

Encouraging learning through external engineering assessment *

D Parsons[†]

Faculty of Engineering & Surveying, University of Southern Queensland, Toowoomba

SUMMARY: *Examinations are commonly used at the end of teaching periods as major components of assessment for external engineering students because they are the only assessment mechanism that examiners can be reasonably sure are completed by students acting alone. However, the literature suggests that examinations are flawed instruments of assessment for many reasons, not least because they encourage poor approaches to learning, but also because they do not allow useful feedback to students. This paper reports on a trial of assignment-based assessment, details of which are sufficiently complex and diverse that they encourage individual work by students, both in course content and in other graduate attributes.*

1 INTRODUCTION

The purpose of assessment in engineering is primarily to ensure that students have the knowledge and skills to practice engineering. So assessment is used to check that learning has occurred and, secondarily, to allow grading that reflects the level of that learning. However, according to Hansen (2004), another purpose of assessment is to motivate students to learn and to encourage students to think about what they have learned in the semester just assessed, and so to learn better.

Most assessment in engineering comprises some assignments plus an examination with significant weighting, which typically focuses on “hard” content. The examination is retained primarily because of the fear that students will cheat if assessed by mechanisms that allow them to seek help from others either voluntarily or by paying for it. There is, of course, significant evidence, both anecdotal and well researched, for the fact that this fear is justified, see for example McCabe (1997) and Carpenter et al (2002), who claim that cheating has increased significantly over recent decades. Certainly my own university has spent a lot of time working

out strategies to combat plagiarism (University of Southern Queensland, 2007) and largely insists on a final examination worth at least 50% of marks awarded so that grading will reflect students’ individual achievements.

2 PROBLEMS WITH EXAMINATIONS

There are however significant problems with examinations as vehicles of assessment. This paper will discuss what these problems are and then move on to discuss possible alternatives.

2.1 Examinations encourage a poor approach to learning

Students seem to decide often to concentrate on the major assessments and specifically on the final examination, rather than participate enthusiastically in more formative activities during the semester (McDowell et al, 2004). Experience suggests that while examiners may want students to learn first and then use assessment to check that learning has occurred, students start by trying to fulfil the assessment requirements. This may mean they miss out on some of the learning that is not assessed formally, such as the need for good organisation and all the other not-codified knowledge (Hansen, 2004). There is substantial evidence for this assertion in the author’s experience teaching external southeast Asian students where the (Australian) not-codified

* Paper D05-008 submitted 12/04/07; accepted for publication after review and revision 1/10/07.

† Corresponding author David Parsons can be contacted at parsonsd@usq.edu.au.

knowledge is not always understood. In this case too, most students are studying externally so there is not much opportunity for not-codified knowledge, such as professional attitudes, to "rub off" onto students by direct contact with lecturers. It also means that at least the brighter students often adopt the strategy of studying just in time for exams, which may be satisfactory for hard technical content, but is unlikely to be a satisfactory way of achieving deeper learning (McDowell et al, 2004).

2.2 Examinations assess limited aspects of learning

A powerful motivation to learn is provided to students by assessments, but examinations probably only produce motivation to learn some of the details expected of a graduate.

Examinations tend to be mainly focused on the lower levels of Bloom's taxonomy of learning, not least because they are conducted over a very short period of time and under stressful circumstances. In other words, examinations tend to emphasise content rather than the numerous other attributes required by graduates, such as life long learning skills, teamwork skills, ability to handle cultural diversity and sustainability, hard work, and good organisation. Examinations are not good vehicles for encouraging students to climb the learning hierarchy, because they do not encourage reflection about past learning (Hansen, 2004), nor are examination results a good measure of students' achievements in these areas. As Knight (2004) says, tertiary education is a complex process and comes from a complex process. An example of such complexity is the ability to talk about thinking or to write about thinking (Calfee, 1995). Competence at skills normally able to be assessed by examination does not necessarily indicate achievement of such a complex condition. Soeiro & Cabral (2004) present some evidence that moving from examinations to distributed assessment leads to improvements in student participation in learning activities and to better grades.

2.3 Examinations affect the way teaching is performed

Relying on examinations as primary assessment instruments also tends to affect the way teaching is performed. Trigwell & Prosser (1996) show that teaching that focuses on a clear relationship between teaching and learning (rather than even just on teaching), leads to higher quality learning. Lecturers also acknowledge the students' imperative to pass the final examination and consequently, in the final analysis, focus on the relevant requirements.

The author has tried the approach of teaching learning skills to students as a means of changing

the emphasis from learning to pass examinations to more general learning, with only limited success (Parsons & Dowling, 2004). This experience is confirmed by Pulko & Parikh (2003), who report that teaching study skills to students was only useful to 10% of students in a UK survey, whereas 41% reported it to be of no use. The solution according to Pulko & Parikh is that teaching staff need to modify their approach to teaching away from that deemed appropriate for hard engineering material (and the corresponding examinations) to something more suitable to such soft skills as how to learn. Later sections of this paper give some examples of how the author has attempted this task in the context of hard engineering content.

2.4 Exams favour certain types of students

Better students (as conventionally defined) may do better in examinations than weaker students and part of this may be that those who are better able to handle the stress of examinations will do better (Gipps, 2003). But is the ability to handle stress really one of the main graduate attributes we wish to foster? Some argue that open book examinations are an appropriate technique for assessment because good application of knowledge clearly involves understanding that is independent of whether the test instrument is open or closed book. Shine et al (2004) suggest that the fact that it takes significant effort to write such questions may be the reason for open book exams not being popular, especially at a time when academic teaching workloads are high.

There may also be other biases in our assessment procedures:

- Formative assessment with qualitative feedback, usually lacking in examinations as expanded below, has been found to result in greater improvements among lower performing (school) students (Gipps, 2003). Greater use of formative assessments, with corresponding lesser use of examinations, may thus help students from a wider range of abilities to reach our required goals.
- A cultural bias or lack of cultural fairness is alleged by some analysts, such as Poortinga (1995), who suggests that lack of familiarity with test procedures and unequal familiarity with the stimulus materials and presentation can lead to disadvantage. The author's experience teaching southeast Asian students has confirmed this.
- A psychological bias because there is some evidence that psychology, as we understand it, is an ethnocentric, western construct, but its use underlies much of our assessment (Poortinga, 1995).

2.5 Students do not get formative feedback from exams

Students do not usually get formative feedback from examinations because they are predominantly end-of-semester assessments intended to assess the overall student learning after the event. That is, they are summative assessments not normally intended to be part of the learning process. This leads to the suggestion that the final assessment should not carry major weighting because such practice means that students receive no useful feedback on, commonly, 60% to 80% of their assessment. What this point does highlight, however, is that if weighted assessments are to be part of the learning process, then more weighting should be placed on earlier, formative assessments that encourage good learning.

There is then a need to use assessments that avoid the problems above and use more formative styles. They must, however, still be of a type that encourages individual work, are broad in what they assess and allow examiners to detect cheating readily.

The complexity of education implied in all the above in turn implies a variety of learning activities that also implies a variety of assessment. It does of course need to be organised variety (Knight, 2004), and to be both formative and summative. That is, the feedback from assignments should help students to know how they are progressing and to give help in what to do next. At the same time, as discussed above, students will usually not do activities unless they are worth marks, a fact most lecturers would attest to. McDowell et al (2004) conclude that feedback should be (more) qualitative by focusing on the learning tasks done and on how the student handled those, rather than (just) quantitative – for example marks for an examination – which can lead to negative reactions especially among those doing less well.

3 AN ASSESSMENT TRIAL

The rest of this paper is about the author’s attempts to incorporate alternatives to examination and technical problem-solving activities into assessment. These attempts have involved increasing the weighting on earlier assignments, which have been made more diverse and more complex, and consequently reducing the weighting on the final assessment.

3.1 Course background

The author teaches a course called Electronic Measurement in which students are learning about using electronics to measure things – other electrical parameters using normal test equipment and more general physical quantities, such as temperature and pressure, using electronic instruments. The course is done at third year equivalent level, mainly by Bachelor of Engineering and Bachelor of Engineering Technology students.

Two major issues in this course are errors in the measuring electronics and interference to that electronics by other electrical equipment. Most of the students enrolled are fully external and have no face-to-face contact with the lecturer during their study of this course. They are required in assignments to design electronic instrumentation, to build it and to use it to measure things. But they are also asked to do many other things to encourage their learning of the technical content outlined above and to help them develop more general skills.

3.2 Planning assessment to encourage learning

Firstly, assessment has been planned in detail by writing down what should be assessed and how to assess it, as illustrated in table 1. This detail is

Table 1: Sample entries in an assessment planning document.

Component	What students should achieve	Students’ assessable work	Marks allocated
Circuit design	<ul style="list-style-type: none"> • Design of gain • Think logically about calculations • Recognition of useful noise reduction techniques • Awareness of practical detail 	<ul style="list-style-type: none"> • Design amplifier gain • Show calculation steps • Choose techniques for noise reduction • Design small input source 	<ul style="list-style-type: none"> ✓ ✓ ✓ ✓
Learning style	<ul style="list-style-type: none"> • Use best way for individual 	<ul style="list-style-type: none"> • Summary of questionnaire responses (VARK) • Plan for specific learning action 	<ul style="list-style-type: none"> ✓ ✓
Sustainability	<ul style="list-style-type: none"> • To become aware of sustainability in electronics • To know some real examples of action 	<ul style="list-style-type: none"> • Select a relevant example • Specify information or action • Give two reasons for avoiding plagiarism 	<ul style="list-style-type: none"> ✓ ✓ ✓

included as an example of applying the ideas of diversity in assessment within the context of hard engineering content, as well as to illustrate the need to plan assessments carefully so that they assess the range of students' achievements expected.

3.3 Productive pedagogies

Many academics have used the ideas of Bloom's taxonomy to guide their students' learning and their own teaching. However, this taxonomy, as usually interpreted, focuses on content – knowledge, understanding, application, analysis, etc, of engineering material, or, to put it another way, on intellectual qualities.

Productive pedagogies (Queensland Department of Education, Training and the Arts, 2004) explicitly go beyond content to encompass other graduate attributes. The author is attempting to use these ideas to guide assessment practices and specifically to help organise assessment details, which assess many of the other qualities expected of graduates. A by-product of this process will hopefully be, as outlined above, the reduction or elimination of summative-only assessments as progress is made towards assessment based on a broad range of types of activity, the responses to which can be expected to be more unique to individual students. Such uniqueness allows examiners to assess work with more confidence that it is indeed the students' own work.

Table 2: Productive pedagogy and student activity.

Productive pedagogy	Student activity in Electronic Measurement
<i>1. Intellectual quality</i>	
Higher-order thinking	<ul style="list-style-type: none"> • Determine amplifier gain and design for that gain • Choose techniques to minimise noise • Base conclusions on data • Reflect on the assignment work • Write coherent reports • Assess quality of measurements made • Eliminate other causes by experimental procedure
Deep knowledge	<ul style="list-style-type: none"> • Design pcb layout using software • Describe one noise reduction technique in detail • Do practical measurements of complex parameters • Understand sources of error
Deep understanding	<ul style="list-style-type: none"> • Have practice at analysing and answering questions • Interpret or apply theory – in words or in circuit sketches • Explain one noise reduction technique • Understand instrument performance before using • Explain processes behind calculations and design choices
Knowledge as problematic	<ul style="list-style-type: none"> • Be explicit about what is required of them by USQ • Argue that measurements are correct • Acknowledge sources of information and explain why
<i>2. Connectedness</i>	
Knowledge integration	<ul style="list-style-type: none"> • Identify an environmental impact of electronics and a possible remedy • Apply reliability theory to constructed circuit • Devise suitable test arrangements
Connectedness to the world	<ul style="list-style-type: none"> • Produce a plan for remainder of course • Identify examples of noise in common experience • Construct an electronic circuit complete with case, connectors, etc • Use real common equipment as noise sources and explain behaviour
Problem-based curriculum	<ul style="list-style-type: none"> • Develop a circuit to specifications • Use developed circuit to do real measurements
<i>4. Recognition of difference</i>	
Inclusivity	<ul style="list-style-type: none"> • Assess own learning style and report on learning activity chosen to match • Use diversity of delivery and learning tools • Share ideas via an internet discussion group

Table 2 shows selected productive pedagogies and the corresponding assessment activity in Electronic Measurement. (Several categories have been left out because, for example, they relate to classroom activity that does not exist for external students.) The student activities include a wide range of types – basic and advanced appreciation of technical content, learning how to learn, reflection, relating content to the real world, practical work, design work, and others.

The intention with assignment details, such as those in table 2, is to put more weighting on broad assignment questions that require individual research, analysis or learning. This allows learning along the way and the opportunity for more useful feedback. The diversity of the assessment items is intended also to reduce the chances of students cheating either by plagiarism or by having others do work for them. This style also of course increases the chances that copied work and plagiarism will be detected.

3.4 The assessments

An outline of the actual assessments is given here together with the allocation of marks used.

3.4.1 Instrumentation amplifier design

The primary technical task here is to use the theory and ideas given in the course material to design an electronic amplifier to allow measurement of temperature using silicon diodes as the sensors.

This task also involves the design of the layout of a printed circuit board to not only be correct but to also minimise errors and susceptibility to interference. The weighting on this assessment is 16%.

Other tasks in the assessment include:

- Students were encouraged to discover how best to learn. So they were asked to analyse their learning styles using a simple online test called VARK (Fleming, 2007), and then to use the provided tips and apply one of them to the course they were now studying – and to report on what action they now proposed to take.
- Write explicitly about what level of response was expected of them in a senior level course.
- Prepare a plan of action to complete the remaining practical activities in the course.
- Students were required to connect theory to reality by realising that interference from electrical noise was a real problem with electronic equipment. So they were asked to identify some examples from their daily lives, to describe the experience they had and to try to relate the experience to the theory.
- Investigate an aspect of environmental concern with electronic equipment.

Some examples of questions asked to students and the responses are given in table 3, to illustrate the breadth of the topics covered. Student responses have been chosen to illustrate both the thoughtful and the rather superficial.

Table 3: Examples of assessment questions and student responses.

Question	Student responses
What evidence is there that good design can overcome most electromagnetic compatibility problems?	<ol style="list-style-type: none"> 1. There is plentiful evidence in papers and conferences that certain design aspects can overcome interference problems. 2. A good design should incorporate features, such as shielding, grounding and twisted pair cable, and should produce expected outputs. 3. My personal experience is that many items of electrical and electronic equipment operate side by side with no noticeable interference.
Describe what you think the staff at this university expect of a person to whom they are to award a degree?	<ol style="list-style-type: none"> 1. Able to comprehend a problem, analyse and interpret what is required and propose several solutions. 2. Able to benefits one’s employer with knowledge obtained and apply some knowledge for the good of society. 3. Able to better society technologically without detrimental side effects.
Assess your own learning style (using a website) and give practical ways you will use your style to study this course.	<ol style="list-style-type: none"> 1. Go through the whole study book few times and jot down some important points. 2. Use simple diagrams when making notes. 3. Do the practical exercises where available, take the study notes apart and rebuild them in the way that I want to see them, and to collaborate with other like-minded learners using forums such as this one.
Describe an observation you have personally made where electronic equipment is disturbed by external electrical noise.	<ol style="list-style-type: none"> 1. Operating the light switch in my lounge room causes the sound and image of my television to momentarily become distorted or disappear. 2. Noise on an AM radio reception when driving underneath high voltage power lines. 3. A baby monitor worked fine until the baby cried loudly, at which point it would trigger the automatic garage opener and the garage door would open.

3.4.2 Differential thermometer

The main technical task here is to physically construct an instrument that can measure the temperature difference between two diodes over a range of 1 °C, and then measure the performance of that instrument in the area of both errors and interference susceptibility. Associated technical tasks are to assess the performance of measuring instruments, such as a multimeter or oscilloscope, which were to be used to conduct the performance measurements of the thermometer. The weighting on this assessment is 24%.

Other tasks in the assessment include:

- Select and use common household electrical equipment, such as food blenders, mobile phones or TV receivers, to provide sources of electrical interference to test their thermometer's performance.
- Apply reliability theory to the constructed thermometer to assess its likely lifetime.
- Report carefully by giving evidence for assertions made about performance.

3.4.3 Computer marked tests

There are also two small computer-marked tests, which comprise either numerical calculations with randomly varied parameters for each individual

student or multi-choice questions, together worth 10%.

3.4.4 Timed assignment

The final assessment is still a major one at the end of the semester, worth 50% of the total. It is, however, an individualised "take-home" test delivered electronically, which the students are given one day to complete. It is individualised by being comprised of questions randomly selected from lists for each topic area, but of such a style that few can be answered by direct reference to source materials. It also incorporates references to specific work done during the semester, intended to motivate students to learn well during those activities. Some examples of questions asked are given in table 4. This is an interim stage in the development of the assessment practices for this course, intended to seek a balance between the stress of examinations and a requirement for individual work.

3.5 Some results

The mix of technical, practical, theoretical and personal activities in the assessments do force a significant amount of individual work, some of which is felt to be unnecessary, particularly by mature age students (who make up a significant proportion of students). The activities are seen as complex by

Table 4: Examples of timed assignment questions. Each student receives the same basic question, but with a different specific detail at the end.

Basic question	Question detail
Describe the nature of the adverse environmental impact caused by the following aspect of the electronics industry. Write about 150 words.	Semiconductor manufacturing; stand-by power consumption of consumer devices such as TV receivers; short life of many items of consumer electronics; etc.
Explain how to measure the following parameter of the instrumentation amplifier used in your assignment. You will need to give practical details, such as actual circuit connections, values of extra components, etc.	Input offset current; input resistance; common mode rejection ratio; etc.
The following situation is an example of the operation of some electronic equipment being interfered with by a signal from another piece of electronic equipment: (a) Explain what evidence there is that it is electromagnetic interference. (b) Suggest how the signal may be getting from the source into the affected circuit by referring to the various known mechanisms for interference transfer.	A food processor causes noise to be heard in an intercom system; a vacuum cleaner causes white flashes on a TV screen; an AM radio sound becoming blurred when underneath overhead electricity distribution lines; etc.
Explain what the following oscilloscope specification says about the performance of the oscilloscope:	Main sweep time scale range of 10 ps/div to 20 s/div; rise time (10% to 90%) of 210 ps; etc.
Explain briefly what the following term means in the context of electronic measuring equipment:	Input attenuation; spectral components; trigger event; etc.

students and those who are experienced in passing courses by simply assimilating facts and mastering procedures, express some prior apprehension about passing. Most explicitly engineering activities are, however, handled without too much hesitation and with typical levels of competence.

The more open-ended activities are not always done well. Responses include:

- Simple failure to comprehend what is being asked – for example, students from some backgrounds often do not appreciate that the environmental impact of electronics may be a problem and so fail to engage.
- Searching the web or books for ready-made answers to questions that demand an application of theory to part of their experiences in the course.
- Providing extensive theoretical responses to questions that asked for more practical detail, such as what conclusions can be drawn from a measurement result.
- Giving superficial detail, such as describing the practical problems of external study when asked to consider what level of learning might be expected of them.

On the other hand, these open-ended activities do elicit thoughtful responses from many students, and responses to related questions in the final timed assignment show appreciation of the depth of learning required in the course. A relatively minor issue, which may be of concern, is that students who do appreciate the need in industry and in life generally for the more general attributes addressed by some activities and assessment questions tend

to do very well. That is, it could be argued that this approach downgrades the assessment of technical competence while putting more emphasis on general attributes.

Enrolments in Electronic Measurement in recent years has included students in significant numbers from Australia/New Zealand, Malaysia, Singapore, Pacific and other southeast Asian nations and, more recently, India/Pakistan. The numbers in each category over the years 1999 to 2007 are shown in figure 1.

Corresponding pass rates for students from these different origins over time are shown in figure 2. Figure 3 shows the breakdown of grades for the same course. The changes discussed in this paper were commenced following experience of the poor pass rates for some groups in 2001 and 2002.

These data suggest that the various strategies tried have little impact on students of Australian cultural background, but have significantly improved the pass rates of those from Asian and Pacific backgrounds. They also show that the strategies employed have shifted student grades upwards (less Cs and more As, etc). Unfortunately it is not possible to attribute these changes to any specific action because of the number of variables involved, as described above. They do, however, show that the changes have made a difference to some students' performance.

4 CONCLUSIONS

There are many reasons why examinations are not the most appropriate means of assessing students' achievement, but their use is commonly retained

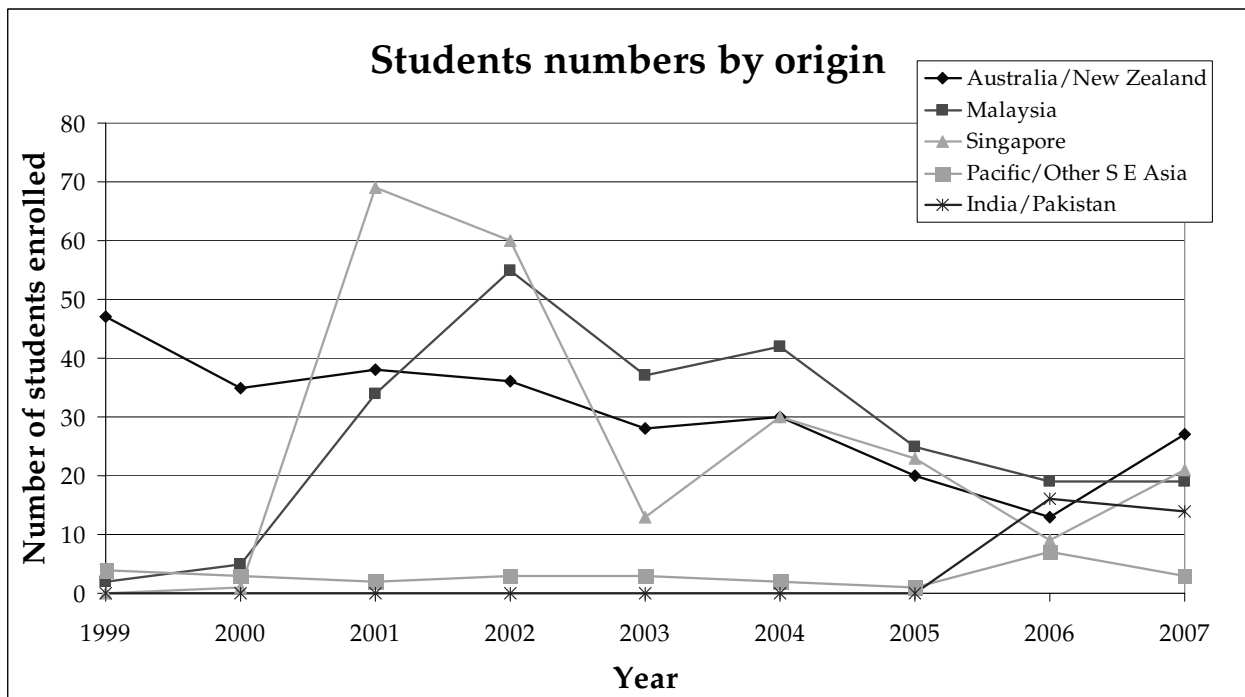


Figure 1: Number of students enrolled each year by global origin.

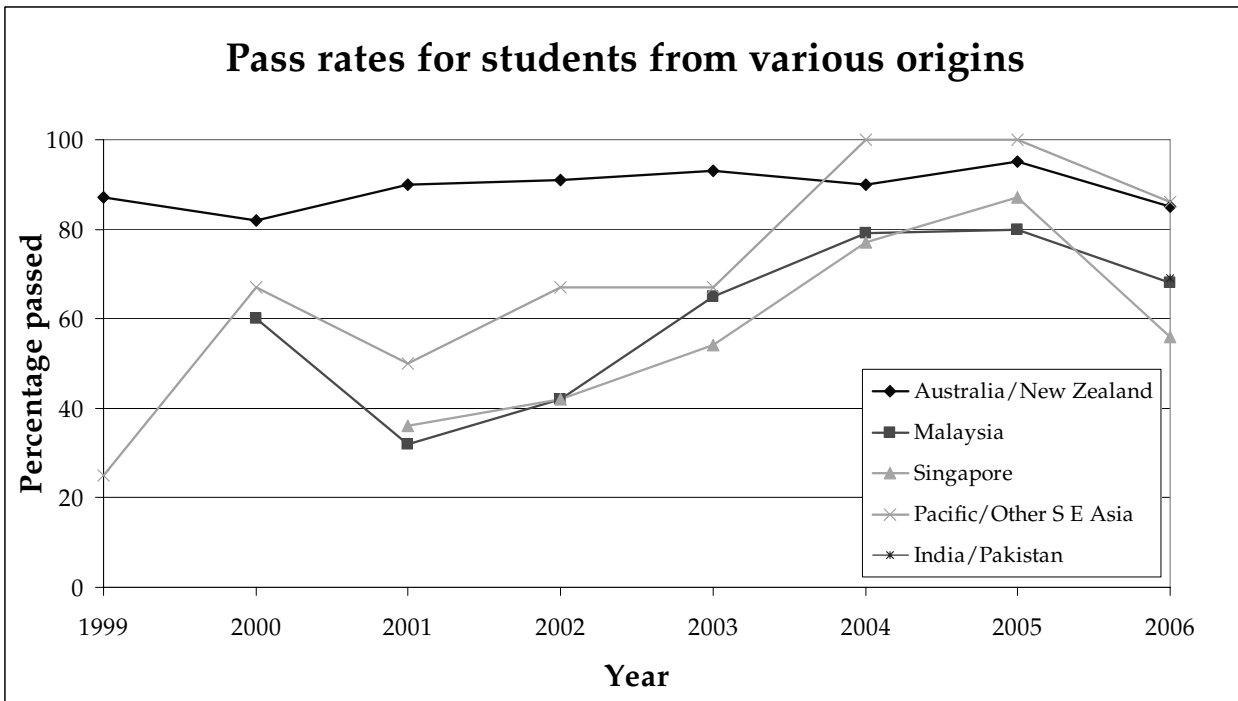


Figure 2: Pass rates over time for students of different global origin.

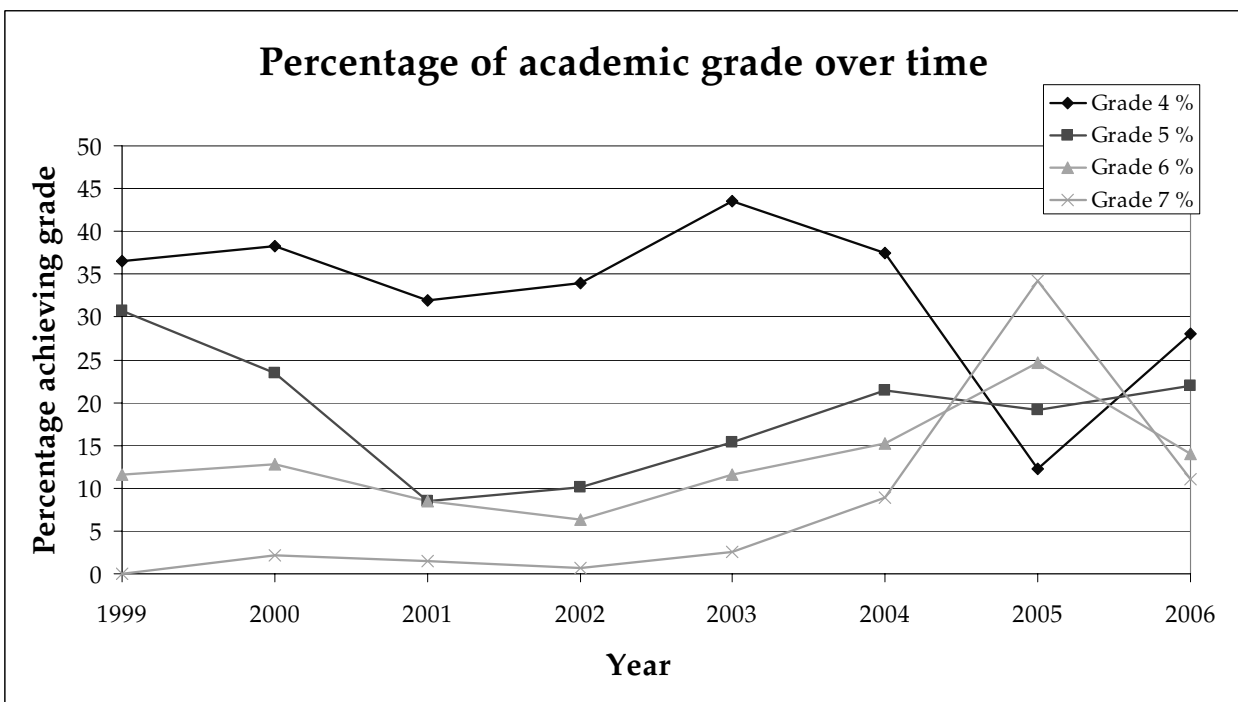


Figure 3: Changes in student grades over the years where different strategies have been trialed. Grades are as conventional in Australian universities where 4 is a basic pass and 7 is an excellent pass.

because they are the only student assessment activity that examiners can be sure were done entirely by the students. This paper has attempted to give an alternative model for assessment based mainly on the idea of giving a more complex mix of tasks that will force students to individually do the work, and allow that individual work to be recognisable to the examiner. Such assessment will, at the same time, help to develop and then assess a wide range of attributes.

REFERENCES

Calfee, R. 1995, "Implications of cognitive psychology for authentic assessment and instruction", in *International Perspectives on Academic Assessment*, Oakland, T. & Hambleton, R. (editors), Kluwer, Boston, pp. 25-48.

- Carpenter, D. D., Harding, T. S., Montgomery, S. M. & Steneck, N. 2002, "P.A.C.E.S. – a study on academic integrity among engineering undergraduates (preliminary conclusions)", *Proceedings of the 2002 American Society for Engineering Education Annual Conference*, Montreal, Canada.
- Fleming, N. 2007, "VARK. A guide to learning styles", www.vark-learn.com/english/index.asp, viewed 30 August 2007.
- Gipps, C. V. 2003, "Educational accountability in England: the Role of Assessment", *Annual Meeting of the American Educational Research Association*, Chicago, April, pp. 1-15.
- Hansen, S. 2004, "A constructivist approach to project assessment", *European Journal of Engineering Education*, Vol. 29, No. 2, pp. 211-220.
- Knight, P. 2004, "Assessment of complex learning: the Engineering Professors' Council's new thinking about first-cycle engineering degrees", *European Journal of Engineering Education*, Vol. 29, No. 2, pp. 183-191.
- McCabe, D. L. 1997, "Classroom cheating among natural science and engineering majors", *Science and Engineering Ethics*, Vol. 3, No. 4.
- McDowell, L., White, S. & Davis, H. 2004, "Changing assessment practice in engineering: how can understanding lecturer perspectives help?", *European Journal of Engineering Education*, Vol. 29, No. 2, pp. 173-181.
- Parsons, D. & Dowling, D. 2004, "Teaching engineering to southeast Asian students", *Proc 15th ASEE Conference*, Toowoomba, September, pp. 375-384.
- Poortinga, Y. H. 1995, "Use of tests across cultures", in *International Perspectives on Academic Assessment*, Oakland, T. & Hambleton, R. (editors), Kluwer, Boston, pp. 187-206.
- Pulko, S. H. & Parikh, S. 2003, "Teaching 'soft' skills to engineers", *International Journal of Electrical Engineering Education*, Vol. 40, No. 4, pp. 243-254.
- Queensland Department of Education, Training and the Arts, 2004, "New Basics Project Productive Pedagogies", <http://education.qld.gov.au/corporate/newbasics/html/pedagogies/pedagog.html>, viewed 30 August 2007.
- Shine, S., Kiravu, C. & Astley, J. 2004, "In defence of open-book engineering degree examinations", *International Journal of Mechanical Engineering Education*, Vol. 32, No. 3, pp. 197-211.
- Soeiro, A. & Cabral, J. S. 2004, "Engineering students' assessment at University of Porto", *European Journal of Engineering Education*, Vol. 29, No. 2, pp. 283-290.
- Trigwell, K. & Prosser, M. 1996, "Changing approaches to teaching: A relational perspective", *Studies in Higher Education*, Vol. 21, pp. 275-284.
- University of Southern Queensland, 2007, "Plagiarism", www.usq.edu.au/plagiarism/default.htm, viewed 30 August 2007.



DAVID PARSONS

David Parsons is an electronic engineer with previous experience in the telecommunications and electricity distribution industries in NSW and South Australia. He is now a senior lecturer in electronic engineering at the University of Southern Queensland, which specialises in external education and has students in most states of Australia, as well as in many parts of southern and southeast Asia, Africa and the Middle East.

David's interests are in teaching and learning in engineering, in the social dimensions of engineering, and in electronic instrumentation and electromagnetic compatibility. More recently, he has been involved in evaluations of the environmental consequences of the electronics industry using life cycle assessment in areas such as batteries, lighting and recycling.