STUDENT LEARNING STRATEGIES FOR SUCCESS IN COMPUTING NETWORKING

Neville Palmer and Jomo Batola
Southampton Solent University, United Kingdom

ABSTRACT

Data has been gathered using various methods from a unit on a computer networking degree programme. This unit is intended to impart experience and theoretical underpinning of the implementation of computer networks to meet the requirements of the real world.

The input data relates to the student effort that can be measured in terms of attendance or engagement at lectures, tutorials and laboratories, access to online learning resources, and the ability to record the results and demonstrate outcomes in networking laboratory sessions. The output data is in the form of student achievement in examinations and in course assessment.

This unit gave the opportunity for various teaching and learning methods including lectures, tutorials, practical laboratories and online learning, as well as a range of assessment types.

Data gathered gave unexpected results. For example it didn't follow that student attendance at lectures related directly to performance in the end of unit examination. Hence it was necessary to examine the student strategy for learning. Initial work indicated that the practical laboratories played an important role in student success, but other factors seemed to contribute. This article will analyse some results, seeking to identify the effectiveness of various teaching and learning methods.

INTRODUCTION

This paper presents an experience of teaching a technology-based subject to a diverse group of undergraduate students in the UK. It focuses on a level two unit on a computer networking honours degree programme.

Programme Design

Newstead and Hoskins(1) have documented student surveys which show that most students see the importance of vocationally related programmes in developing their careers and job prospects. During the programme design process it was decided that there should be at least one unit that addressed the needs of business and industry in equipping networking students with experience of the theoretical and practical design and implementation of computer networks. These goals were seen as important in meeting the expectations of industry and are consistent with the aims of the British Computer Society (BCS), as well as meeting the aspirations of students.

The computer networking degree programme has been approved and accredited by the British Computer Society (BCS). This was seen as a significant step in developing a curriculum reflecting professional industry standards.

Subject Particularity

One of the key units chosen to present the vocationally oriented aspect of the programme became known as Network Implementation and was originally a 30 CAT Point Unit, corresponding to 25% of the Level2 units, and is delivered over the whole academic year. This gave the opportunity for various delivery and assessment methods.

Originally it took part of its inspiration from vendor specific professional qualifications such as the Microsoft Certified Systems Engineer and the Cisco Certified Network Associate certification programmes. Vytautus and Strom(2) identified that professional development and public awareness of available systems were important aims in the teaching of computer networking.

In order to meet the requirements of a largely practically based unit it was seen as necessary to deliver the unit with a combination of lectures and practically based laboratories. The lectures would deliver the theory and the laboratories would put this into practice. Some of the laboratory tasks were based on the more advanced aspects of the professional programmes. For example students might be expected to implement a Windows Active Directory infrastructure, or to configure a large network comprising a number of Cisco routers.

TEACHING, ASSESSMENT & LEARNING EXPERIENCE

The unit gave the opportunity for both individual and group work.

Teaching Format

The supporting lectures and tutorials focussed on the operational theory of current network systems and services. This included the planning, integration, management and troubleshooting of these systems.

A one hour lecture supported the unit throughout the whole year. Additionally a one-hour tutorial was followed by a two-hour laboratory in the first period of the academic year, and in the second period the laboratory was extended to three hours without a tutorial.

The two hour laboratories enabled individual introductory tasks to be introduced, whereas the extension to three hours enabled more elaborate computer network systems to be implemented with each student being allocated a series of tasks in the grander scheme. Whilst the lectures could deliver a high degree of theoretical underpinning the tutorials were flexible in either supporting the lectures or the laboratories by demonstration of systems.

Students were expected to prepare for each laboratory session before they were timetabled. To this end a list of laboratory topics was published, along with deadlines for completion of each. The detailed tasks for each laboratory topic were also handed out well in advance.

Practical laboratory sessions were conducted within a dedicated computer networking laboratory, with each student having access to their own computer.

Assessment of Learning Outcomes

Ramsden(3) stresses that assessment needs to align with and address the learning outcomes of a particular unit and that it should also ensure that students have the problem solving abilities required by the world of work. The unit required various assessment methods to assess learning outcomes of the unit.

Success might be perceived as an ambiguous term that means ‘achieving intended learning outcomes’ from the teaching team point of view, while often meaning ‘getting a pass’ from a student point of view. However, these different views can be seen as convergent if one sees academic success as a flag for employability success.

The Laboratory Tasks. The practical learning outcomes were assessed during the laboratory sessions. Each student was required to demonstrate successful understanding and completion of each task within a laboratory.

Many of the laboratories were designed to be modular so that parts could be completed in isolation and assessment of individual tasks was possible. Some laboratory sessions required collaborative work, which Hamilton(4) considers important, in varying group sizes from two to four.

During some laboratories students may be allocated to a larger group of four and in turn the groups were expected to work together towards a common goal. For example the whole class would be given the task of implementing a network for a company with a number of branch offices. The class would be split in to a maximum of five groups of four students, with each group representing a branch office.

Students were required to demonstrate successful completion of each major task within the laboratory. Groups were assessed as a whole. This scheme is a quantitative measure rather than qualitative, however the marks are accumulated over the course of the year. It was important to ensure that all group members were actively engaged in the laboratory work and the tutor needed to be pro-active in this respect.

The Assignment. Beatty(5) suggests that case studies are useful for vocational degrees. For this unit a scenario based assignment was developed where the emphasis was placed on the application of systems and techniques to specific real world scenarios rather than simply on one requiring students to recall facts that could have been copied from the Internet.

An assignment was developed that required students to work in groups of two, or individually where this was not possible. It introduced an important element of teamwork in the planning of computer networks. In order to relate the assessment to the needs of business, and to enable students to apply theory and analysis techniques, each group was required to select a basic scenario relating to a particular computer networking topic from a list issued with the assignment brief. Only one group could select each topic, and they were required to expand the scenario into a workable solution. The first student had to develop a set of requirements based upon a scenario and the second student would in turn produce a design or set of technical recommendations to form a workable solution.

The students were required to submit a fully referenced report in two parts, identifying the author of each part and then to deliver the important points in the form of a two part oral presentation. Dunn *et al*(6) emphasises the importance of oral presentations involving requirements and design in Engineering in developing skills in workplace communication.

Generally this assessment method seemed to give a number of benefits over an individual assignment based around the same topic for all, requiring re-statement of technical facts, and in so doing it was felt enhanced the student learning experience, as evidenced by the significantly positive feedback from unit questionnaires.

Allowing the students to present their work and findings to the class meant that they could benefit from the work of others. The students could learn from their peers.

The Logbook. Network managers and engineers often use logbooks to record information on system configuration, for instance, as a point of reference should problems arise in the future, while report writing is an important activity in the lives of scientists and engineers (Dunn *et al*[6]).

Logbooks should be more reflective, presenting the aims of particular laboratory work, discussing observations and conveying an understanding of systems rather than just detailed configuration information.

Students were required to maintain a laboratory logbook with a record for each session. Guidelines were issued for the logbook and assessment criteria required students to discuss the laboratory tasks, analyse results, drawing technical conclusions and to answer questions that generally required a descriptive answer.

The End of Year Examination. The examination offered a significant portion of the unit assessment. The type of question that appeared in the end of unit examination typically required students to discuss the principles of systems (assessing knowledge), and the application of them to various scenarios, which may include a troubleshooting exercise or application of theory (assessing understanding). It should be mentioned that the examination papers for this unit received favourable feedback from external examiners.

Some students appeared to be good at practical work, but seemed to lack understanding of the systems that they were implementing. However at honours degree level from the second level onwards understanding is particularly important and should form a significant part of the assessment process. Understanding and synthesis are the factors that, on the face of it, most clearly define the difference between a higher education degree and vocational qualifications, which may include vendor specific qualifications. The vocational aspirations of our students should be to engage in the management and development of systems.

Marking Scheme Strategy. The coursework mark comprised an aggregated mark of the laboratory based assessment and an assignment, including a presentation.

The laboratory-based assessment included the demonstration of laboratory tasks and production of an accompanying logbook and accounted for 40% of the total unit mark. The assignment issued to students, forming the remaining one 20% of the total, intended to meet the learning outcomes of the unit relating to network planning, requirements analysis and design.

Finally an end of unit closed book examination formed the remaining 40% unit mark. This was not aggregated with the coursework mark, meaning that students were required to pass both the examination and coursework in isolation in order to succeed in the unit as a whole.

Students Feedback and learning Experience

The positive feedback from unit questionnaires indicated that students appreciated the importance of the laboratories in meeting their vocational objectives. It was felt that the practical laboratories enhanced the student learning experience by enabling them to interact with systems and to put into practice the theoretical principles.

DISCUSSION

Employability

Knight and Yorke(7), while introducing the issue of higher education and employability in the UK context, offer us a definition of employability as '*a set of achievements, understandings and personal attributes that make individuals more likely to gain employment and be successful in their chosen occupation*.' By equipping students with experience and understanding of real world systems this can be better achieved.

Monitoring and Reflective Practice

Nicholls(8) defines effective teaching as '*how best to bring about desired learning outcomes and change the way students think by involving them in learning activity*.' Ramsden(3) emphasises that deep learning is desirable and, in order to foster this, teaching and assessment should encourage students to actively engage with the subject.

Teaching

Lectures. There are various schools of thought on the purpose, conduct and effectiveness of lectures. Some people feel that lectures should deliver information to students in a cost effective way. However lectures can be used to introduce students to a topic and to discuss ideas. Ramsden(3) discusses some issues associated with lectures, but it is apparent that most teaching professionals continue to regard them as very important teaching tools. Lectures can be seen as assisting in filling in parts of the picture. The lectures were designed to present theoretical concepts. The coursework was designed to assess the practical implementation and application of theory.

Tutorial. The tutorials gave an opportunity to engage in small group teaching with a variety of techniques. Sometimes tutorial questions were given to students. It was also possible to demonstrate systems, including software simulation.

Laboratory. Beatty(5) observes that laboratory experiments should enhance the skills of observation and recording in order to develop a relationship between theory and practice. Instructions for laboratory work should be clear enough that the laboratory objectives can be achieved, however vague enough that students have to think for themselves in achieving them. It was stressed to students that they must engage in research prior to the laboratory sessions as well as attending the supporting lectures and tutorials. The laboratory tutor had to be pro-active whilst ensuring that the students were able to complete the tasks by applying their knowledge and using their own problem solving abilities. The laboratories enabled students to develop essential problem solving skills and to work collaboratively, something that Dunn *et al*(6) mentions as being important.

Virtual Learning Environment. The University hosts an Intranet, with a Virtual Learning Environment (VLE) called LearnWise, where teaching and learning materials, assessment details, and other information can be posted for each unit. Pettit and Mason(9) discuss how Virtual Learning Environments are increasingly seen as an important way to support teaching and learning.

Access to each unit on LearnWise can be monitored. It is possible to see which students have enrolled on the unit and the documents they have accessed. Specifically it is possible to see whether a particular student has accessed the notes for a particular lecture.

For the Network Implementation unit a great deal of information was made available online, including unit information guides, complete with teaching schedules, assignments and guidelines, details of laboratory topics and guidelines for logbooks, lecture notes, and other useful information. Students were encouraged, in addition to attending lectures, to study the lecture notes made available on LearnWise before or after the lecture.

TEACHING AND LEARNING PATTERN: ASSESSMENT RESULTS WITH REGARD TO ATTENDANCE AND INDEPENDENT LEARNING

An attendance register was made at every lecture.

It was noticed that some students had excellent attendance at lectures, however they were still failing the examination. The attendance at lectures and the examination results for were compared (**figure 1**). For each individual the percentage of the number of sessions attended and their examination score were recorded. It was clear that there was no correlation between participation in lectures and examination results. It was therefore necessary to see whether reasons for this could be identified. Perhaps a particular student attended the lectures in body, but did not study afterwards.

It may not always be possible to take adequate notes during a lecture and much of the information is forgotten once outside of the lecture theatre, therefore students were strongly advised to study the lecture notes on LearnWise.

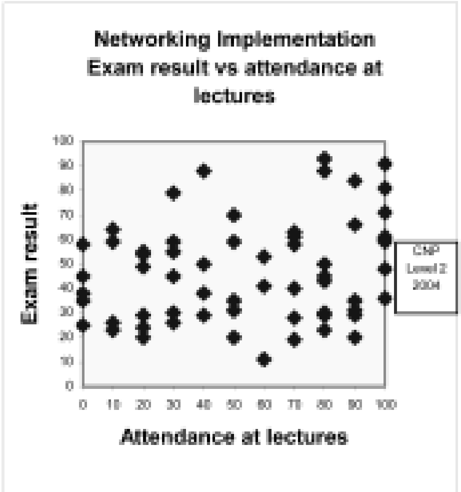

Figure 1: Graph of attendance at lectures versus examination results

However, even if they had done this, there may be other factors involved. Some people may be good at practical work and not so comfortable with examinations. Others may be good at theoretical application, but are poor at expressing this on paper. It was also noticed that some students had poor attendance at lectures, but were still passing the examination. By what means did they achieve this?

This is not to say that examinations, or indeed lectures, are a bad thing. One could be equally critical of other methods. For example, assessment of practical laboratory work may not really test the student's understanding of the subject, although the discussion and analysis in a logbook can be used to indicate evidence of understanding.

It can be difficult to ensure that coursework in the form of an assignment is the work of the student actually submitting it. It is becoming increasingly easy for students to access material from the Internet that can be copied directly into an assignment.

However in the case of the unit in question measures have been taken to reduce the possibilities for these problems to occur. Firstly the students have to present their work orally, which makes it difficult to hide a lack of understanding of the material in question. Additionally by basing the assignment on a contrived real world scenario the originality is improved.

Some students seemed to perform well in practical implementation and in discussing their results in a logbook, whilst under the time pressure of a formal examination they were not able to perform as well. One might argue that these students would be better suited to a more vocationally oriented programme of study, however it may not mean that they are not independent learners able to discuss systems and issues. It may just be that for complex reasons they may not be able to perform well under time pressure, or that they are not good at recalling facts. Maybe open book examinations could overcome some of these problems, requiring students to study a textbook or additional documentation and apply it to a question. This is the kind of exercise that defines the work of postgraduate professionals. Rather than recall basic facts from memory they will study a text book for many new situations.

The assignment and presentation may give them time to demonstrate their ability to engage in independent learning and application of knowledge. Nevertheless a closed book examination in controlled conditions can be used to guarantee the source of assessed work. The examination questions should not rely on recalling facts, but enable students to apply background knowledge to particular scenarios. Then how can we ensure success?

CONCLUSIONS AND RECOMMENDATIONS

Examinations may not be the optimum method of gauging the academic level of students, although in a world where it may be difficult to guarantee originality of assessed work they have an important role to play. Perhaps we need to revisit examination methods and how best to prepare for them in light of an increasingly diverse student population.

The lectures and tutorials were used to deliver the principles to support the practical implementation of systems. In turn the practical laboratory sessions were used to re-enforce the theoretical discussion, develop student professional skills and employability. Application of theory stimulates students to study and research the solutions, thereby acquiring knowledge and understanding in the process.
Whilst it was possible to judge practical effort in the laboratories and to easily gauge lecture attendance, and to some extent access to lectures notes made available to students on LearnWise could be monitored, it was difficult to monitor other activity.

What seems to be apparent is that a successful student learning experience does not depend on lectures alone. It seems that providing a variety of teaching and learning experiences and methods to students with diverse educational maturity and from a diverse background is a possible solution to enable them to succeed as a cohort. In a vocational programme, a large practically and professionally orientated teaching strategy on some units could lead to a successful student learning experience and employability. One should note that such an approach does not prevent students from progressing towards postgraduate study. Indeed, our teaching strategy encourages students to gain independent learning skills and personal responsibility.

Where possible students should be encouraged to apply the subject material to real world examples, through the use of theoretical scenarios or through practical work. Practical application may appear passive, but this may stimulate an interest in the subject and support knowledge and understanding.

Some students were using other resources such as the Internet to study, as resources referenced in logbooks and assignments suggested. It was certainly known that some students had configured their own network at home, and perhaps that could also play a part in the overall picture. If this is the case, then whilst this has not been monitored at present, it may be the stimulus provided by the practical applications of the unit that drive some students. Anything that fosters interest and encourages independent learning will stand a good chance of succeeding. It is also important to demonstrate the relevance of the syllabus in terms of future career.

The means to offer a realistic satisfactory educational experience to students on this form of programme requires a student to staff ratio that should be as low as feasible with regard to the financial constraints of each institution.

REFERENCES

1. **Newstead, S. E. and Hoskins, S.**, (2003) *Encouraging student motivation.* In Fry, H., Ketteridge, S. and Marshall, S. (2003) Editors, A handbook for Teaching & Learning in Higher Education: Enhancing academic practice. 2nd Edition. Kogan Page. London. ISBN 0-7494 3799 5
2. **Vytautus, R. and Strom, J.**, (1995) T*he Educational Demands of Networking Development in Lithuania.* [On-line]: Available: www.isoc.org/HMP/PAPER/110/html/paper.html, Accessed: 12 Dec 2005
3. **Ramsden, P.**, (2003) *Learning to Teach in Higher Education*, 2nd Edition; Routledge Falmer, London; ISBN 0-415-30345
4. **Hamilton, J. S.**, (1997) *Collaborative Learning: teaching and Learning in the Arts, Sciences, and Professional Schools*, 2nd Edition, Published by Center for Teaching and Learning, Indiana University, USA
5. **Beatty, L.**, (2003) *Supporting Learning From Experience*. In Fry, H., Ketteridge, S. and Marshall, S. (2003) Editors, A handbook for Teaching & Learning in Higher Education: Enhancing academic practice. 2nd Edition. Kogan Page. London. ISBN 0-7494 3799 5
6. **Dunn, L., Morgan, C., O'Reilly, M. and Parry, S.**, (2004), *The Student Assessment Handbook, New Directions in Traditional & Online Assessment*, RoutledgeFalmer, London, ISBN 0 415 33530 2
7. **Knight, P. T. and Yorke, M.**, (2003) *Assessment, learning and employability. Society for Research into Higher Education & Open University Press*, Maidenhead. ISBN 0 335 21228 X
8. **Nicholls, G.**, (2002), D*eveloping teaching and learning in higher education*. RoutledgeFalmer, London, ISBN 04152 36967
9. **Pettit, J. and Mason, R.**, (2003) *Virtual Space, Real Learning: an Introduction to VLEs*. In Fry, H., Ketteridge, S. and Marshall, S. (2003) Editors, A handbook for Teaching & Learning in Higher Education: Enhancing academic practice. 2nd Edition. Kogan Page. London. ISBN 0-7494 3799 5

ESSAY COMPETITIONS - VALUABLE FEEDBACK FROM ENGINEERING STUDENTS

John Davies[1] **and Carol Arlett**[2]
[1]Coventry University, United Kingdom
[2]Higher Education Academy Engineering Subject Centre, United Kingdom

INTRODUCTION

This paper considers the use of essay competitions for gaining student feedback on engineering education. It refers particularly to essay competitions for engineering students run in recent years by the Engineering Subject Centre of the HE Academy. It considers the characteristics of this approach to gaining student feedback and describes some other examples of essay competitions used for similar purposes. It describes the organisation of the competitions run by the Engineering Subject Centre and assesses the level of engagement by academic staff and students. It summarises the feedback on experiences of engineering education that has been gathered by these competitions so far.

The Engineering Subject Centre of the UK Higher Education Academy (previously 'LTSN Engineering') is the national support centre for all UK engineering academics, promoting quality learning and teaching by encouraging the sharing of good practice and innovation through a variety of mechanisms, including providing events and producing resources. In 2003/04, 2004/05 and 2005/06 the Engineering Subject Centre has run student essay competitions. The idea started from a simple desire to gather student views on engineering education. It was hoped that the shortlisted essays published on the website would be a useful resource for engineering lecturers. Another incidental but valuable aim was to increase the involvement of students with the subject centre.

The title in 2003/04 was 'What makes a good engineering lecturer?'. In 2004/05 it was 'What makes the best learning experience for an engineering student?'. The competition is being run again in 2005/06, with the title 'How does your experience of your course compare with any expectations you may have had?'. The 2004/05 and 2005/06 competitions have been run simultaneously by other subject centres.

ESSAYS AS FEEDBACK

As a method of gathering student feedback, an essay competition differs in a number of ways from the usual student feedback mechanisms. Most student feedback is collected in the context of a particular institution, for a specific part of a course, delivered by specific individuals. A feature of these competitions is that they are not institution-based. The exercise has created a resource in which no individual academics are being judged - at least not in a readily identifiable form. The titles have encouraged emphasis on positive rather than negative aspects. And because students have freedom to write what they want (in response to the title), some of the submissions are very entertaining. A thorough judging process has ensured that the best essays have been identified, and these are available to engineering lecturers via the Centre's website. They form a valuable resource: well thought out and well expressed insights into students' preferences in learning and teaching.

In each year, a specific title has been set. Other similar student essays competitions, with the aim of eliciting student feedback on teaching and learning experiences, are often less specific about title. For example, HE Academy, Health Sciences and Practice, has run a competition for a number of years starting in 2001. The competition has asked for essays on learning experiences but a specific title has not been specified. A commentary on the winning essays in 2001, 2002 and 2003 has been published on the website (McKee[1]). This identifies the main themes and concludes, 'through research we will examine more closely what it is really like in higher education for both tutor and student, grounding definitions of good practice in an understanding of the realities on the ground.'

The University of St Andrews learning and teaching unit (SALTIRE: St Andrews Learning and Teaching: Innovation, Review and Enhancement) has an annual student essay competition across all subject areas in which students are invited to ‘review their learning experiences here at St Andrews in a creative, succinct and meaningful way’ (University of St Andrews[2]). The winners are published on the website. The essays are on a very wide range of topics. No overall analysis has been carried out so far - the essays are considered to be a resource in themselves.

Clearly a successful exercise of this sort can be conducted without specifying a title, but then, obviously, it will not necessarily draw out comments in specified areas.

ORGANISATION

The idea of running the competition came up at an Engineering Subject Centre Management Committee meeting and was taken up enthusiastically by Centre staff. This was because it seemed to achieve a number of goals: making the subject centre better known among engineering students, using and celebrating what students might have to offer, eliciting views that would be of interest to engineering lecturers, and creating an opportunity to publicise the work of the Engineering Subject Centre generally.

The primary aim of the design of the competition was simplicity – to make it easy for lecturers to understand and promote, for students to participate in, and for the Subject Centre to run and assess.

The information for lecturers was kept simple with promotional material supplied to them by web and email. The Subject Centre supplied them with posters and flyers (if required) and also handled all submissions through an online process. This meant that lecturers could easily participate in many different ways from fairly passive (put poster up in department), through quite active (talk about competition, hand out flyers, remind students of deadline etc) to very active (build competition into module, ensure internal deadline is before competition deadline, and encourage best authors to submit their essays). The Subject Centre Administrator acted as a dedicated contact for lecturers and co-ordinated the whole competition.

For students, the rules were kept to a minimum and made available via posters, flyers and the web. The essay word count was relatively short with a maximum of 1000 words, and as much freedom as possible was given in the writing (within the constraints of the title). The submission process was simple and was known to work well as it had previously been widely and successfully used for similar Subject Centre activities.

The Subject Centre has an established network of Departmental Contacts across the UK higher education engineering community to enable the Centre to communicate with departments effectively (www.engsc.ac.uk/an/contacts/index.asp). The competition was promoted to students through this network of contacts. Initially a few departmental contacts were informally approached and were all enthusiastic in their support of the initiative. The initiative was then advertised on the centre’s email list and engineering academics were asked to volunteer as contacts to receive and distribute the publicity material. The volunteers all then received posters to display around their departments and flyers to distribute directly to their students. In addition, all Subject Centre departmental contacts received one poster and postcards.

Direct online submission reduced the likelihood of errors or ‘lost/late’ entry complaints. A similar assessment process to conference/journal paper review (see below for more details) was used, keeping the required assessment of the reviewers to a minimum and ensuring the active involvement of senior academics from across the UK.

Sponsorship and publicity were obtained retrospectively once support for the competition and quality of entries was known.

In 2003/04 the Centre received 29 entries from engineering students at the following nine institutions:

- University of Bristol
- University of Brighton
- University of Cambridge
- Cardiff University

- Coventry University
- University of Oxford
- Sheffield Hallam University
- University of Sheffield
- University of Strathclyde

It is interesting to note that students submitted essays from a relatively small number of institutions, with an average of three students per institution. This is possibly due to the motivation of a few lecturers who encouraged their students. However essays were submitted from only 6 of the 24 institutions where academics had expressed a specific interest and volunteered to promote the competition. This suggests that the students themselves were more drawn to the competition at certain universities.

In 2004/05 there was a stronger response, with 43 submissions from engineering students at the following 16 institutions:

- University of Bristol
- University of Cambridge
- Cardiff University
- University of Central England in Birmingham
- Coventry University
- University of Durham
- University of Essex
- University of Exeter
- University of Glasgow
- Imperial College
- University of Liverpool
- University of Manchester
- University of Nottingham
- University of Oxford
- University of Strathclyde
- University of Wales Swansea

Judging in both years followed a similar procedure. Each essay was anonymously reviewed (in much the same manner as conference papers) by two reviewers. One reader was drawn from Subject Centre staff and the other from the Centre's Steering Group, which is made up of senior engineering academics and engineering educators from across the UK. Each reviewer read five or six papers. Each reviewer scored the essays in the following way:

A. Essay deserves Engineering Subject Centre Student Award
B. Essay at least deserves to reach the shortlist
C. Essay not of sufficient quality to reach shortlist
D. Unable to make decision

The results were used to draw up a shortlist. The Centre's Management Committee approved the shortlist and selected the winner. Judges were guided to ask the following questions when making their decision.

- Do you believe that the content of the essay answers the question well? The essay may be humorous or totally serious, relate to personal experience or be more general – however, use of a particular style may make you feel that it makes the essay particularly outstanding.
- What are your views on the essay structure and writing style, grammar, spelling etc? We obviously wish to publish something written to a high standard.
- Do you believe that the essay could ultimately be used to form the basis of a resource for the Subject Centre? For example, is the content of the essay constructive?
- Is the essay of sufficient quality (e.g. stands out from the crowd) to be worthy of national exposure and therefore a national award?

In both 2003/04 and 2004/05, 11 essays were shortlisted and published on the Centre's website where they are still available:

www.engsc.ac.uk/an/student_awards/archive

Some of the clear messages from the shortlisted essays together with selected extracts are presented below.

2003/04 – WHAT MAKES A GOOD ENGINEERING LECTURER?

There were some areas of clear consensus in the shortlisted essays. Virtually all refer to three characteristics: that a good engineering lecturer

- is enthusiastic
- gives clear, well-structured presentations
- uses real-world engineering examples backed up by industrial experience

A number of the essays specifically place enthusiasm (or passion) at the top of the list. John O'Brien, first year Engineering student from Cambridge and the eventual winner, says, '*Enthusiasm is the single most important trait that a lecturer can have . . . (It) will make the students listen, and it will make them want to learn*.'

Lecturers should be good speakers and speak with clarity. Lectures should be well structured. These points are made, sometimes briefly, in nearly all the shortlisted essays. A few point out that since students are expected to make presentations themselves they should see good examples from their lecturers. Adam Carins, first year Civil Engineering student at Coventry, says: '*good lecturers know that their lecturing style will be adopted by some of their students as a model, if not during their time at university then later in their engineering careers*'.

Use of practical real-life engineering applications and examples is widely valued. That lecturers should have industrial experience is also seen as important by many. Andrew Von Hirschberg, third year engineering student from Cambridge, points out that 'it is all too easy to spot a lecturer who has spent his whole life in education and merely conveys the bones of the subject matter without the flesh that real life would provide.'

It is significant to note therefore that the number of lecturers with industrial experience may be decreasing. In relation to UK civil engineering education for example, the Joint Board of Moderators (of the Institutions of Civil, and Structural, Engineers), in its Annual Report for 2003 (JBM[3]), expresses concern that there is 'pressure on departments to recruit new staff with a proven research record . . . [with the result that] suggestions in the recruitment process that new staff should have practical experience may be carrying insufficient weight'.

The full text of the 11 shortlisted essays is available on the Engineering Subject Centre website (address given above) where a fuller commentary on the content is also available.

2004/05 – WHAT MAKES THE BEST LEARNING EXPERIENCE FOR AN ENGINEERING STUDENT?

The 2003/04 essays had consistently placed emphasis on the role of a lecturer in delivering of lectures rather than in stimulating learning in other ways. Partly for that reason the 2004/05 title deliberately placed the emphasis on the student not the lecturer. Perhaps because the students were less comfortable writing about themselves than they were writing about other people, the 2004/05 essays tend to be less lively - certainly less entertaining - than the 2003/04 essays. Also, perhaps because there are more students than lecturers, or more learning styles than teaching styles, there is a less clear consensus in the 2004/05 essays. But each essay represents a valuable insight into the learning preferences of the writer.

Martin Stanley, fourth year Civil and Environmental Engineering student at Imperial College London and the eventual winner, states his preferences in this way: '*all engineering students need to be taught the theory behind whatever discipline they are studying. This should not be sacrificed in order to attract more students, to the detriment of future projects. However, in order that students can learn, as well as being taught, opportunities should be made available both within university and, where possible, in industry, for students to experience engineering at first hand. It is these experiences that have proved to be the best learning experiences for this civil engineering student*.'

The 2004/05 title was used by other subject centres within the HE Academy. In total 200 essays were received by 18 subject centres. The overall winner was Jessica Haglington, a second year student in the Department of Biological Sciences at the University of Exeter (HE Academy (4)). She summarises her ideal mix of learning experiences ('ingredients') as follows.

'*Although quality ingredients are fundamental to a good learning experience, much more is needed to make a fantastic one. It is not merely the departmental resources or quality of teaching staff that makes a degree exceptional, but the extra touches of spice and individuality* *that can personalise studies and make them relative to peoples' own experiences. As with life itself, a Biology degree needs to constantly evolve and adapt to meet the needs of its students. And like a good meal, it can completely awaken all of the senses. It can provide an enriching and fulfilling experience that just like a satisfying dinner, can provide enough intellectual sustenance for a memorable learning experience, and ultimately, a rewarding career*.'

2005/06

The competition is being repeated in 2005/06, by the Engineering Subject Centre and by all other Subject Centres within the HE Academy. The title is 'How does your experience of your course compare with any expectations you may have had'. Again there will be a student winner within Engineering (and the other subjects), and a winner overall.

CONCLUSIONS

Through good promotion, and the enthusiasm of staff and students, some fascinating accounts of the student experience of engineering education are emerging from the student essay competitions run by the HE Academy Engineering Subject Centre.

A thorough judging process has ensured that the best of the essays are available as a valuable resource for engineering lecturers via the Centre's website. A commentary on the 2003/04 essays (on 'what makes a good engineering lecturer?') is also available on the website.

Participation in the Engineering Subject Centre competition increased significantly between 2003/04 and 2004/05, and the involvement of the other subject centres of the HE Academy in 2004/05 and 2005/06 means that the resulting resource will have even wider interest.

The Subject Centre is achieving its aims for the competition: creating a useful resource for engineering lecturers and increasing the involvement of engineering students with the Centre.

The shortlisted essays are well worth reading. They provide student feedback on engineering education given freely, with great enthusiasm, with more than a smattering of humour, and often with genuine warmth.

REFERENCES

1. **McKee, A.**, 2006, *Reflections on student essays*. www.health.ltsn.ac.uk/publications/studentessay [accessed January 2006]
2. **University of St Andrews**, 2006, *Student Essay Competition* www.standrews.ac.uk/saltire/Students/essay_competition.php [accessed January 2006]
3. **JBM**, 2004, *Annual Report for 2003*. Joint Board of Moderators, Institution of Civil Engineers, London.
4. **Higher Education Academy**, 2005, *Student awards winners*. www.heacademy.ac.uk/news/media/Student_Essays_2005 [acessed January 2006]

CASE STUDY RESEARCH INTO AUSTRALIAN MECHANICAL ENGINEER ATTRIBUTES

Clive Ferguson
Deakin University, Australia

ABSTRACT

The 1996 Johnson report on Australian engineering education recommended the development of a limited number of broadly defined attributes in engineering graduates as well as a broader based engineering education. Within a year the Institution of Engineers, Australia responded by switching the focus of its engineering course accreditation to graduate attribute outcomes. It was to be the role of engineering school advisory panels to give greater definition to those attributes, but the scope of engineering is broad and the views of advisory panel members are largely influenced by their own often unique professional formation.

This paper presents a single discipline case study approach to identify the relative significance of a wide range of attributes required for the most common mechanical engineering roles in those industries that employ the greatest number of Australian mechanical engineers. Six industries were identified that between them employ more than half of all Australian mechanical engineers, and most frequent or generic mechanical engineering roles within those industries were studied.

Key findings of this research are then reviewed in the context of changing global engineering environment and educational practices.

INTRODUCTION

In 1996 the Johnson report(1), a stakeholder review of Australian engineering education, recommended a broader engineering education and the development of a number of graduate attributes. The following year the Institution of Engineers, Australia (now Engineers Australia) responded with a fundamental shift in course accreditation policy from a focus on course content to one on graduate attribute outcomes(2) and was revised with only minor changes in 1999. This essentially represented the adoption of the functional analysis development of competency based education and training (CBET).

Washington Accord Attribute and Professional Development Frameworks were developed over the period 2003 to 2005 resulting in new Engineers Australia Stage 1 Competency Standards for the accreditation of engineering degree programs(3). In this the limited range of attributes was increased and for the first time the attributes were expressed in the format of functional analysis where ‘Units of Competency’ are broken down into assessable ‘Elements’ and ‘Performance Criteria’ are specified to enable assessment of the performance in each element(4).

Conceptually this principle is a major breakthrough in the educational formation of engineers. However as Engineers Australia is an institution for all Australian engineers regardless of discipline, the attributes are loosely defined to fit all disciplines.

Industry members of engineering school advisory panels were to give greater definition to those attributes for the various engineering courses of the engineering school to enable more focused effective and efficient educational formation of graduate engineers. However the views of the engineering school advisory panel members are subjectively influenced by their own engineering education and range of industrial experiences.

This role-based case study research presents key findings of an analysis of the relative significance of an extensive range attributes required for mechanical engineering practice in Australia. Associated with this research is an historical and contemporary study of

(All) Mechanical Engineers		Graduate Mechanical Engineers		
Industry	**% PERS**	**Industry**	**% GES**	**% GDS**
Consulting and Technical Services	16.2%	Consulting	15.6%	16.4%
transport Equipment manufacturing	12.6%	Mining	9.7%	8.5%
Electricity and Gas Supply	8.1%	Transport Equipment manufacturing	9.2%	–
Mining and Quarrying	6.7%	Defence	–	9.2%
Construction Contract and Maintenance	6.3%	Financial Insurance Property and Business	–	8.5%
Defence	5.6%	Construction	8.1%	5.9%
Industrial Equipment manufacturing	4.7%	Electricity and Gas	6.0%	2.18%

TABLE 1 - Industry employment profile of Australian mechanical engineers and graduate mechanical engineers

PERS: Adjusted distribution of mechanical engineers by industry based on the adjusted APESMA Professional Engineer Remuneration Survey data.

GES: Based on data from the APESMA Graduate Engineer Survey.

GDS: Based on data from the Graduate Destination Survey by the Graduate Careers Council of Australia with allowance for public sector employment.

mechanical engineering (5,6) providing essential context for the outcomes of this research.

METHOD OF ENQUIRY

Case studies were carried out through interviews with engineering managers responsible for both Stage 1 and Stage 2 engineers[1] engaged in the most common mechanical engineering roles in the industries that employ the largest proportions of Australian mechanical engineers.

Table 1 summarises the statistical analysis of the industrial employment profiles of all Australian mechanical engineers and of Australian newly graduated mechanical engineers.

Data for the industrial distribution of all engineers were derived from the Association of Professional Engineers, Scientists and Managers, Australia (APESMA) Professional Remuneration Survey Data[2] taken over a number of years and adjusted to account for public sector bias. The analysis shows the industries Consulting Engineering, Transport Equipment Manufacturing, Electricity and Gas Supply, Mining and Quarrying, Construction Contract and Maintenance, and Defence, together employ more than 50% of (all) Australian mechanical engineers. The analysis also shows that in Australia the employment of mechanical engineers in manufacturing is dominated by transport equipment manufacturing and in turn that is dominated by the automobile industry.

Data for the industrial distribution of graduate engineers was similarly derived from APESMA/

[1]The definitions of Stage 1 and Stage 2 engineers are broadly in line with the Engineers Australia definitions: a Stage 1 engineer is a BE graduate with less than three years professional experience and a Stage 2 engineer is one with greater than 3 years professional experience and thus is eligible to apply for full chartered membership.

[2]These were derived from unpublished data kindly provided by Dominic Angerame, Research and Surveys Manager of APESMA.

Institution of Engineers, Australia Graduate Engineer Survey Data and the Graduate Destination Surveys of the Careers Council of Australia. The latter lists those in the public sector separately from the industries they serve. Adjustment for this factor was derived from the adjusted public/ private sector proportions for each industry obtained from the APESMA professional remuneration survey data.

The main companies or organisations selected to represent those industries were those with the greatest number of mechanical engineering respondents to the IEAust/ APESMA graduate engineer surveys within those six industries. As all operate internationally, have international partnerships or are part of global organisations, their attribute significance responses should address global requirements.

For two industries it was felt necessary to use two or more complementary companies/ organisations to provide balanced representation. For the Transport Manufacturing industry a major tier supplier supplemented the prime manufacturer. For the Defence industry case studies with a private contractor (munitions R&D and production roles) supplemented those from Australian Defence Force divisions responsible for R&D and project management. Mechanical engineers directly employed in the armed services (army navy and air force) were not included in this study.

An eighty four attribute survey instrument was developed. It extended the 10 attributes of the 1999 IEAust accreditation manual by:

- Breaking attributes down (e.g. communication skills were broken down into various forms of written and oral communication);
- Including attributes more specifically related to mechanical engineering roles (e.g. 3D visioning, dynamic visioning);
- Including a wide range of attributes from numerous surveys relating to the desired attributes of graduates – both engineering graduates and graduates in general; and
- Including personal attributes (e.g. interpersonal skills and time management)

Further, as ‘engineering knowledge base’ and ‘mathematical skills’ universally form the core of undergraduate mechanical engineering degree programs they were also included for comparison.

Each study participant was asked to assess the significance of each attribute to the execution of the role as required of a Stage 1 engineer and of a Stage 2 engineer and to assess the average ability of recent graduates in that attribute.

Five point Likert scales were used. For the attribute significance the five points were ‘no use’, ‘rare’, ‘occasional’, ‘significant’ or ‘essential’. For graduate ability they were ‘none’, ‘poor’, ‘moderate’, ‘significant’ and ‘excellent’. Respondent were allowed to straddle the Likert points. For example they could assess an attribute as ‘rare’ to ‘occasional’.

To minimise *measurement error*[3] a response block definition of terms was provided to reduce variations in interpretation. All study participants were asked to read this before the interviews and keep it at hand for reference throughout the interviews.

To avoid conflict between concepts of ability level and the level of significance of an attribute to a role, respondents were asked to consider only the significance of the attribute to that role regardless of the necessary ability level. For graduate ability the requirement was for an assessment relative to the level required for the role.

In the analysis numerical values ranging from 0 for ‘no use’ to 4 for ‘essential’ were applied to the results for the level of significance of an attribute to a role. Similarly values ranging from 0 for ‘none’ to 4 for ‘excellent’ were applied to the results for graduate ability. Weightings relating to assessments of the proportion of Australian mechanical engineers in each role were applied before averaging the results across the roles to produce attribute ratings, and calculating variances.

Seventeen mechanical engineering roles at both Stage 1 and Stage 2 engineer level across

[3]*Measurement error* is the difference between the respondants answer and the ‘correct’ answer.

	New Graduate Ability Groups	Average Rating	Stage 1 Engineer Attribute Groups	Average Rating	Stage 2 Engineer Attribute Groups	Average Rating
1	Mathematics	2.89	Communication	2.92	Management	3.51
2	Personal Attributes	2.83	Management	2.91	Communication	3.48
3	Communication	2.45	Personal Attributes	2.81	Personal Attributes	3.24
4	Management	2.38	Problem Solving	2.79	Problem Solving	3.23
5	Research Skills	2.36	Computer Skills	2.77	Design	3.17
6	Information Sources	2.15	Information Sources	2.71	Information Sources	2.97
7	Problem Solving	2.15	Design	2.65	Business Skills	2.83
8	Computer Skills	2.09	Engineering Drawing	2.51	Mechanical Engineering Knowledge Base	2.77
9	Mechanical Engineering Knowledge Base	1.97	Mechanical Engineering Knowledge Base	2.32	Engineering Drawing	2.45
10	Design	1.95	Business Skills	2.25	Research	2.42
11	Business Skills	1.80	Research	2.16	Computer Skills	2.29
12	Engineering Drawing	1.66	Mathematics	1.78	Mathematics	1.78

Table 2: Group average ratings

the six industries were studied. Several of the seventeen roles were generic roles combining several roles with fewer engineers and taking weighted averages of attribute significance.

RESULTS

To enable a perspective overview, attribute ratings were grouped and group average ratings are presented in **table 2**.

Personal Attributes

The Personal attributes group included Foreign Language skills which were rated rare overall and significant in only one role. All of the remaining attributes in this group - time management, social/ interpersonal skills, flexibility, conscientiousness, reliability, and the expectation and capacity to undertake lifelong learning - were considered essential in most roles for a Stage 2 engineer. The removal of the attribute Foreign Language skills from the Personal Attribute group makes this the most significant group for Stage 1 and 2 engineering roles and graduate abilities.

With the exception of time management skills graduate abilities in the remaining attributes were rated significant or better. Graduate ability in time management was rated moderate to significant. One survey participant pointed out that this represented a noticeable improvement over the last decade and suggested that it was probably due to the need for students to take on increasing hours of part time work to support their studies.

Management and Communication

Table 2 shows Communication and Management to be the most significant attribute groups with strong correlation of graduate ability to role significance.

Planning and Organisation Skills (including self-management) were considered essential for all Stage 2 engineers. Other skills considered essential in most roles were:

- Occupational Health and Safety (OH&S);
- Team Skills;
- Leadership;
- Project management Skills; and
- Ethics.

Only Team Skills and OH&S were considered essential for most Stage 1 roles. New graduates were assessed as having significant Team Skills, reflecting an increasing emphasis in engineering courses over the last few decades. They had moderate to significant skills in all other attributes but OH&S, Project Management and Political Awareness, which were less than moderate.

The most significant forms of written communication (reports and emails) and all forms of oral communication (seminars, meetings, one-to-one technical and one-to-one non-technical) were considered essential for most roles at Stage 2 level.

Problem Solving and Design

The attribute Recognition and formulation of a problem was considered an essential skill for Stage 2 engineers across all roles. The Application of Science and Engineering fundamentals, Broad engineering knowledge base, Ability to recognise when to use engineering analysis and Critical thinking were also considered essential problem solving skills for roles at Stage 2 level.

The Application of standards and statutory regulations was rated an essential design skill for a Stage 2 engineer in almost all roles[4] but was the worst rated graduate attribute. The following were considered essential design skills for Stage 2 engineers in most roles:

- Ability to sense the design looks sound:
- Ability to know when to call in a specialist;
- Documentation;
- Ability to recognise calculations are 'in the right ballpark';
- Customer oriented;
- Dynamic visioning; and,
- 3-D visioning.

Mechanical Engineering Knowledge Base

The relatively low role rating for the mechanical engineering knowledge base group is a factor of averaging the significance of each mechanical engineering subject specialism across all roles and belies the fact that for most roles at least one mechanical engineering subject specialism is essential. All roles list at least one as significant. Nevertheless the overall rating for graduate ability in the mechanical engineering subject specialisms – the core of mechanical engineering undergraduate pro-grams – is less than moderate and should be of concern.

A more reliable overall assessment of the significance of the mechanical engineering knowledge base can be inferred from the problem solving and design group attributes for which the mechanical engineering knowledge base is an enabling attribute. These include:

- Broad engineering knowledge base (1.85; 3.11; 3.69)[5] ;
- Application of science and engineering fundamentals (2.81; 3.41; 3.67);
- Recognise when to use engineering analysis (1.95; 3.11; 3.67);
- The ability to know when to call in a specialist (1.66; 2.65; 3.56); and
- In-depth discipline knowledge (2.04; 2.97; 3.30).

As expected, the poor level of enabling mechanical engineering subject specialism skills is reflected in the generally poor ratings of graduate ability in these attributes (with the exception of the application of science and engineering fundamentals).

Mathematics

Like the Mechanical Engineering Knowledge Base, Mathematics is traditionally and universally the core of university mechanical engineering courses. In contrast the average graduate engineer's mathematical skills are considered significant (relative to the requirements of the role) in all forms of mathematics but statistics, whilst their average direct use in engineering practice is less than occasional. Nevertheless they remain essential

[4]This was the most significant Information source attribute for stage 2 engineers.

[5]The first number in the brackets is the rating of the new graduates' abilities; the second number is the attribute rating for a Stage 1 engineer; and the third is the rating for a Stage 2 engineer.

enabling skills in the formation of the engineering knowledge base.

Geometry and Statistics are considered most significant with nearly half considering Geometry to be significant or essential at Stage 2 level. The increasing adoption of 6 Sigma is anticipated to increase the significance of statistics in a number of roles particularly in the automotive industry.

Improved Attributes

The ratings for many of the mechanical engineering graduate abilities previously assessed as deficient such as effective communication skills(7,8), lifelong learning (7,9), team skills(7,10) and time management(8) are now rated substantially better than moderate, or significant. Whilst some improvement in these deficiencies may be credited to engineering school initiatives, much can also be credited to key competencies developed in secondary school and other factors. Graduate abilities in other attributes previously assessed as deficient e.g. critical thinking, intellectual curiosity, independent thought and problem solving(7), appear also to have improved but only to a moderate ability level.

KEY CONCLUSIONS

During a period of competency focus in secondary and higher education, graduate abilities in many attributes previously considered of concern such as team skills appear to have improved significantly and are generally rated moderate to significant. However the graduate ability of the mechanical engineering knowledge base is generally rated as moderate or less.

Few roles have every mechanical engineering subject specialism highly rated whilst attributes for which the subject specialisms are enablers, such as Broad Engineering Knowledge Base, were highly ranked. This prompts the recommendation that mechanical engineering courses develop a broader engineering knowledge base in the first degree and advanced knowledge in selected specialist topics appropriate to the intended mechanical engineering career role in a subsequent master's degree.

REFERENCES

1. **Johnson, P.**, 1996 *Changing the Culture, Engineering Education into the Future* IEAust, Canberra, Australia.
2. **IEAust.**, 1997 *Manual for the Accreditation of Professional Engineering Courses* IEAust, Canberra, Australia
3. **Bradley, A.**, 2005 *Engineers Australia National Generic Competency Standards – Stage 1 Competency Standards for Professional Engineers*. Engineers Australia, Canberra, Australia
4. **Ferguson, C.**, 2001 '*Competencies and Attributes' in Engineering the future - Preparing Professional Engineers for the 21st Century.'* Lloyd, B.E., Ferguson, C., Palmer, S., and Rice, M.R. APESMA in association with Histec Publications, Melbourne, Australia.
5. **Ferguson, C. and Lloyd, B. E.**, 2004 *International Conference on Innovation, Good Practice and Research in Engineering Education* 3,147-152.
6. **Ferguson, C.**, 2006 *Defining the Australian Mechanical Engineer* (accepted for publication in European Journal of Engineering Education)
7. **Prescott, J.**, 1992 *Education: A Foundation for the Wealth of Nations*, Business/Higher Education Round Table, Melbourne, Australia.
8. **Burtles, S.**, 1992 *A study of postgraduate training supported by the SERC's Engineering Board*, Science and Engineering Research Council, London.
9. **West, R.**, 1998 *Higher Education Review - Final Report* DEETYA, Canberra
10. **Fairclough, J. E.**, 1995 *Competence and Commitment*, The Engineering Council, London.

ASKING CULTURALLY NEUTRAL QUESTIONS IN ENGINEERING

Peter Goodhew
University of Liverpool, United Kingdom

SUMMARY

Specific problems can arise in classes containing students from a variety of cultures with different experiences, attitudes and expectations of education, and often a very different range of relevant engineering experiences. It is possible inadvertently to set assessment questions or tasks which require responses of a type which are unfamiliar or antipathetic to the student, which use vocabulary which is not understood in a sufficiently sophisticated way or which implicitly require a set of experiences or knowledge which not every student possesses. There is very little literature on this topic relating to engineering students. In this paper I cite several examples of culturally loaded questions and suggest that all engineering assessments should be scrutinised from the cultural perspective.

INTRODUCTION

‘*Some academics . . . write exams in which part of the challenge is to work out what the question means before answering it. Too often academics applaud this approach for being ‘clever’, claiming that assessment is to sort out the sheep from the goats, and understanding the question’s true meaning is part of that. ‘Nice one’, their colleagues say, ‘the clever ones will work it out’. But we do not include ‘cleverness’ among the intended learning outcomes. . .*’

Phil Race, The Higher,
December 23rd 2005.

We may not intend to write ‘clever’ exam questions but without sensitive scrutiny some difficult-to-decode questions may slip through the net.

It is self-evident that all students are different. It is equally clear that for every student in a cohort, the assessment associated with that module is the same. This is usually true for both the method(s) of assessment and for what is assessed. If, as is now regarded as good practice, the assessment is intended to verify the achievement of the intended learning outcomes, then it seems obvious that it must be the same for every student. This is surely required to ensure equity of treatment among students and between groups of students, and to establish confidence in the evidence provided by the assessment outcome (e.g. exam mark).

On the other hand, there is plenty of evidence (both academic and derived from common sense), for the difficulty of devising assessments which are totally free from bias towards or against one or more groups of students. There is a substantial literature relating to unintentional bias in assessment. Researchers have identified the potential for bias arising from cultural differences, gender difference, disability and other factors(1-6).

BIAS IN ENGINEERING ASSESSMENT

Let us define a ‘neutral’ assessment item (exam question or any other type of assessment) as one in which every student has an equal opportunity to demonstrate the extent to which they have met the intended learning outcome (ILO) which is being tested. The item must therefore relate to an ILO which has been published to the students in advance, and it must be phrased so that the way in which the ILO should be demonstrated is clear to the student at the time of the assessment. In less pompous words, the question should be clearly understandable and relate to the appropriate curricular content. This is easier to write than to achieve.

There are a number of features of engineering education, at least in the UK, which either increase the difficulty of devising neutral assessment exercises or tend to disguise the presence of bias. Among these are:

- A high percentage of students for whom English is not their first language. This can be as high as 50% in many classes. In many UK universities the Engineering Faculty contains the highest proportion of overseas students in the university.
- Many classes contain students from several quite different cultural backgrounds. For these purposes there are significant cultural differences between students within Europe (Northern Europe vs Eastern Europe vs Mediterranean Europe for instance) as well as between the continents and sub-continents of Asia, America and Africa. Not least among the differences is the understanding of what an engineer is and does – the very word has no universality of meaning.
- A significant content of practical work, in laboratories and on field trips.
- A large mathematical content, which can often mean that connected prose writing is not required in order to meet many of the ILOs, but on the other hand;
- A professional milieu which demands clear reporting, both written and spoken, and a proportion of professional (as opposed to technical) material such as project management and business skills.
- The high cost of provision of a good engineering education, because of the need for laboratory space, equipment, materials costs and high staffing levels to ensure safety and practical skills training.

The net effect of these factors on assessment is that there will be items which are essentially numerical, mathematical, practical, oral and essay-based, but that no one of these forms dominates. These items will be attempted by students who have different English language skills, different understanding of engineering and different expectations of higher education, for which they may be paying an apparently high price. It is therefore quite easy for biased items to be hidden within this welter of assessment styles.

Types of Bias

Level of ILO. In higher education we expect to be assessing ILOs at all six levels of Bloom's taxonomy – simply expressed as knowledge, comprehension, application, analysis, synthesis, evaluation(7). However these are merely the levels of cognitive skills, based around knowledge. In a professional engineering education we also expect to develop (and therefore must test) the affective and psychomotor domains, that is attitudes and practical skills. I suggest that we nowadays rarely test practical skills, although our students are often exposed to practical experiences, and we almost never assess attitudes. As Elton(6) rather resignedly reports 'The difficulty with designing attitude assessments is that in traditional forms of assessment, e.g. essays, it is almost impossible to distinguish a genuine attitude from a pretended report.' However, he offers no alternative!

In the domain of cognitive assessment, which is in practice where most engineering assessment items remain, the first two levels of Bloom's taxonomy present relative few problems (but not none – see below). We can assess knowledge (level 1) by demanding the recall of information and comprehension (level 2) by asking for an explanation in the student's own words. Even at this level we meet a cultural issue – it is deeply embedded in many (predominantly Eastern) cultures that there is no point in re-writing the words of a great master, because s/he has already expressed the ideas to perfection and it would be discourteous to paraphrase. Although many academics would have difficulty describing themselves as a great master, nonetheless this is how they may be viewed by some students. This issue can only be addressed by attempts to change attitudes prior to assessment, and is often tackled in the (unfortunately pejorative) context of plagiarism.

At level 3 and above (application, analysis, synthesis, evaluation) potential problems of bias abound. Words we might use in assessment items could include analyze, categorize, compare, compose, contrast, create, criticize, critique, deconstruct, defend, demonstrate, design, devise, discriminate, distinguish, evaluate, generate, interpret, illustrate, justify, manipulate, modify, plan, predict, relate, reconstruct, relate and show. Each of these requires a sophisticated grasp of language as well as the required cognitive understanding. At levels 5 and 6 (synthesis and evaluation) a critical approach is essential and it would be impossible to demonstrate ILOs at these levels without using words and phrases which had come neither from lecturer nor book.

The above paragraphs have focused on answering the question. This is predicated on the writing of a clear question, which has two elements – the use of a vocabulary which is understood and the use of contextual examples which can be interpreted on the basis of the student's prior experience. An extreme example illustrates this latter point. Many universities in South Africa are now teaching engineering to a cohort of students some of whom have grown up in townships without electricity. Following a course on materials selection it would not be helpful to base an assessment on the reverse engineering of a 13 amp plug (which is an example used in many UK universities).

More subtle examples can be found when teaching management or business studies to engineers. A module on Project Management at Liverpool is given to a large class drawn from every engineering discipline, computer studies and some pure sciences. To assess at level 3 (application of knowledge in a new situation) it is necessary to select a number of 'new situations' but to choose them in such a way that they are equally accessible to all the students. This rules out using excellent project scenarios based on dam-building (familiar to the Civil Engineers but to no-one else), or software engineering, or car manufacture, or banking or in fact almost anything! A level 3 question such as 'devise a work breakdown structure for . . . (some familiar process)' is very difficult to write in a neutral manner. What process is familiar enough to all students? No industrial process, certainly. One cannot assume that every student has, and has taken apart, a car, or even a bicycle. The unfortunate result is that the remaining scenarios are mundane, unexciting and tend to lack complexity – which is the key aspect which makes a task worth undertaking as a project. Domestic scenarios like 'preparing a meal", as well as being seen as trivial, are in fact not universal. Quite a number of students have never prepared a meal from raw ingredients, as becomes evident on reading their answers.

Similar issues arise from a question designed to allow students to be creative in the context of a SWOT analysis. The obvious question is 'Analyse the Strengths, Weaknesses, Opportunities and Threats of the following proposition, and then make a recommendation whether it should be adopted.' It is very difficult to then identify a neutral proposition. Consider the proposition 'let us build a fourth Mersey tunnel for the use of pedestrians and cyclists.' However, many Liverpool students, although aware of the existence of the road and rail tunnels, have never been through any of the existing tunnels and do not understand how they were and are funded, so a proper analysis is not available to all students. In an attempt to use only concepts known to everyone, I used the real proposition (reported in The Times) 'An advertising company should rent advertising space on students' foreheads.' This appears to be totally neutral: surely every student understands advertising and certainly every one has a forehead. However on reading 220 answers (some very imaginative) it became clear that a small minority (2 or 3%) of students did not understand the word 'forehead'. This was clearly a failure of general (not technical) vocabulary, but it arose from the most thoughtful and well-meaning intentions.

Vocabulary. The vocabulary available to students is worthy of separate consideration. There have been many studies of the vocabulary skills of school students; one of the most relevant is by Farrell and Ventura(8), who looked at the technical and non-technical vocabularies available to 300 17 year old A-level physics students. These are the students from whom Engineering undergraduates are drawn one or two years later. Farrell and Ventura measured both the claimed understanding and the actual understanding of 50 non-technical and 25 technical words, all taken from A level exam papers. Their results revealed some astonishing disparities, even among non-technical words. 96% of the surveyed students claimed to understand 'transmitted' whereas only 30% could explain or define it. The equivalent results for 'qualitative' were 66 and 29%; for 'marked' they were 82 and 12% and for 'significant' 91 and 46%. The situation was similar for technical words. For example 'couple' scored 97 and 24%. The conclusion must be that we cannot assume that the vocabulary used in assessment items can be universally understood, even when questions are couched in 'ordinary' English. Particular misconceptions revealed by Farrell and Ventura included 'qualitative' meaning 'of fine quality' and 'yield point' defined as 'the amount given out'.

My own experiences recently revealed first year engineering students who did not understand 'opaque' or 'inflammable'. The vocabulary used in the last three years' exam papers on Project Management in Liverpool included the following words which were not defined in classes:

Assembly, auditor, balanced, batch, blizzard, chromium, client, construction industry, deadline, deliverable, finishing, functional, generalist, Human Resources Department, machining, morale, particulate, polishing, process, rapid prototyping, resource, revenue, review, sandwich, script, shooting (of film), stamping, standards, stock, trollies.

It is not clear whether all of these were understood by all students, although their inclusion was intended to give appropriate contextual colour to otherwise dry questions.

There are also cultural and contextual differences of meaning for identical words. This section of the paper started with a discussion of the vocabulary skills of 'school students'. In a recent question it became clear that some students interpreted this to mean undergraduates at university, while others took the intended meaning of secondary school students. Farrell and Ventura(8) give a similar example with the word 'primary'. This is readily understood by A level students in the context 'primary school' but not in the intended context 'of primary importance'.

CONCLUSIONS

Under UK quality assurance procedures examination papers, but not always other assessment items, are usually checked both by the setter and by a moderator. If the assessment is not supposed to be a test of language skills, then it should be checked for technical accuracy, for alignment to the ILOs and for grammatical accuracy. This review indicates that moderators should also be asked to check for unintentional bias. It would not be easy to produce a comprehensive check list for this purpose but the issues and vocabulary discussed in this paper could form a starting point.

Recent trends in engineering education may also help to mitigate the problem of cultural bias. Movements such as CDIO(9) and ALE(10) promote active learning which makes it less likely that any student can remain culturally isolated. Students who are regularly working in teams, making engineered products and considering the engineering context of their studies will have a better chance of absorbing the local engineering (and wider societal) culture.

REFERENCES

1. **Martin, L. T. F.**, 2003, *Cultural differences in risk perception: An examination of USA and Ghanaian perception of risk communication*, MS thesis, Virginia Polytechnic Institute
2. **McCullough, L.**, 2004, *Gender, context and physics assessment*, J International Women's Studies 5, 20-28
3. **Watkins, D.**, 2000, *Learning and Teaching: a cross-cultural perspective*, School Leadership and Management, 20, 161-173
4. **De Vita, Glauco**, 2002, *Cultural equivalence in the assessment of home and international business management students: a UK exploratory study*, Studies in Higher Education, 27, 221-231
5. **Baumgart, N. and Halse, C.**, 1999, *Approaches to Learning across Cultures: the role of assessment*. Assessment in Education: Principles, Policy & Practice, 6, 321-339
6. **Elton, Lewis**, 2003, *Assessing Materials Students*, UK Centre for Materials Education
7. **Bloom B. S.**, 1956, *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. New York: David McKay Co Inc
8. **Farrell, M. P. and Ventura, F.**, 1998, *Words and Understanding in Physics, Language and Education*, 12, No 4, 243-253
9. **CDIO:** *Conceive Design, Implement, operate*, www.cdio.org
10. **ALE:** *Active Learning in Engineering Education network*, www.ale.tudelft.nl