic Engineering in Degree Courses*, University of Hull, UK (1988).
10. S. E. Aldred, *The Direct and Indirect Costs of Implementing Problem-Based Learning into Traditional Professional Courses Within Universities*, Canberra: Department of Employment, Education, Training and Youth Affairs. (1997)

Graham Rogers is Senior Lecturer and Program Leader for the Mechatronics Engineering degree program at Curtin University of Technology. His research interests are concerned with PBL based teaching methods and KBS tools for assembly system design analysis. Prior to joining Curtin University he worked as a control systems engineer for Rolls-Royce (Aero) and was lecturer in electronics and mechatronics for 7 years in the UK.