A Review of Teaching Strategies in Practical Work for Mechanical and Mechatronic Engineering Students Studying Via On-Campus and Distance Education

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ABSTRACT: A review of the conduct of a suite of practice courses is presented. On-campus and external students enrolled in three mechanical and mechatronic engineering programs at the University of Southern Queensland undertake these courses. Feedback from students, staff and management are examined and recommendations made for further enhancement of the teaching of practical work.

KEYWORDS: mechanical & mechatronic engineering, practical work, distance education

Introduction

A number of significant changes are presently occurring within the engineering education landscape. The greatest of these is the inclusion of wider generic skills in the engineering curriculum and the apparent subsequent shrinkage of discipline specific technical content.

One of the most expensive academic activities is laboratory or practical work (Boud, Dunn and Hegarty-Hazel, 1986), and this facet of engineering education has undergone a number of dramatic changes over the past decade or so. The high cost of demonstrators and equipment, increasing student numbers and a steadily mounting student dissatisfaction with course content, workload and assessment, has, in some cases, degraded the traditional form of laboratory education to little more than attendance to glean the minimum information necessary to write a lengthy report (Snook and Luxton, 1994). The growing fixation of students on "marks for everything", rather than on the excitement of learning, is an indication that the course objectives are not clear to most students. Despite this, on-campus laboratory work often continues in its current form and escapes the scrutiny that academic courses are subject to.

Kirschner and Meester (1988) have expressed the situation well: "Despite the fact that the results achieved in the laboratory setting are not always in proportion to the time, energy and money spent, and that they are seldom in accordance with the expectations of those who designed them, it is very rare that one asks fundamental questions as to the use of the laboratory as an educational tool".

Distance education (also called external or off-campus studies) is now becoming more common in the engineering education landscape. This relatively new mode of education brings new problems for the provision of practical work, but also provides an opportunity to reassess the role of practical work in both modes of study.

In this paper, a brief review of a suite of practice courses is presented. These practice courses are offered to on-campus and external students and feedback from students and staff is discussed.

Programs at USQ

The University of Southern Queensland (USQ) is a recognised leader in the field of distance education (ICDE, 1999), and also offers somewhat more traditional on-campus studies. USQ was established in 1992, some 25 years after the opening of the Darling Downs Institute of Advanced Education from which it originated.

The Faculty of Engineering and Surveying is one of the foundation faculties at USQ and offers a wide range of on-campus and external studies in engineering. It offers three programs within the discipline of mechanical engineering; associate degree (AD), bachelor of engineering technology (BEngTech) and bachelor of engineering (BEng). In addition, there is a bachelor of engineering major in mechatronic engineering. All of these programs may be undertaken on-campus or via the distance education mode.

Associate Degree

The Associate Degree in Mechanical Engineering is a two year full-time program (or four years externally) that has been developed for those students whose aim is a career as a **Chartered Engineering Officer**. Engineering Officers apply practical analysis and standard technical principles to new and existing areas of design, testing, inspection, operation and manufacturing processes. They often work, "at the coal-face", as support staff to Professional Engineers.

Bachelor of Engineering Technology

A Mechanical Engineering major is available in the three year full-time Bachelor of Engineering Technology (BEngTech) program. This program can also be studied externally over six years.

The BEngTech award leads to a career as a **Chartered Engineering Technologist**. At USQ we believe that engineering technologists and engineering officers are best educated alongside their professional counterparts. In all engineering disciplines there is a need for suitably qualified engineering technologists to work with and under the direction of Professional Engineers.

Bachelor of Engineering

The Bachelor of Engineering (BEng) program at USQ leads to a career as a **Chartered Professional Engineer**. Professional Engineers develop solutions to problems in new and existing fields of research, development, construction and manufacturing. They use advanced skills and knowledge in analysis, design, science, technology and management to find those solutions. The Professional Engineer may not spend as much time doing "hands-on" practical work, but require considerable practical experience to supplement their technical and professional training.

Practice Strand

In 1998, the Mechanical and Mechatronic Engineering discipline at USQ separated the practical work from the academic courses in all of its programs. It now utilises nine practice courses to support its programs and these are considered as the Practice Strand (Walkington, Pemberton and Eastwell, 1993) shown in Table 1. In this table, the practice courses are attributed to the relevant engineering program.

Each practice course represents a notional 50 hours of student effort. On-campus students normally conduct this work for three hours per week throughout the semester, whilst external students attend a one week intensive residential school on-campus. A central feature of this suite of practice courses is the decoupling of practical work from the academic courses. Instead, videos and computer demonstrations are used where a practical context is required to supplement the academic material within a course. Thus, the practice courses are free to concentrate on the specific educational goals of the practice experience.

	AD	BEngTech	BEng (Mech)	Beng (Mtron)
Engineering Practice 1	√	√	√	√
Electrical Practice A				√
Mechanical Practice 1	√	√	√	√
Mechanical Practice 2	√	√	√	√
Mechanical Practice 3	√	√	√	
Mechanical Practice 4		√	√	
Mechatronic Practice				√
Professional Practice 1			√	√
Professional Practice 2			√	√

Table 1 Practice courses in each of the Mechanical Engineering programs

Engineering Practice 1 (ENG1901)

Engineering Practice 1 is intended primarily to cater for the needs of recent school leavers and people with limited working experience in engineering industry. A student with a trade certificate and sufficient industry experience may be able to claim exemption from the course.

This course is the first of a series of practice courses that are intended to enable students to acquire engineering and professional practice skills. Engineering practice skills, such as the ability to perform practical and project work, innovation, problem identification and solution, and engineering judgement, are developed as students progress through their programmes of study through activities such as laboratory and field work, engineering design and project work. Students generally work in teams to assist with the building of group interaction skills such as negotiation and interactive thinking.

In this introductory course, external students attend a residential school for one week and undertake practical work primarily in the areas of instrumentation and measurement, or engineering materials and manufacturing. They prepare a comprehensive report and present a seminar on one aspect of this work. Students are also introduced to the library and computing facilities of the University and are expected to utilise these resources in the compilation of their reports and seminars. A series of keynote addresses are staged to assist students with their task.

On campus students also undertake practical work in the areas of instrumentation and measurement, or engineering materials and manufacturing, and prepare a comprehensive report and present a seminar. For these students, the practical work is performed throughout the semester. All students are introduced to the Workplace Health and Safety Act and undertake a preliminary workplace health and safety exercise.

Mechanical Practice 1 (MEC2901)

This course presents a series of activities designed to develop specific skills and knowledge relevant to Mechanical Engineering. These activities are carried out on an individual or small group basis, and the student team-work through a smorgasbord of activities until the specific course objectives are met. Typical activities include linear measurement, performance measurement, simple mechanical workshop exercises and device strip and assembly.

Mechanical Practice 2 (MEC2902)

This course falls naturally into three parts: Part One consists of a design activity where a small team of students develop a design concept for a device capable of satisfying a broadly specified task. Part Two comprises the procurement of appropriate resources and the construction of the device in accord with the design specification developed in Part One. Part Three covers the testing of the device and encourages the student to reflect on the activities and outcomes of the work conducted in Part One and Part Two above.

The **Warman Student Design and Build Competition** forms the basis of the design activity and is used exclusively as the vehicle for this practice course, including the national competition perspective. On-campus students conduct the work in this practice course throughout the first semester in a three hour class per week. External students attend a one-week block in the second semester, and thus are not directly involved in the National Competition.

Mechanical Practice 3 (MEC3903)

This course continues the development undertaken in mechanical practice 1 and mechanical practice 2.

On completion of this course, students should be able to: conduct and utilise an engineering test in accord with a given general requirement; operate a range of engineering metrology equipment and evaluate the data obtained; co-operate within a team-work environment; review CNC machining processes; prepare CNC programs to machine a number of simple engineering components; participate in the CNC machining process for two simple engineering components.

Mechanical Practice 4 (MEC3904)

This course aims at providing the student with practical skills needed in many industrial processes. It is designed to demonstrate the different ways of measuring velocity of a fluid (gas or liquid), to determine the forces due to fluids, and temperature of a fluid or a solid and heat flux, to estimate flow rates and head losses in fluid systems, and heat flux in thermal systems. The course is designed to help students review some of the basis of fluid mechanics and heat transfer as well as validate and relate these to practical situations.

Mechatronic Practice (MEC3905)

In mechatronics; mechanical, electrical and computing elements are combined to form an integrated whole. This course draws together mechanical, electrical, software and interfacing aspects of a mechatronic system through a progressive sequence of experiments. A motor is connected to a computer through a power amplifier, while another motor in tandem is monitored through an analogue interface to determine its speed. A line or two of code makes speed control possible. A belt drives a 'trolley' of which the position is monitored and more effort includes nonlinear strategies to result in a 'crisp' position controller of an industrial standard. An inverted pendulum is added to the trolley and the student devises a control scheme to keep it balanced. Several further, brief experiments give familiarity with pneumatic positioning, simple vision interfacing and a hydraulic robot. This course was developed to round off the formation of a mechatronics engineer.

Electrical & Electronic Practice A (ELE1911)

This course is service taught from Electrical discipline into the Mechatronic engineering program and until recently consisted of two practice courses.

Professional Practice 1 (ENG3902)

This is the first of two courses, which address, in a generic sense, the practice of professional engineering. The course is concerned largely with non-technical matters, generally independent of the specific engineering disciplines, which involve the particular work undertaken, performance and responsibilities borne by the professional engineer.

The major manifestations of this professional practice are the participation in professional development activities and the planning, execution and reporting of project work. This preparation includes attendance at the annual "Project Conference" in which Professional Practice 2 students present their completed project work to other students, staff and members of various professions. Students also participate in, and report on, a range of laboratory sessions, demonstrations, seminars and workshops provided both by staff of the Faculty and by industry. These activities (labelled "Booths") seek to provide the student with some insight into the "cutting edge" of current engineering practice.

Professional Practice 2 (ENG3903)

This course is concerned with developing in the student an awareness of professional ethics, environmental responsibilities and sustainability principles. This course also provides guidance and experience in both verbal (seminar) and written reporting skills and is undertaken to complement the formal presentation of the students honours project.

Review of practice courses

Table 2 shows the enrolments in the practice courses from their introduction in 1998 to the present 2002 semester 1. Note where there are two numbers given then this indicates semester 1 and 2 figures respectively. Day (D) and external (X) offerings are included. All courses have shown healthy numbers except mechatronic practice, which reflects low first level enrolments in this recently introduced program. In a recent review of its undergraduate programs, the faculty examined the current suite of practice courses and no changes were recommended (Dowling, 2001).

Course	1998		1999		2000		2001		2002	
	D	X	D	X	D	X	D	X	D	X
Engineering Practice 1	136	66 58	135	62 54	89	41 33	108	21 22	76 45	26 27
Mechanical Practice 1	19	10	18	22	26	19	17	16	34	6
Mechanical Practice 2	15	13	23	30	30	18	17	20	38	31
Mechanical Practice 3	16	16	12	29	13	28	22	28	13	30
Mechanical Practice 4	12	3	15	8	14	18	14	20	9	23
Mechatronic Practice	5	-	10	3	2	2	5	3	2	2
Professional Practice 1	52	68	72	47	48	54	54	79	57	43
Professional Practice 2	62	22	38	28	69	37	53	36	57	76

Table 2: Enrolment history in practice courses

Student comments

These questions were developed to assess the overall student enthusiasm for, participation in and the percieved worth of, the practice courses.

Which of the mechanical engineering practice courses did you enjoy the most? Why?

It comes as no surprise that Mechanical Practice 2 (based on the Warman competition) is the most popular course amongst on-campus students. It is a little more surprising to note that external students appreciated the team-based activity even though the level of manufacturing in this course is limited. The open-ended activities within Mechatronic Practice are also popular.

Which practice course do you believe was most worthwhile with respect to practical knowledge?

Responses from students were varied and approximately evenly distributed from all of the four mechanical practice courses. Most students from the Associate Degree program preferred the CNC activities within Mechanical Practice 3.

Which practice course gave the best outcome with respect to engineering skills?

Again there was a reasonable spread of responses across all courses. Specific student comments included:

Mechanical Practice 2: We got to try our ideas & skills within a given timeframe. Had to go through an engineering problem from start to finish. Designing and building ideas. Because of group work. Allow you to design and construct a device.

Mechanical Practice 4: Learnt measurements and application of fluid dynamics equations.

Professional Practice 1: Gave me opportunity to learn wider aspects of engineering. Enjoyed seminar presentations in September.

Should we add another practice course?

Expand Mechanical Practice 1 and Mechanical Practice 2 (x4).

Have more hands-on tasks where information needs to be gathered and then design, build and test the device that your team has built.

Add more machining practice skills.

Allocate more time to MechPrac1 so you have the chance to do all the activities.
No. Wait until you get a job and have proper practical experience.
Add an electrical practice course for Mechanicals.
Add another course where you have a problem and have to solve it.
Add more time to Mechatronics Practice with more hands on experience with mechatronic systems. (x3)
Add specific experience with PLC's (x2). Add specific experience with vision systems.
Add a Dynamics practice course.
A few more hours of everything would be good.

Examiner Comments

In general, the examiners of each of the practice courses were pleased with the way in which their course was conducted. The following points merit discussion:

Students generally perform well but two of the examiners were concerned that the student's knowledge of background theory was lacking.
On-campus and external students generally complete the practice work within the allotted time. However, students in Mechanical Practice 2 and Mechatronic Practice tended to spend much longer on the practice work (because they enjoyed doing so). As examiners we do not wish to stifle such enthusiasm but are concerned that this may have an adverse effect on the student's academic courses.
It is alarming to note that most examiners knew little of the content or conduct of the other practice courses. Despite this, they thought there may be no clear and coherent theme to the practice courses.

Management Comments

There is no formal student evaluation survey of practice courses as in the academic courses. The academic instrument is not appropriate for this purpose and no alternative was ever created. In many ways the review discussed in this paper was initiated because of this oversight.

Sequencing of practice courses generally follows their corresponding academic courses but is not fixed by prerequisites or co requisites. Students following the recommended enrolment pattern will do the practice courses in order. This order is not actually necessary and some slight variation is acceptable.

The timetable for external students attending residential school may need to be adjusted. At present some practice courses run in the same week. This is a particular problem for overseas students who must then travel to Australia many times for a one week block when they would rather travel half as often but for two weeks at a time.

Practice courses have simplified and justified the attendance of external students at residential schools on campus. Given that most overseas students attending have considerable travelling and accommodation costs, this is now easier to explain and facilitate.

Conclusions

The work within the Mechanical Engineering Practice Strand is generally popular amongst students. Both staff and students perceive benefits in the sequencing and in the particular practical work component.

Students have fully realised the aims of practice work and appreciated its place in their programs and even suggested it might be increased to cover more academic areas.

The Discipline should consider renaming the practice courses to better describe their content and to remove the implicit sequencing requirement.

The Discipline should consider sharing knowledge of practice course content across all examiners involved so that common outcomes maybe reinforced.

Practice courses are quite expensive and any expansion therein will need to be well argued in their cost-effective contribution to undergraduate outcomes per the recent accreditation review.

Practical work is doubly expensive when considering students who enrol via the external mode. In this case, the Faculty bears the considerable cost of demonstrators, equipment and laboratory space; whereas the student must take leave from work and pay for travel and accommodation at USQ.

The Faculty of Engineering and Surveying needs to develop a formal evaluation instrument specific to the practical work objectives.

References

Boud, D., Dunn, J. & Hegarty-Hazel, E. (1986). *Teaching in laboratories.* SRHE&NFER-Nelson, UK.

Dowling, D. (2001). Review at USQ: Redeveloping the bachelor of engineering program for 2002. In L. Dawes, W. Boles & A. Maeder (Eds.), *Proceedings of the 12th AAEE conference on engineering education*. (pp. 309-314). Brisbane, Australia.

International Council for Open and Distance Education (ICDE), 1999 Prize of Excellence for Institutions, http://www.icde.org/

Kirschener, P.A. & Meester, M.A.M. (1988). The laboratory in higher education: Problems, premises and objectives. *Higher Education*, 17, 81-89.

Snook, C.P., & Luxton, R.E., A challenge for laboratory based learning programs. In P.J. Parr & S.F. Johnston (Eds.), *Proceedings of the 6th annual convention and conference of the Australasian Association for Engineering Education*, (pp. 772-777). Sydney, Australia.

Walkington, J., Pemberton, P. & Eastwell, J. (1993). Laboratory work in external engineering courses. In R.M. Sharp & H. Silyn-Roberts (Eds.), *Proceedings of the 5th AAEE conference on engineering education*. (pp. 401-406). Auckland, New Zealand.