

CREATING A POSITIVE EXPERIENCE FOR DISABLED ENGINEERING STUDENTS

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ABSTRACT

This paper focuses upon the outcomes and outputs of Loughborough University's national project, DART (Disabilities: Academic Resource Tool) <http://dart.lboro.ac.uk/>. The project resources enable an enhanced learning experience for disabled students within Engineering by providing academics with bespoke advice, guidance and resources on developing a more accessible curriculum. The materials have been produced based upon the real-life experiences of disabled students.

This paper highlights the outcomes of a qualitative survey of engineering students with a range of disabilities carried out as part of this project. Twenty-Five student case studies were developed detailing the students' experiences and examining critically the methods used by students, and their academic tutors, to help resolve or ameliorate difficulties encountered. Attention is given to a range of learning and teaching situations including lectures, group-work, laboratory work, fieldwork, site visits, resource-based learning and assessment.

This paper also describes the main features of the web-based DART Tool (<http://dart.lboro.ac.uk/tool>) that provides access to a searchable database. It explains how using the tool enables academic tutors and others to create a more accessible curriculum and overcome the barriers to learning experienced by disabled students. In addition, the results of an extensive evaluation of the tool by academics, disabled students, and disability specialists are discussed.

BACKGROUND

The DART Project was one of 24 projects funded by the Higher Education Funding Council for England (HEFCE) during the period 2003-2005 to support the development of learning and teaching resources to enhance provision for disabled students. Focusing on

Engineering and the Built Environment, the aim of this project was to enhance the experience of disabled students by enabling institutions, departments, and individual academic tutors to assess their current level of provision in terms of how accessible it is for disabled students, and by offering clear guidance on how to improve accessibility.

The DART Project had two main objectives: the development of student case studies based on a comprehensive survey of disabled engineering students, and the development of a web-based auditing and diagnostic tool for use at various levels within Institutions, to address the quality of provision offered to disabled students.

Each student case study was based on an extensive interview with the student, focusing on that student's experiences prior to and during higher education. Particular attention was paid to the student's experience of various learning and teaching contexts such as lectures, laboratory work, group work, accessing online and paper-based resources, fieldwork, and work placement. This was usually supplemented with interviews with academic tutors and academic assistants. In some cases the students were also observed within a particularly problematic learning situation. The aim of this approach was to draw a holistic picture of the student's experiences, and to draw out conclusions and recommendations that would provide academics with practical advice on responding to the needs of such students. Moreover, an overview of the survey material was used to identify common barriers affecting the learning experience of disabled students.

The web-based DART Tool offers tutors and others a resource providing bespoke advice on how to make the curriculum more accessible. Previously academics had to rely, in the main, upon paper-based diagnostic guides. Whilst useful, these lacked the accessibility and immediacy of a web-based option. The DART

Tool provides immediate feedback, access to appropriate case-study materials, and specific advice to academics seeking to meet the needs of their disabled students. Furthermore, the web-based medium means that the DART Tool can be updated with fresh material, examples of good practice, evolving case law etc . . .

SURVEY OUTCOMES

By investigating and understanding the experiences of disabled students it is possible to identify recurring themes. Each student case study developed as part of our survey is unique, but generic lessons can be drawn from the aggregation of the case studies.

Our survey of disabled engineering students highlighted a number of potential barriers faced by disabled students. These included:

- The physical environment
- Institutional policy, practice, and systems
- Programme specifications and regulations
- Staff knowledge and skills
- The design of programme/module learning outcomes
- The communication of programme/module learning outcomes
- Assessment methods
- Delivery methods
- Learning methods
- Group processes

By addressing these potential barriers the learning and teaching experiences of disabled students – and potentially all students – could be enhanced. Inclusive practice and generic guidelines for accessible practice can go a long way to removing the barriers experienced by disabled students.

Nevertheless, whilst generic guidelines for accessible practice may indeed address many issues, it must still be realised that for some students more specific adjustments may still be required. In this respect the individual case studies contextualise the application of generic guidelines, highlighting where an additional response is in order. Such a response may be very individual to the student concerned.

If an over-riding theme emerges from our survey, it is the need for student and tutor to engage in a meaningful an on-going conversation. Regular

communication between student, tutor, and where relevant the institution's disability support services is key to the disabled student having a positive educational experience.

THE DART TOOL

Many academics do not have sufficient experience of working with disabled students to confidently respond to their needs or to offer a fully accessible and inclusive curriculum. This is probably even more so in Engineering where the nature of the activities involved is likely to discourage disabled students from pursuing degree programmes.

In the UK, there is a growing literature of guidance and advice to academics, largely driven by SENDA legislation(1) on how to offer a more accessible curriculum that meets the needs of disabled students. Most of this, however, is quite generalised, and there is little specifically targeted at the engineering academic, the Higher Education Academy Engineering Subject Centre Guide, 'Working with Disabled Students', Hopkins *et al*(2) being a notable exception.

Most guides lack the sophistication to enable academics to both audit their current provision and to diagnose specific action to enhance the learning experience and academic progress of their disabled students. Moreover, most of the available guides are not necessarily readily accessible, being in paper rather than electronic (web-based) format.

This gap in accessible support for academics in Engineering is one that the DART Tool seeks to remedy. The web-based tool enables academics in Engineering to both audit their current provision, and to identify effective practice for a given context. The DART Tool enables users to access a database offering bespoke advice based on the real-life experiences of disabled students within engineering.

The DART Tool: Design and Development

The DART tool has been developed using PERL and a MySQL database. All pages generated are validated as XHTML 1.0 Transitional, and has been developed with the consideration of all users, by checking their compliance with the WAI Content Accessibility Guidelines 1999/05/

05(3). All pages are compliant at support level Triple-A(4).

The design for the database component of the tool is based upon the assumption that a user would enter the database seeking initially some 'general' advice or guidance. Thus, on accessing the tool the user is presented with a matrix that offers the option of choosing a criteria from one of three main routes or entry points into the database. These routes are 'Barriers', 'Context', and 'Disability'. Barriers details those factors that create or provide obstacles to disabled students accessing the curriculum effectively. Context refers to the different learning and teaching modes or mediums used. Disability refers to the type of disability, impairment or condition that the student experiences. Each route contains a range of criteria.

On choosing one of the criteria presented the user is offered: 'general' advice based on the criteria selected, the option – presented as a secondary matrix - of seeking more 'specific' advice by selecting an additional criteria from one of the two remaining routes offered, links to related Case Studies, and links to related sites of interest on the web.

Potential Uses of the DART Tool

The DART Tool can be used by academics for a variety of purposes. Decision-making and practice at Institutional, Departmental and individual academic tutor level can be enhanced through use of the DART Tool. Five potential scenarios - with an indication of how the DART Tool might be of assistance in each example – are presented below:

Addressing the Needs of a First-Year Disabled Student. In addressing the needs of a first-year disabled student a tutor could seek advice by initially reviewing the advice offered within the contextual pages on 'disabled students' and 'accessibility' at the front end of the DART Tool. This advice could then be supplemented by examining the guidance offered about the student's specific disability, impairment or condition through following the 'Disability' route within the DART Matrix. The tutor could also expand his/her understanding beyond the general advice offered by examining relevant student case studies, exploring external

links related to the disability, impairment or condition, as well as refining his/her search by seeking specific advice relating the disability, impairment or condition to criteria under either or both of the two other routes ('Barriers' and 'Context') within the Matrix.

Reviewing the Accessibility of a Laboratory Based Module. In this example an academic tutor could seek advice by initially reviewing the advice offered within the contextual pages on 'disabled students' and 'accessibility' at the front end of the DART Tool. He/she might then select the 'Context' route offered in the matrix of the database. Within this route the criteria ('Laboratory Work') will offer advice appropriate to the task. In addition, other criteria within this 'Context' route (e.g. 'Group Work' and 'Assessment') could offer further relevant advice. The academic could also expand his/her understanding beyond the general advice offered in each criteria by examining relevant student case studies on each chosen criteria as well as refining his/her research by seeking specific advice relating each criteria to criteria from the other routes ('Barriers' and 'Disabilities') by, for example, relating 'Laboratory' to a particular disability.

Introducing a more Inclusive Assessment Strategy for a Work-based Module. In terms of introducing a more inclusive assessment strategy for a work-based module, the tutor might begin by reviewing the advice offered within the contextual pages on 'disabled students' and 'accessibility' at the front end of the DART Tool. Then, he/she might opt to gather advice and guidance by selecting the 'Assessment' criterion from the 'Barriers' route within the DART Matrix. The tutor could then seek more specific advice by relating 'assessment' under the barriers route with 'work placement' under the context 'route'. A further review of the information offered by the links to external sites and case studies might complete this investigation.

Developing more Accessible Programme or Module Specifications. In addressing this scenario a programme or module leader could seek advice by reviewing the contextual information at the front end of the tool, and accessing various criteria from the 'Barriers' route offered in the matrix of the database. Within this route two criteria ('Design of

module/programme learning outcomes', and 'Communication of intended learning outcomes') will offer advice appropriate to the task. In addition, three further criteria within this 'Barriers' route ('Learning methods', 'Delivery methods', and 'Assessment') will offer further relevant advice. The programme/module leader could also expand his/her understanding beyond the general advice offered in each criteria by examining student case studies that shed light on each chosen criteria, as well as refining his/her research by seeking specific advice relating each criteria to criteria from either of the two other routes ('Context' and 'Disabilities').

Conducting an Institutional Review of Disability Provision. For those tasked with reviewing disability provision within an Institution, the DART Tool can be of assistance. Contextual information relating to current disability legislation, and the institutional response to disabled students would be a sound starting point. Additional review of advice and guidance under various criteria (e.g. Institutional Policy, Practice, and Systems, the Physical Environment, Staff Knowledge and Skills, Assessment etc.), allied with reference to student case studies to appreciate the contextualisation of the advice offered, would be of benefit to those conducting an institutional review.

The above examples demonstrate that the tool can be used in a very flexible manner to address the varying needs of the academic community within an institution faced with the task of ensuring an inclusive and accessible curriculum for all of their students. The same task can be approached in a number of ways, calling upon a selection of relevant sources of information. Academics can be confident in the advice offered as all advice has been scrutinised and validated by disability specialists, whilst the experiences of disabled students captured in the case studies provides a real life dimension to the information offered by the tool.

Piloting and Evaluating the DART Tool

In early 2005 the DART Tool was piloted in five UK-based Higher Education Institutions (Loughborough University, Nottingham Trent University, Sheffield Hallam University, the University of Bolton, and the University of Central England). Evaluation feedback was sought from academics, disability specialists

and disabled students who were asked to use the DART Tool and to provide feedback by exploring various scenarios and completing a detailed questionnaire. In total nearly sixty replies were received.

The purpose of this evaluation was to measure the extent to which the tool, though yet to be fully populated, enabled academics to find information and advice to respond to the needs of disabled students, and in enabling them to provide a more accessible curriculum. In addition, advice was sought on what refinements and additional functionalities would increase the effectiveness of the tool, so that ongoing development was targeted upon the requirements of the intended end user.

Evaluation Feedback. The feedback received was overwhelmingly positive and enthusiastic. Most academics commented that the tool offered them both an insight into the educational experiences of disabled students and guidance on how to meet the challenge of offering a more accessible curriculum. Disability specialists commented upon the accessibility and quality of advice offered, and all felt that the DART Tool was a resource that they could happily recommend to academics within their Institution. Furthermore, all the disabled students questioned stated that they would be happy for academics to use the DART Tool as a primary resource on disability advice.

Comments received from academic respondents included:

- 'A very useful tool indeed. Quite illuminating and informative as it provides clear guidance about the most appropriate course of action.'
- 'It was relatively easy to source relevant information on each area of disability.'
- 'I have DART on my favourites list.'

Comments received from disability specialists include:

- 'This is exactly the kind of tool that I think would benefit our academic staff. They need something that they can refer to time and time again without it getting misplaced or lost, and that offers a whole kaleidoscope of advice and guidance.'

- 'I would feel justified in recommending academic staff to use the DART Tool.'

Comments received from disabled students include:

- 'I feel very comfortable that all academics should have access to this tool.'
- 'The structure and presentation of the information was excellent.'
- 'I think that the DART Tool is a useful starting point for staff to find out about disabilities and to develop an understanding of disabled students.'

In addition to the favourable comments received, a number of suggestions were offered on how the tool might be improved further. These included advice and comment relating to:

- accessing the database
- navigation throughout the site
- user viewing options
- additional user advice
- compatibility with accessibility standards
- user feedback facility
- presentation of information
- rationalisation of external links

A thorough analysis of the feedback received from this evaluation exercise led to a further programme of revisions to the tool to address the issues raised.

Integrating the use of the DART Tool within Higher Education Institutions

Workshops were held in late 2005 at each of the partner institutions – Loughborough University, the University of Bolton, and the University of Central England - involved in the DART Project. These workshops, involving academics, disability specialists, and senior managers, sought to find means of engaging academic take-up, embedding the use of the tool as a primary disability-related resource within the institution, and exploring the potential for transfer across discipline areas. Means of integrating the use of the DART Tool within the institution was discussed, and an action plan for doing so was shaped at each of the workshops. Promotional material has been prepared and

circulated through the Higher Education Academy Subject Centres for Engineering and the Built Environment to raise the awareness of academics within these discipline areas to the availability of this tool. Dissemination activities, including presentations at academic conferences and other events, are ongoing throughout 2006, whilst the project team continue to seek further opportunities to build upon the success of the DART Tool.

CONCLUSION

The previous gap in support materials for academics in Engineering to provide an accessible curriculum is one that the DART Tool has helped to fill.

By enabling academics to audit current provision, create more accessible and inclusive programmes and modules, and to identify effective practice for a given context, the DART Tool should provide a most useful point of reference. Furthermore, the tool offers advice based on the real-life experiences of disabled students within engineering.

The use of the web-based medium enables both access to relevant links elsewhere on the Internet, and the ability to refresh content as and when required. Feedback by those who have used the DART Tool confirms that it offers academics one solution to the challenge of providing a more accessible curriculum, and in so doing creating a positive experience for disabled engineering students.

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INCREASING AND ENHANCING FEMALE PARTICIPATION IN ENGINEERING EDUCATION

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ABSTRACT

This paper examines some of the reasons for the low participation of females in engineering education, drawing upon empirical research from the author's recent doctoral study of sixth formers' A-level and career choices and their images of engineering as a career. The paper then describes some strategies for increasing female participation and creating a positive experience for female students.

BACKGROUND

Despite numerous initiatives since the 1970s to encourage girls and women into professional careers in engineering in the UK, these occupations have remained overwhelmingly dominated by men. UCAS data(1) show that in the 2004 year of entry, women comprised only 13 per cent of UK students accepted to the 'engineering' subject group.

In addition to the issue of female under-representation, a second problem is that women who *do* enrol in engineering education are less likely to stay in engineering than men. While many female students may be successful on their courses, women and men engineering graduates tend to use their qualifications in different ways. An analysis of labour force data conducted by Glover(2) shows women are less likely than men to be employed as professional engineers, less likely to be managers and more likely than men to be in non-professional jobs. Government concern about female attrition from science, technology and engineering (SET) has focused on the waste of investment, productivity and talent that occurs when trained women leave courses and jobs. The Department for Education and Skills (DfES) recently set up the UK Resource Centre for Women in SET to tackle this issue.

The problem of female attrition from engineering is as relevant to higher education as it is to

industry. For example, Lewis(3) and others have observed that the university engineering department can be a 'chilly climate' for women. Erwin and Maurutto(4) note that while female students may set out with all the advantages of their male peers:

something happens during this period that undermines their determination and deflects their ambitions.

The problems of low female participation and retention in engineering point to the need for universities to implement strategies of intervention that address the problems women confront in their pursuit of engineering training 'before, during and after their undergraduate education'(4).

This paper further examines these related issues of female recruitment and retention and discusses some possible solutions. It will first identify some of the factors that contribute to girls' 'avoidance' of engineering as an educational and career choice, drawing on evidence from the literature and from recent empirical research conducted by the author(5). The paper will then outline some of the barriers to females' persistence in engineering studies. Finally two intervention strategies currently being adopted in the author's university will be described and discussed. The first of these is aimed at increasing female access and participation and the second is aimed at creating a positive experience for female undergraduate students and nurturing their aspirations towards a career in engineering.

WHY GIRLS DON'T CHOOSE ENGINEERING

A substantial body of previous research has uncovered a number of social explanations for the lack of female participation in engineering education and employment. For a recent and extensive review see Blickenstaff(6). Key

factors include: the historical construction of engineering as men's work; gender socialisation into 'appropriate' roles at home, school and the workplace and the resultant stereotyping of specific disciplines and occupations as 'appropriate' for one sex or the other; and the masculine culture of engineering education and the profession.

The research reported here used a gender analysis to explore the social barriers to participation in engineering affecting young people of both sexes in schools. The study explored A-level students' gender constructions of three interrelated topics: 1) subjects of study at school, 2) careers and 3) engineering as a career. A mixed method approach was used, which combined a postal self-completion survey with group interviews. Participants were in their first year of sixth form study in co-educational state comprehensive schools in two cities in the South West of England. Survey respondents were 606 students, of whom 320 were girls and 278 boys (gender was undeclared for 8 respondents). Interview participants were 56 students from four schools, interviewed in single-sex groups of between 5 and 9 students.

Findings

Attitude measures showed that while the majority of students held liberal views on gender equality in subjects of study, engineering remains strongly masculine stereotyped. Whereas all other subjects were perceived as equally suited to both sexes, 55% of respondents agreed that engineering is 'on the whole' or 'definitely' best suited to males. Despite the students' liberal beliefs, many subjects were found to be gender stereotyped in terms of actual participation. Girls were far less likely than boys to be studying the pre-requisite A levels for undergraduate engineering, such as mathematics, physics and technology. Measor(7) discusses the ways that choosing male-stereotyped subjects can make for discomfort for girls who have to cross the gender boundary. Certainly the present study found that some boys 'ridiculed' girls' abilities in male dominated subjects such as mathematics. Girls pointed out that boys feel threatened by successful girls, especially in 'male' subjects:

'They (boys) hate girls being more authoritative than them. They can't handle it. It's weird really, 'cause we do so much better at school than they do' (female 6th former, group 6)

Engineering had low career 'visibility', particularly amongst the girls, who were less likely than the boys to have knowledge of engineering, unless through family members in the profession. Girls' perceptions of the career tended to be narrow and limited to building sites, manual labour, hard hats etc. Engineering, especially the intellectual/professional end, was much less visible to them than building sites and apprenticeships. These findings support those of Foskett and Hemsley Brown(8) and MORI(9).

Correlational techniques showed that an aspiration *towards* Engineering was significantly associated with a number of characteristics: a liking for practical tasks, computers, maths, science and sport, and a dislike of written work. This specific form of masculine identity not only discourages girls, but also many boys whose interests and identities do not conform.

Achieving a work-life balance was important to both sexes when considering a career. Even at the age of 16 or 17, these girls anticipated the challenges of balancing work and motherhood when weighing up career choices, a finding supported by Tinklin *et al*(10). Engineering is not considered 'family-friendly' in the way that, for example, teaching is.

'Because if women like, have kids or something, then it's not really . . . you can't really sort of plan your kids around engineering' (female 6th former, group 4)

Although believing in gender equality themselves, the girls expected employers to discriminate against female engineers when recruiting:

'A lot of the engineers, they'll virtually be all male anyway. They'll have had male engineers, so a female engineer they wouldn't look at.' (female 6th former, group 4)

Finally, participants of both sexes also expected those women who had been successfully recruited, to face a hostile environment in engineering companies:

'Old fashioned bosses and that, they don't like the idea of working alongside a woman in a man's job' (female 6th former, group 8)

'You'd have all the mechanics, the blokes, who think that's the men's job, so women would have problems fitting in' (male 6th former, group 3)

BARRIERS TO THE PERSISTENCE OF WOMEN UNDERGRADUATES

The findings above suggest that girls considering engineering degrees will need to be highly motivated to step into a predominantly male learning environment where they may feel a sense of isolation or of not belonging or being welcome.

Brainard and Carling(11) found that factors that contribute to women's attrition from engineering education and careers included: being disappointed or bored with the course, experiencing a drop in academic self-confidence, not feeling prepared for their career, a lack of female role models and feeling isolated, intimidated and unsupported. Obviously many of these factors do not exclusively affect women. However, for women as 'outsiders' in a male-dominated field, these experiences can undermine their determination and reinforce doubts about whether women can succeed in engineering careers.

In making our Engineering Faculties and Departments more welcoming and supportive for women students, we can help to improve retention and progression rates and in so doing, help to change the culture of engineering education, which in turn, should create the conditions for other women to be attracted. In this regard, the next section will describe two strategies currently being trialled in the author's university.

INTERVENTION STRATEGIES

Programme 1: The 'Girls into Technology' activity days

'Girls into Technology' is an outreach programme for schoolgirls in co-educational secondary schools. It is designed to increase female participation in engineering and

computing courses. The 'girls only' idea was informed by research suggesting that single-sex learning can be beneficial to both sexes in situations where a subject has historical associations with the other sex(12). The visits to the University provide the opportunity for the girls to experience hands-on engineering and computing activities in a fun and supportive environment, away from the often competitive environment of the mixed-sex classroom. The girls try their hand at four or five activities designed to promote awareness of what engineering can offer. Examples of activities include: construction tasks such as bridge and tower-building; testing materials for their properties and appropriateness in design and manufacture; electronics and robotics projects and graphics workshops. During 2005, 132 secondary schoolgirls between the ages of 13 and 16 participated in visits. Evaluation of the sessions was conducted using observational methods and self-completion questionnaires. When teachers and pupils were asked whether girls-only visits are a good idea, the response from the overwhelming majority was 'yes'. Written feedback from teachers included:

'It allows them to discover unknown futures without anti-academic male pressure' (male teacher)

'It separates the girls from other pressures and lets them succeed without the condemnation' (female teacher)

'They could be themselves with no "male pressure", mistakes were "fun" to make and not ridiculed' (male teacher)

The girls' responses included:

'Girls can really show their interests without fear or prejudice' (Year 10 pupil)

'We get to see what type of things we can do without the boys' (Year 8 pupil)

'I didn't feel as embarrassed or shy' (Year 10 pupil)

'You have a chance to ask stuff instead of the boys' (Year 10 pupil)

'It really gives girls confidence to just go for it' (Year 11 pupil)

'It gives you an insight into jobs/careers that are normally male orientated' (Year 10 pupil)

Listening to the girls' questions and observing their interactions with the technology during visits has suggested to us that we could develop activities to further highlight the human and social contexts and applications of the engineering courses we offer. The popularity of girls' visits amongst school teachers looks set to continue, with all available visit dates for 2006 already booked.

Programme 2: The Women in Technology Network (WiTNet)

WiTNet is a personal and professional support network for women students in engineering and computing disciplines. It aims to make female undergraduate students feel welcome, promote their success and of course, encourage future cohorts of women to apply to us. Before the network was formed, the opinions of female undergraduates were sought, whose responses included:

'Meeting new women socially would be a benefit. Sometimes when a student is new to the University, they may find that they are the only female student on their course.'

'If a potential student finds they may be the only girl on their course, this may put them off studying it. If they knew that there would be a support network, it may encourage them to study here.'

WiTNet is funded by the DfES from their 'SET for Work' initiative, which currently supports 16 universities in their aims to ensure female students are supported in science, engineering and technology courses and are encouraged and supported into employment or higher study in these disciplines. WiTNet is student-led, while supported by staff. It aims to provide social and academic support by connecting women studying technology courses. Activities include regular get-togethers, a peer mentoring programme and career development opportunities through workshops, talks and links with employers and graduates in industry.

At this early stage (the network has been in existence since the beginning of this academic

year), the success of WiTNet is difficult to assess. A mixed picture is emerging. On the positive side, a small core of final year women students have become regularly involved in WiTNet activities and have forged some connections with students on the foundation year. By sharing their experience and enthusiasm, they are able to inform and encourage foundation students to progress to one of the engineering degree programmes. Many students have shown an interest in becoming peer mentors and several have now been trained to support others.

Less positively, attendance at regular get-togethers has been very low and despite regular advertising of the mentoring programme, no student has yet requested a WiTNet mentor. It has also proved particularly difficult to engage younger students in the Network. To date, higher level students (e.g. final year, Masters), older students and international students have been more likely to participate in the Network than younger students or newer recruits. Achieving a sense of community can also be difficult in such a broad network, which attempts to connect women studying a very diverse range of courses from Foundation to Postgraduate level. There are indications that smaller, discipline-based groupings are more cohesive.

Reasons for the lack of active participation in WiTNet will require further investigation. One explanation may simply be a lack of time, due to outside responsibilities such as paid employment and childcare. However, it does appear that many students support the idea of a Women's Network in principle. Longitudinal research from the US has shown that many students rate such networks as important without actually participating in them, simply knowing they are there helps them to feel supported(11).

DISCUSSION

While both these initiatives have been very positively received by the majority, a few schoolgirls and undergraduates have expressed concern that female-only initiatives might be considered 'unfair' on male peers. It is therefore important to convey the message

that female networks are widely considered to be good practice and are not a form of positive discrimination. It is also important to be aware that some women students are not comfortable with the idea of 'female-only' groups. Some consider them patronising, which is understandable if such interventions appear to suggest that girls and women are somehow 'deficient' and need to change.

For this reason, it is important that ownership of student participation and retention is taken at the institutional level as well as by the students themselves. This means going beyond existing 'women focused' recruitment and retention strategies to examine ways in which the academic culture of engineering itself might change. Historically, men have determined how engineering is taught because they have dominated the discipline numerically. Making changes would entail looking at how faculty teaching practices, assessment and the curriculum itself can be made representative of the experiences, interests and learning styles of women and other 'non-traditional' engineering students. Lewis(3) identifies some of the key features of a gender-inclusive education as: social and environmental curriculum contexts; collaborative team approaches; open-ended, problem-based learning and a diversity of teaching and assessment approaches. The underlying assumption of this educational model is that it will attract and retain a wider diversity of female *and* male students than is currently seen in engineering education(3).

CONCLUSION

This paper has examined some of the reasons for low participation of females in engineering education and the lack of persistence in engineering education and careers beyond graduate level. The paper has described two intervention strategies and assessed their impact to date. Further evaluation of the impact of these strategies will now be needed, to ensure that aims, needs and outcomes are being met and achieved.

Future directions for the Girls into Technology visits could include developing existing and new activities to both capture the interests of girls and represent engineering at Plymouth in

the broadest, most inclusive ways possible. WiTNet will need to continue to reflect on good practice, seeking the most apt and effective ways of ensuring that female undergraduates feel accepted, achieve success on their courses, actively prepare for their careers and sustain their ambitions to become engineers.

In conclusion, programmes such as the two described above may be necessary, but not sufficient, to increase and enhance female participation. This is because they require women to make adjustments, while the engineering learning environment remains the same. A further step would be to examine ways in which engineering education itself can become more gender-inclusive. In so doing, we can create a learning environment which will attract and retain a wider diversity of female and male students. This will benefit the engineering community and society as a whole.

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EDUCATIONAL BENEFITS OF THE MODEL SOLAR VEHICLE CHALLENGE

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ABSTRACT

Many competitions aim to encourage motivation of school students and to develop an interest in engineering while working within curriculum guidelines. Model Solar Car and Boat Challenges have run in Australia since 1990, fostering deep levels of understanding of mechanical and electrical concepts, within an environmentally aware context.

The Challenge is designed as a problem based learning exercise in which younger students develop boats while older ones focus on cars. The authors contend that learning, centred on a challenging, enjoyable project is likely to be deeper and more likely to influence subject and career choice than that learnt from regurgitation in exams.

Survey and interview data from students involved in the car race over the last decade will be examined so as to explore the projects' high levels of motivation; levels of understanding; the potential for influencing student behaviour and the positive effect that the challenge has on selection of subsequent studies.

INTRODUCTION

The concept of racing model solar powered cars was developed in Victoria, from the World Solar Challenge, where solar powered cars were raced from Darwin, 3000km across Australia, to Adelaide. Student enthusiasm and learning prompted establishment of a Model Solar Vehicle Challenge (MSVC), to enable more students to have a similar experience but requiring far less time and money but with similar emphasis on solar energy, efficiency, team work, design, construction and testing, along with the motivation of a race. The concept was adopted in other Australian states by 1993 and a Model Solar Boat Challenge

started for younger students in 1994. This paper will discuss the subsequent student learning, motivation and the influence on student decision making about future studies and careers.

OBJECTIVES OF THE (MSVC)

The objectives include developing:

- Motivation for students to apply their knowledge to a real social issue.
- Experimental skills to analyse vehicle inefficiencies.
- Team skills.
- Project management skills.
- Ability to meet the regulations.
- Satisfaction through achieving.
- Insight into engineering processes.
- Real problem solving skills.
- Learning from others – by discussion and observing other entries.
- Increase science and engineering interest.
- Influence student subject selection.

EDUCATIONAL RATIONALE

The basic educational rationale for the MSVC can be summed up by Ritchie(1) who quoted Piaget as saying 'I'm told and I forget; I see and I remember; I do and I understand'. He identified the key elements of learning in technology as design, manufacture and evaluation. Design can provide the foundation for future employment (Eggleston,[2]) and a motivating context for demonstrating real understanding by applying knowledge to a problem using literacy, numeracy, IT and team work. Murray(3), identified 20 needs which students wish to satisfy including Order, Achievement, Autonomy, Affiliation, Dominance (of environment), Exhibition, Play, Counteraction (trying again), and Understanding. Dewey(4) and Klainin(5) considered practical, personal experience as

central to learning, with intrinsic motivation essential, while Swartz and Fischer(6) stated that critical thinking is required to solve real problems The MSVC aims to address all these areas.

Mark and Osborne(7) flagged the significance of open ended learning allowing for student ownership of the investigation, but designers of learning experiences need to consider what, how and why learning occurs. Peer pressure can often discourage brighter students from standing out in terms of ability or effort. These constraints do not apply to boys for sporting competitions (including car racing) whose identities are often their heroes. Hence social stigma is likely to be reduced when developing a competitive vehicle, where there are rewards for good performance. Staff at Box Hill High School stated that the top MSVC Teams at Box Hill (girls and boys teams) are the role models for other students, more of whom desire to participate than can be accommodated.

Through tinkering boys usually have a greater technology background than girls, enabling boys to appear more confident with practical activities and have a higher self-esteem in technical fields which is important in establishing motivation and a positive academic self image (Fennema and Leder,[8]) when making subject choices (Griffiths,[9]; Ainley,[10]). Girls appear more concerned about the environment and people (Blatchford,[11]). This can be the catalyst for girls making model vehicles. Fensham(12) highlighted the socio-political context of science education and the increasing emphasis of designing learning experiences around topics of social concern. The *What School Kids Want* survey (Zyngier,[13]) clearly expressed students wanted a curriculum that tackled community and social issues. Experience with solar cells at school is intended to develop an ongoing positive attitude to environmental concerns.

Australian curriculum

Australian Education is a state responsibility with variation in curricula and support in each state. However, the various curriculum frameworks include aims that students will be able to think creatively, identify and solve problems,

work with a team, be autonomous learners and communicate their findings.

Victorian Essential Learning Standards (VELS,[14]) covers the school curriculum from years 1-10 identifying essential skills and knowledge at different educational stages and based on opinion that content should provide rigor and challenge; all students can learn; student engagement results in increased effort; and options need to be considered when solving problems. The curriculum must allow for flexibility to experience and develop problem solving skills and effective teams, while students develop knowledge and behaviours that will prepare them to manage change and environmental and social complexity for a sustainable future.

The MSVC addresses the VELS levels 4, 5 and 6 (years 5-10) but the breadth and depth of the project is determined by the students involved and their levels of knowledge and skills including:

- Working cooperatively in a team, to allocate tasks and develop time lines.
- Learning with peers and independently, showing motivation and persistence.
- Participating within a school or community event and make decisions.
- Science of the environment, energy, materials, asking and answering questions using scientific methods.
- Mathematics – measurement, symmetry and graphing results.
- English – writing for a purpose.
- Communicating and presenting ideas.
- Following a design brief; generating and justifying ideas; considering the purpose and environmental impact of their product; making their product; evaluating and modifying their design.
- Use Information, Communications Technology for thinking, eg. CAD design for cars; creating posters and communicating ideas
- Thinking to solve problems, initiate creative solutions and self reflection.

Problem and other action based learning approaches combine learning from different areas and often involve students working in teams over a number of lessons. The MSVC elements (boat or car, poster, interview and

team uniform) and open-ended structure provides for differentiation of student's learning so that team members can contribute to the project in ways that reflect their different levels of knowledge, skills and diverse learning and thinking styles, and use transferable skills (Barell *et al.*, [15]).

Motivation

Eccles and Wigfield(16) discussed the importance of the task's value in influencing student motivation; self perception; intrinsic interest; extrinsic value in preparation for possible future careers; and the cost in terms of effort. We believe that the MSVC offers intrinsic interest, and is important in affecting students' self perception by being able to make a complex product work, especially if they envisage a career as a scientist or engineer. The Challenge requires a level of effort, which if they are prepared to put in, provides extrinsic value by addressing the serious world problem of energy for transport in at least a minor way.

Costa and Garmstom(17) define 5 passions that drive, motivate and inspire humans – craftsmanship, flexibility, consciousness, interdependence and efficacy. MSVC allows students control over their learning, flexibility in adapting their knowledge and showing their understanding; reflecting upon their learning; and relating their knowledge to energy use and the environment.

CHALLENGE STRUCTURE

Australian states hold their own annual events with the top entries competing at a national final, sometimes along with overseas entries – eg Canada, Argentina, Vietnam and New Zealand.

Cars up to 650mm long, 320mm wide and 180mm high use silicon solar panels of 5 to 10 watt output to provide all motive power. The solar panels are ballasted to a standard power to weight ratio. The cars carry an egg as driver, to emphasize safety and need for robust construction, as the egg is not allowed to crack in an accident. The competition is held as a series of match races between pairs of

cars steered along guide-ways on a figure '8' shaped track. Despite cloud reducing the normal solar intensity from up to 1,000w/m², the best cars are able to complete the course under most conditions, although climbing the 500mm high hill at the 80 metre mark has not been achieved in light intensity under 100w/m². The finals end with a collision with a 650gm styrene foam block, again emphasising safety.

The Boat Challenge requires boats less than 550mm long, 300mm wide to be fitted with guides running along a taught fishing line, 300mm above the water. They use solar cells up to 350cm².

The MSVC addresses generic goals by requiring teams to make a poster on the development of their entry. A number of English and Art teachers advise on making a visually appealing informative poster which is interesting and readable.

A concern of competitions for school students is how much of the work the students do and to what extent do they receive teacher or parent help. While each student is required to sign a form disclosing help received, the learning of each team is evaluated in an interview carried out by committee members.

EVALUATION OF THE MSVC

Motivation

Surveys of participants in the Victorian Car Challenge have provided significant insight into the motivation of students to participate. Students do the project as either an integral part of their course; an elective subject or an extra curricula activity. **Table 1** indicates average responses on student motivation on a 1-5 Likert scale from 180 female and 274 male students over the period 1998 – 2005.

Motivated students were identified as those who did the Challenge as an elective activity. It appears in **table 1** that real projects which build a working product, provide an inherently motivating challenge for many students, especially in a team situation. It is also apparent that boys are much more car focussed and girls more environmentally aware.

Question	Average				
	Overall Total	Male	Motivated Male	Female	Motivated Female
Enthusiasm to:					
Design a vehicle	4.03	4.16	4.17	3.81**	3.96
Build working model	4.23	4.22	4.24	4.23	4.37*
Work as part of a team	3.64	3.58	3.59	3.72	3.79
Be creative	3.82	3.78	3.78	3.87	3.98*
Help clean environment	3.04	2.89	2.88	3.25**	3.29**
Develop organizational skills	3.25	3.31	3.34	3.16	3.25
Accept a real challenge	4.00	4.06	4.14*	3.91	4.02

* indicates a statistically significant result on a 2 tail t test at the 0.1 and ** at the 0.05 levels

Table 1: Summary of Motivation 98-05 Victorian Model Solar Challenge (VMSC)

The significance of the competitive aspect has also been explored. A mean of 82.5% of the 454 students surveyed, were motivated as new entrants to achieve a functioning car, or one which completed the circuit or was fast, with only 17.5% wanting to win or come in the top 4. As students compete for a number of years, the competitive element increases, but getting the car to perform in low light conditions or rain also becomes a significant challenge.

Student Learning

The major goal of the event organisers is to develop student interest and learning in alternative energy and engineering. **Table 2** indicates the extent of learning students feel they have made. However, this is a very

Item	'01	'02	'03	'04	'05
Solar cells	2.6	2.6	3.2	3.5	3.9
Electric Motors	3	2.7	3.3	3.3	3.7
Gears	3.1	2.6	3.6	3.6	3.4
Aerodynamics	3.2	2.8	3.5	3.4	3.6
Bearings	3.1	2.8	3.5	3.6	3.5
Efficient design	3.5	3.9	3.8	3.7	4
Stable design	3.9	3.1	3.5	4	3.6
Making things	3.9	3.3	4	3.8	4
Organising self	3.4	3.1	3.7	3.1	3.3
Organising others	3.2	2.5	3.5	3.1	3.2
Planning	3.6	3.1	3.8	3.6	3.4

Table 2: Student perceptions of topics learnt from survey

subjective measure and so team interviews were implemented at the Victorian competition in 1998 and at the national level in 2003.

The outcomes of interviews in Victoria have shown marked improvement in knowledge by most students on gearing, aerodynamics, and design for efficiency and stability, although understanding of the solar cells is still mediocre and only the best teams have much understanding of electric motors. Too many teams still have poor understanding of series and parallel wiring but top teams now use electronic maximisers, although only the best have a good understanding of how they work. The project management issues are still poorly understood by most students and often their teachers as well.

Career choices

As described above the MSVC involves students understanding basics of mechanical and electrical power systems, topics in technology, physics and other science subjects between years 4 and 12, and provides motivation to continue science throughout school and attracts significant numbers to select engineering as a career. From the results of the responses to survey questions in **table 3**, it is apparent that most students plan to continue studying science or technology, with over a third influenced by their involvement in the MSVC.

On average, less than 40% have definite

Item	Mean
Project influenced later subject choice	36.9
Those studying technology or science in subsequent years	85.4
Project influenced career choice	17.9
With definite career plans	38.4
Plan career in science or engineering	56.3

Table 3: Attitudes to future study and career. Percentage of students who responded to the questions 1999-2005

career plans but of those who do, 56% plan to do engineering or science, with almost 20% having been influenced in that decision by the Challenge.

COMMENTS FROM TEACHERS, STUDENTS AND SPONSORS

Comments, made by teachers and participants, perhaps most effectively exemplify the Challenge benefits.

'I would like to comment on what a wonderful experience both the workshops and competitions were for everyone. It was of enormous benefit to our students to mix with people of all ages who have a passion for learning in all its forms.' (Jobling,[18])

'By observing the students from Lynall Hall Community School it was clear that this task had a considerable amount of emotion attached to it. The excitement was really quite electric. It would be hard to imagine students becoming so excited over making measurements to confirm Ohm's Law or measuring rolling resistance of a wheel and yet all these types of tasks form the backbone of competing at this event' (Fong and Sutton,[19]).

'The Solar Car Challenge has not only been an enjoyable and exciting experience for all involved, but has provided us, as future citizens, scientists and engineers of Australian society with an opportunity to expose ourselves to renewable energies and new technologies.' (Genazzano Team,[20])

'I happened to be standing near the . . . cheer

squad during their participation in the finals. The girls were obviously hugely committed and supportive of their team, and were encouraging the car handlers at every opportunity. Their level of excitement reached a crescendo when their vehicle hit the front, only to turn to sheer disbelief and anguish when the car left the track on the last bend. This is only one example, but it highlights why your Model Solar Vehicle event is so important, with the great team spirit and excellent introduction to competitive Australian product development it engenders in our future engineers.' (Clerk,[21])

'In terms of assessment, the solar car project provides an authentic learning experience that students find relevant and engaging. While the authentic model of assessment does not have acceptance in schools at present, the solar car project represents a very useful case study of the value of authentic learning and the possibilities for authentic assessment. At a more personal development level, students exhibit genuine enthusiasm and a determination to find solutions to the various challenges, despite a few setbacks and disappointment. (It appeared failure inspired determination). It was notable that one by-product of the project was that a number of students had solved a novel problem in the application of first order differential equations and it was unlikely that this would have occurred in the course of a standard mathematics curriculum. Finally this type of project that can be implemented without having to resolve any contested issues related to curriculum and assessment. The program blends in particularly well with a school's technology resources and confers immediate personal development and learning benefits to all participants.' (Cosgrove,[22])

CONCLUSIONS

The Model Solar Car and Boat Challenges are providing an opportunity for teachers to provide students from years 4 to 12 with an experience of student centred learning, which prompts students to participate in a renewable energy engineering experience.

ACKNOWLEDGEMENTS

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ENGINEERING ENGINEERS - BIG QUESTIONS, LITTLE QUESTIONS

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INTRODUCTION

The **recruitment** of suitable students, **retention** of undergraduate engineering students, and **development** of well-rounded, technically competent engineers who are able to communicate well, are three major issues for 'engineering engineers'.

The current culture of engineering education often assumes that this education begins at university; and that the 'best' performers in maths and science at school will be those who choose to enrol and succeed in engineering courses. The major flaw with these assumptions is that unless school students and their teachers have direct contact with an engineer through family or friends, they may never have articulated the word 'engineering' until they are expected to make, or support students in, their career choices. This then affects the student diversity and intake attributes of students in engineering courses, as well as the overall community perception of the engineering profession.

The University of Technology, Sydney (UTS) Faculty of Engineering offers a five-year Engineering Internship program that integrates academic study with at least two semesters of engineering workplace experience. This gives our students a portfolio of academic and workplace-based achievements. Our course also provides students with the option, through a substantial elective component, of either deepening their understanding of their chosen area of specialisation or extending themselves into new areas.

To better inform a proposed redevelopment of three elements for which I am responsible, eight big questions must be answered. These lead to many little questions that must also be answered.

RECRUITMENT

Why are fewer students choosing engineering as a career path?

From our own research (Jacobs and Scanlon[1]) and other literature (Mori[2], Heist[3], Grossman and Shackelford[4], to name a few) it is apparent that problems with student diversity and decreasing enrolments in engineering can be attributed to negative and outdated perceptions of engineering in students, teachers and parents. This leads to exclusion of engineering as a career option at an early age, before informed perceptions are developed at senior school level through careers education or university promotional activities.

How do we define recruiting?

Most universities would equate recruiting with marketing. They actively promote engineering as a career option. They spend large sums promoting to Year 11 and 12 school students. In the current economic climate, it is seen as more immediately cost-effective for faculties of engineering to encourage 'brand-switching' from customers who already want to purchase the product (engineering). To change overall perceptions of potential students and families and encourage them to 'buy' a product for the first time and so choose engineering, is more difficult and thus more expensive.

Recruitment as marketing has measurable results. This feature encourages universities to support the status quo, i.e., better marketing attracts better students. However, given how little students know about engineering and how many students have no identifiable aspirations or career plan, it is unrealistic to think that an advertising campaign or a visit to a careers night will make any difference. If the word 'engineering' is not in regular use in the media, in classrooms and in everyday conversation, school students cannot learn to

articulate what it means to be an engineer. The role engineers play in society in the 21st Century will continue to be misunderstood.

At what age should we start 'recruiting' engineers?

In Australian schools, Careers Advisers begin working with students in Year 10. Taccori(5) describes this as 'getting in early'. However, research shows that children form attitudes that affect subject and career choices made in high school and as adults, before age nine (Hofman[6]). More recent research even suggests that these attitudes are forming as early as age four (Care[7]). However, universities still focus on Years 11 and 12 to inform, influence and change perceptions of engineering.

Recruitment therefore must be broader than a marketing campaign and include education of younger students, their teachers and parents. Results of this style of 'recruitment' may never be quantifiable in terms of university intake.

RETENTION

What expectations and experiences of first year students need to be addressed?

A recent Australian study presents findings in six key areas that influence the learning of first year university students (Krause *et al.*[8]).

They report that the important factors that influence decisions to enrol in university are both interest-related and job-related.

Occupational aspirations are more important in the 21st century than in the 1990s. Much research has been done to clarify the issues involved (e.g. Seymour[9])

Experience in both school and university systems shows that negative experiences arising in first year often develop from a mismatch between senior secondary school and university expectations. These include:

- the misconception that knowledge gained for the Higher School Certificate (HSC) is the total amount of knowledge

in that subject. 'But wait! there's more!' comes as a surprise to many

- plagiarism is not considered an issue in school written work beyond encouraging students to 'put it in your own words'
- group work is often expected in both systems, but group working strategies are rarely made explicit
- library research strategies must develop beyond the skills of analysis to the synthesis phase of understanding
- teacher-student relationships often change from one of 'teacher as font of all knowledge' to one of 'teacher as facilitator', or to teachers and students learning together - from 'sage on the stage to guide on the side'.
- managing commitments and people is no longer directed but left to students to sort out. Students need to be responsible for their own learning.

How can we make academic learning more student-focussed?

It is well-documented that one of the most effective ways of engaging students in their learning is to ground the learning opportunities in real-life situations. UTS Engineering provides such opportunities through its internship program but it can also be done in other areas of learning, like opportunities to work as a volunteer or to embed academic work in real-life scenarios. However, we must remember that 'While experience may be the foundation of learning, it does not necessarily lead to it: There needs to be active engagement with it' (Boud *et al.*[10]). To generate active engagement and motivation we have to consider both learning styles and teaching styles. Tasks need to reflect what engineering students encounter in other subjects as well as in the workplace. They must suit their generally analytical and logical approach to learning. Biggs asserts, if teachers can 'teach in such a way that students build up a good knowledge base, achieve success in problems that are significant and build up a feeling of 'ownership' over their learning, motivation follows good learning as night follows day' (Biggs[11]).

What opportunities can we provide to maintain commitment and enthusiasm for learning?

By becoming involved in their own learning process students develop commitment to their learning. There are a number of levels at which this involvement can occur from as simple as choosing or negotiating a topic for an assignment, to more complex levels like volunteering for a task, negotiating a learning contract, becoming involved in a real research project or community issue.

To retain our students we need to incorporate the results of both research and experience in addressing the expectations of students and in creating more student-focussed learning opportunities.

DEVELOPMENT

How can we encourage transfer of learning from the lecture/tutorial to the real world?

In line with current research, the practice-based approach at UTS is grounded in the recognition that vocational and professional skills are best learnt through contextualised, meaningful participation. Research on the social construction of knowledge, communities of practice and situated learning that allows for experiential learning in the context of use (Lave and Wenger[12]), states that a deep approach to learning will result if accompanied by reflection. Kolb's experiential learning cycle (cited in Jaques[13]) suggests that we learn best when we are personally and actively involved in the learning process and that reflection is integral to this process.

How can we develop reflective (life-long) learners?

Brockbank and McGill(14) suggest that using an 'internal' dialogue to aid reflection is no more than a preliminary step for reflective thinking to be of use and for deep learning to take place. They propose that a reflective dialogue with others is also necessary. However, true reflective learning also requires students to discuss their experiences in learning at more than just the 'it was good/it

was bad' level. Providing scaffolds for them to reflect on past, present and future directions and their learning processes will lead them on a continual quest to improve and learn: life-long learning!

Situating learning in real-world experiences and encouraging deep reflective processes will support the development of life-long learners in an engineering setting.

THREE ELEMENTS

The three elements in UTS Engineering for which I am responsible are the Engineering Links outreach program, Engineering Communication (a compulsory core subject) and Professional Service Project (an elective subject). These elements overlap in an ad hoc manner but the links could be streamlined and made more explicit and economical of Faculty resources.

The **Engineering Links program** attempts to broaden the focus and scope of engineering education to change community perceptions of both the engineering profession and engineering in our lives. Care is taken not to reinforce old perceptions by promoting engineering in terms of engineers of the past, but in terms of the new breed of engineers needed in the 21st century. The focus is on the interests and needs of the audience rather than the needs of engineers to tell their story. The disciplines of science communication, science teaching, and museum education have informed the intellectual rigour of this area and underpinned the modelling of good practice in both engineering communication and social responsibility. The overall aims of all activities and resources developed are to:

1. answer the question 'What do engineers do?' thus 'making engineering visible'
2. encourage the users to articulate the word 'engineering' i.e., 'get people talking about engineering and engineers'
3. promote engineering as a career option
4. promote UTS Engineering courses.

The Faculty supports the Engineering Links program at both strategic and operational levels. Through the program it taps into the learning and experience of our undergraduate

engineering students. The program is flexible and outcomes are negotiated with each educator and the undergraduate student involved. Presenting engineering as a vital career option for young people that supports diversity can only help to develop positive perceptions.

This is voluntary service work for our students and requires a different range of skills from those normally developed in traditional engineering courses. It also needs an understanding of the issues important to sections of the community not directly associated with industry or the university.

The Engineering Links program has now run for six years and needs to be reworked to better integrate with the academic learning of our students and current research into career attitude development and managing volunteers. The large volunteer student team that supports this program needs to be managed effectively to maintain commitment.

Engineering Communication is a compulsory core subject in the second year of our engineering course. Engineers need to communicate effectively with their colleagues, competitors, clients, managers, workshop and site workers, the public, in multi-disciplinary teams and to advocate engineering as a viable profession (Engineers Australia[15]). To develop such skills in our undergraduate engineers at UTS, Engineering Communication has run for many years. It covers basic communication skills for engineers but also grounds these skills in an engineering workplace setting. The major changes recently made to make this subject more student-focussed include:

- describing clear subject outcomes in terms of five simple communication concepts
- distilling the lecture component
- supporting tutors as facilitators of learning for a learner-centred workshop approach in tutorial sessions
- providing a scenario based on a real engineering situation meaningful to all Fields of Practice
- embedding collaborative group work theories more explicitly in practice
- developing opportunities for more formative assessment strategies

- incorporating a series of reflection tasks
- providing a technical sketching component.

Engineering Communication is now being redeveloped to become a first year subject rather than its current position in second year. This will need to incorporate results of research into the first year experience.

Professional Service Project (PSP) is an elective subject available to students at any stage of their engineering course. It provides an innovative opportunity for engineering students to achieve academic recognition for their voluntary service work. Its major aims are to develop in students an appreciation of the service obligations, personal development opportunities and other non-financial rewards associated with working as a professional engineer. The subject has a structure that encourages undergraduate engineering students to become involved on a voluntary basis at anytime throughout their course. 'Professional Service Points' for volunteer work are accrued. When and if students choose to enrol in the elective subject, they must then:

- achieve the required number of points
- attend formal workshops on required skills for targeted audience(s)
- research and practice oral, graphic and written communication skills specific to their audience(s)
- prepare written, oral, graphic materials and/or artefacts required for their contact with their client
- present written, oral and graphic reports on their academic learning achieved and reflecting on the process and how it has helped towards achieving both required graduate attributes and certification as a practising engineer.

Because the Engineering Links outreach program is linked with the PSP subject, the cost to the faculty of running such an outreach program is minimised.

The PSP subject has settled into a pattern that requires evaluation and possible changes in its structure and management.

Publications that outline the history and operational structure of these three elements

are available (Jacobs[16], Jacobs and Griffiths[17], Jacobs *et al*[18]). Descriptions and photographs of some of the activities and their outcomes can be seen at www.eng.uts.edu.au/links.

BRINGING THINGS TOGETHER

To review and improve the effective learning outcomes and integration of the three elements for which I have responsibility, answers have been sought for these eight big questions. It is now time to consider if these answers are (or can be) incorporated into the three elements, and if in doing so, integration of the three can be more effective.

Perhaps a fourth element that links the three previously discussed is the Student Volunteer Team. Redevelopment of this dimension could address many of the issues in the other three.

However, more questions now arise!

- What perception of engineering and engineers do we want to promote?
- How can we develop skills in our engineering students to allow them to improve perceptions of engineers rather than merely reinforce old perceptions?
- What features should be added to each element to create a more student-focused learning experience?
- What tools are available for managing individualised projects and volunteers?
- How can commitment of volunteers be maintained?
- How can individualised learning contracts be structured to encourage deep reflective learning?
- How can the progress and effectiveness of each element be monitored and documented for each stakeholder?
- How can the outcomes of each element be evaluated so that further review is possible?
- How can real-life situations for learning be found and used effectively by reflective learners?
- How can the three elements be better integrated to use Faculty resources more effectively?

Perhaps these questions are best grouped into

three major areas for investigation – perceptions, accountability and volunteers.

Perceptions

Kam(19) discusses why women are not entering engineering courses. He suggests that universities should ‘try consciously to develop an engineering curriculum aimed deliberately at young females’ rather than merely be inclusive’. He claims that this new curriculum would ‘also appeal to many talented men who are repelled by the same deficiencies . . . that have driven most women away.’ His comparisons of perceptions of law, medicine and engineering point out some of the features to be avoided – lack of immediate connection to real-world applications, a curriculum that is overcrowded, monotonous, tense and demanding and a workplace that is stressful and of questionable permanence. An excellent description of engineering has been developed at the Whiting School of Engineering, John Hopkins University(20). This could well be used to underpin redevelopment of the three elements.

The success of many of the activities relies on the impression students give of UTS and the Faculty of Engineering to their clients and potential students. It is paramount that students must not see volunteer work as ‘just a laugh’ or the PSP subject as ‘an easy way to earn 6 credit points’. They must recognise the need to develop the communication, co-operation, practical and management skills required before they undertake the service activity. Students must be striving for a High Distinction, not just a Pass. Many of these skills are also seen as important for practising engineers. The volunteer activities must therefore include briefing, participation and debriefing components to ensure that the needs of all the stakeholders are met.

Accountability

Learning contracts must ensure equity in assessment for PSP. This is a major issue for the co-ordinator of any subject. While one volunteer may undertake the whole project, others may be part of a team to achieve the whole. But is time spent compiling an address

list and mailing promotional material equivalent to time spent preparing and presenting the activity being promoted? Without either part the activity could not happen!

Monitoring of all engineering students ensures that changes in attitude are detectable, quantifiable and comparable. Although increased intake of a more diverse range of students into engineering courses may be one outcome that justifies the program, an equally worthwhile and socially responsible outcome is a community that is more aware of engineering and its impacts. As many of the participants in Engineering Links are quite young we may only achieve a more informed community, rather than just convincing students to do engineering at UTS.

Evaluation and reflection by all our clients is encouraged while our undergraduate students must submit written reflections as part of their compulsory assessment tasks. In both cases these evaluations and reflections are positive. It is interesting to note that the program has so excited some of our own students that they ask to stay on our volunteer list long after graduation and continue to pass on helpful information as they find it. They continue to spread the word encouraging schools and community groups like Guides and Scouts to become involved in the program.

In our redevelopment, avenues must be created for monitoring, evaluation and reflection and these must be better documented. Amey(21) lists specific stages that can be evaluated in an outreach program: clear goals, adequate preparation, appropriate methods, significant results, effective presentation and reflective critique. By incorporating clear outcomes for each of these stages into all three elements both at their development stage and at the student outcomes stage, more effective evaluations will be achievable.

Volunteers

Despite the opportunity provided by PSP for 'reward' for service, many students still volunteer with no intention of ever claiming their 'payment' except in the form of a

certificate that says 'well done' (and even many of these are never collected).

However, there are a number of limitations to managing student volunteers outlined by Drinkwater *et al.*(22). These include: difficulty in matching skills and workload; high turnover rates; lack of foresight and experience; and the need for training. One source of valuable information for managing volunteers and projects has been prepared by Volunteering Australia and is available at www.volunteeringaustralia.org.

The management and co-ordination of volunteer projects is many-dimensional. Sometimes it is as simple as being given an activity, finding volunteer students and support staff, then working through the activity. However, more often it is a task of juggling time, activity requirements, suitability of students and staff, resources, networking effectively and the 'image' of UTS engineering. Hopefully the juggler does not drop the balls too often.

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KEYNOTE PLENARY STUDENT ENGAGEMENT AND PROGRESSION

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INTRODUCTION

Those of us involved in engineering education in HE have, in recent years, acknowledged that poor student progression is our problem and that it will not go away of its own accord; this is a significant change from the days in which we blamed the students, schools, the government, the nature of the subject, and other social and political factors. Our subject area is not a popular choice for young people and we put too much effort into recruiting students to be willing to lose them because they don't learn in the way we learn.

Here we examine some of the factors associated with poor student progression and examine a range of strategies for improving it.

Some Observations on Student Progression

Figure 1 plots first year attrition rates against

average A-level points at entry across a range of institutions from both the pre- and post-'92 sectors. Clearly, the trend is downwards and attrition rates decrease as A-level entry points increase. But the enormous scatter shows that some of us retain student with the same level of achievement very much better than others. For example, for an A-level entry level of 10 points one department has an attrition rate of 30% while another has an attrition rate of less than 15%. Similar disparities exist throughout the range of levels of attainment at A-level.

Of course, it is possible to say that departments who accept most of their students with modest A-levels and have low attrition rates are merely teaching easier material than other departments with less impressive progression rates. However, this is unlikely to be wholly, or even substantially true, in my opinion; it is amazing how similar final year examination papers from different institutions look, how similar is the standard of project work, and how similar is the final pass

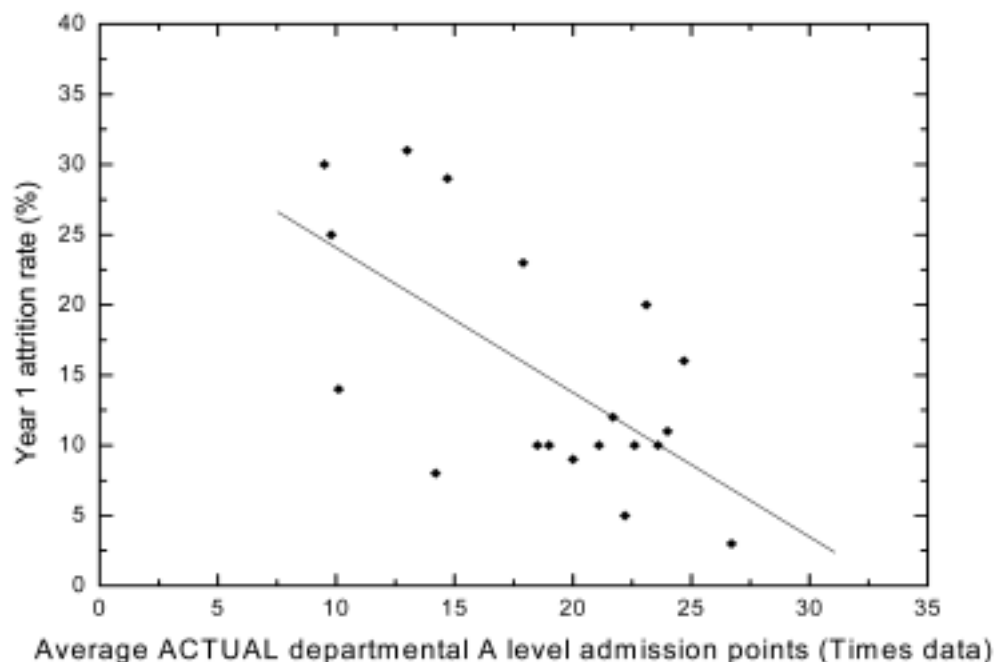


Figure 1: Year 1 attrition rate versus average A-level points

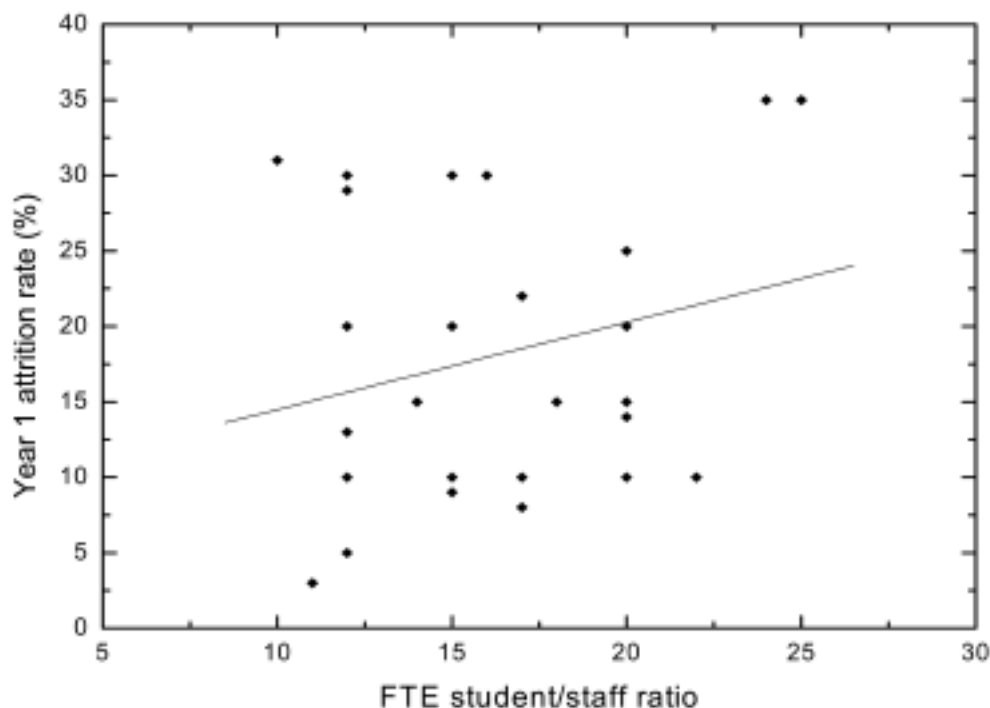


Figure 2: First year attrition rate versus student-staff ratio

list; the difference is the number of students who have been 'lost' between first semester and final semester, and this is a complicated issue.

It is easier to blame high SSRs for poor progression but **figure 2** forces us to question the truth of this. There is, indeed, a slight upward trend in attrition as SSRs increase, but some institutions with SSRs not much greater than 10 retain a lower percentage of students than others with an SSR at or above 20, so SSRs are at most only one aspect of the problem and a minor one at that.

Another temptation is to think that we can solve the problem if both we and the students spend more time in formal teaching/learning activities. However, **figure 3** illustrates that this 'Boxer approach' does not necessarily work; the decline in attrition rate with increased contact hours is almost negligible and, again, there is an enormous amount of scatter in the data.

Of course these scatter plots, derived from surveys conducted during the Progress project, conceal a great deal of information which we might hope would reveal more obviously useful information. Sadly, analysis showed no really clear trends in terms of now

different combinations of student attainment at entry, SSR and contact hours combine in relation to progression rates. Perhaps the most positive correlation is that the department with the lowest first year attrition rate (approximately 3%) has a low SSR of 12:1, a high average entry attainment of 27 points and 25 contact hours per week. This would not surprise most of us, although some of us would question whether such bright students would not be better educated using more independent learning and less direct teaching.

Causes of Failure

Examining the results of assessment, module by module, is the most obvious approach to identifying the immediate cause of failure, since programme failure is the cumulative effect of module failure. **Figure 2** summarises the results of a survey of heads of teaching in a range of universities. As most of us would expect, a high module failure rate is associated with mathematics and with analytical modules which depend on it. However, nearly 10% of departments cited programming as a problem and a smaller, but significant, number cited industrial practice. In any event we cannot continue indefinitely reducing the analytical content of our teaching

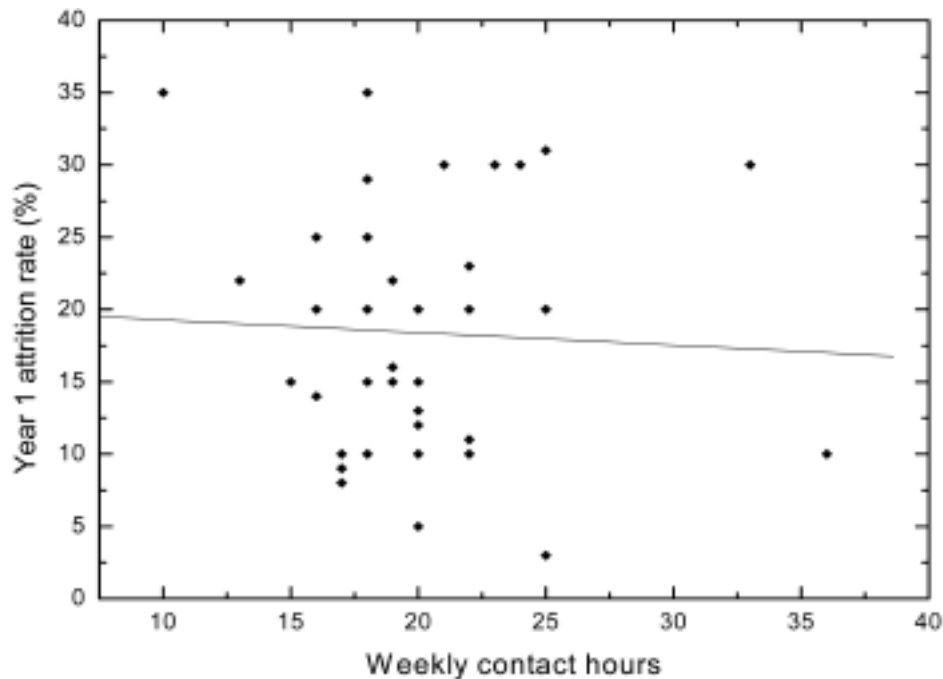


Figure 3: First year attrition rate versus weekly contact hours

in order to retain our students. High failure in subjects such as programming and industrial practice also, in some ways, counter the popular view that failure rates can be reduced by using more assignments or coursework in the assessment process and reducing the dominance of the formal unseen examination. Such 'conundrums' illustrate the value of seeking information from other sources.

Other causes of poor progression, identified by staff and students, include:

- Pastoral issues and financial difficulties
- Study skills
- Assessment difficulties and lack of feedback
- Poor attendance

We now consider these difficulties individually and summarise strategies for improvement. Although difficulties are discussed individually, if a department has a problem with student progression it is probably more likely to identify itself as having nearly all of these difficulties than just one of them. The positive side of this is that addressing one problem may well produce improvements in other areas. To take an obvious example, if we cure an attendance problem then we might expect that the mathematics problem diminishes

because students are attending mathematics lectures!

SOME PROPOSED SOLUTIONS

Mathematics and related analytical topics

There can be little doubt that the background in traditional mathematics of students entering engineering programmes has deteriorated. Most of us, who continue to offer courses with high analytical content, must, therefore, address this problem and it is likely that a combination of strategies will be needed. These might include:

1. Establishing carefully the needs of the students

Unless we take care to establish what mathematical skills our students need it is almost certain that they will be taught more mathematics than they need. It is also important to establish the level of skill the students need in each mathematical topic—students need some skills to a high level so that they can perform operations almost without thinking whereas, for other aspects a 'passive' understanding is adequate and students need only be able to accept the reasonableness of the operation to follow a

argument. It is important that students are given plenty of practice in the core mathematics they will need to use in engineering topics. Diagnostic testing, soon after students arrive at university, is also crucial to establishing the level of mathematical skill, and this gives us our baseline from which we can start to work with our students.

2. Teaching mathematics 'in-house'

This works well at several institutions, possibly because engineering staff have more credibility in so far as students accept that they are teaching material relevant to engineering. Bringing mathematics teaching 'in-house' is also a useful precursor to embedding it into other modules which helps to establish relevance.

3. Mathematics 'drop-in' facilities

Help provided outside the department can often be attractive to students who know, perhaps as the result of a diagnostic test, that they are weak in mathematics. On the other hand, other departments feel that they provide remedial support well within their departments. Sometimes timetabled sessions with small groups can be arranged and these can help students to form up into 'study teams' for the rest of their work.

4. Increased maths tuition with extra staff for support

This, of course, is labour intensive but can help greatly in improving skills of students. A flat floor is helpful so that students can work in groups with plenty of room for staff and students to move around. Plenty of praise helps, too!

5. Streaming

It makes sense to group students and according to their performance. However, it is important that students do not feel that they are being classified as inherently less able than their peers, but rather as having a less good background in mathematics.

Perhaps the most important concluding remark I can make in discussing solutions to the 'maths problem' is that we must truly solve the problem and not merely appear to do so. There is nothing to be gained by arranging, by whatever means, for students to pass first year mathematics if they have failed to acquire the

skills necessary for study of engineering topics in subsequent years or in professional practice; if we do this we are sweeping our problem ahead of us and are heading for a very high wall.

Pastoral Issues

Time was when pastoral care meant dealing with homesickness, illness and maybe the occasional case of exam nerves. Students, by and large, came from a narrow social stratum and most had parents who had experienced higher education themselves. That time has gone, and our increasingly diverse student population brings an increasing range of pastoral problems. The more common problems today might be:

- Severe financial problems and the need to work as well as study
- Parental opposition to study
- Unreasonable parental pressure to succeed
- Adapting to a new culture for both home and overseas students
- Opposition of spouse or partner
- Divorce
- Pregnancy
- Wife/partner's pregnancy
- Childcare problems

In the light of this list of quite serious problems it is not surprising that pastoral care at departmental and institutional levels is of increasing importance. In Hull's survey of students across several institutions, the most popular support strategy reported by students was having the same person act as academic and pastoral tutor in the first year; 90% of those experiencing it found it useful. In any event it is necessary to have integrated pastoral support at departmental, residential, and institutional level in order to handle increasing student numbers as well as an increasingly diverse student population having increasing financial problems. It appears from Donard deCogan's booklet 'Pastoral Care Issues in Engineering', that key features of such a successful and economical system would include:

- Real support for pastoral staff at institutional level

Issue	Reporting Frequency
Mature student issues	55%
Disabled student issues	33%
Gender related issues	17%
Ethnicity related issues	40%

Figure 5: Frequency of 'active' response to minority pastoral care issues

- Initial and ongoing training
- Use of trained postgraduate and senior undergraduate students in pastoral roles

It is also reasonable to suggest that, as our student base has become more diverse, the number of students who would in the part have been viewed as 'non-standard' and likely to have specific difficulties has increased.

Figure 5 shows the percentage of departments surveyed which described themselves as 'active' in making some type of special provision for students in particular categories. These figures seem extremely low and an improvement in this situation seems due.

Study Skills

Whereas teaching staff perceive students as lacking in study skills, most students who have been taught study skills do not see it as beneficial; in Hull's national survey only 10% found it very useful whereas over 40% reported it as being of no use. Part of this problem might be that students have a superficial knowledge of study skills on arrival at university and are unwilling to engage with the material again. The fact that young men reportedly have difficulty taking advice from authority figures (Lloyd, 1998) is also likely to play a part. This highlights the need for appropriate teaching techniques which force engagement and show students that they need to develop their skills while not embarrassing them. There is also anecdotal evidence that students don't feel that engineers need, for example, group working skills or writing skills. Their perception of engineering as a profession is clearly faulty.

As part of the Progress project the University of Hull, in collaboration with a professional trainer,

developed a new delivery approach for core study skills (Pulko 2003). To 'force engagement' the approach involved almost continuous interaction and activity. Interaction took the form of the lecturer's posing questions and (gently!) challenging students' perceptions. Activities included buzz groups, demonstrations and role play. Light heartedness was key in, and small prizes for particularly good answers or other contributions helped greatly in ensuring an appropriate atmosphere.

Group activities were carefully designed to allow students to make mistakes in safety so that they became aware of the limits of their skills. At the end of each activity each group was asked to report its experiences to the class as a whole. Of course, if these activities are to work well students must feel comfortable with the teacher and their classmates, and not be embarrassed by their failures. Atmosphere is key.

Sessions were held in a lecture theatre to a large group of students which is hardly ideal. The session length was two hours. Additional resources were minimal, although students were given a handout containing copies of the powerpoint slides used by the lecturer as well as printed material needed for the activities.

It is hard to say how these changes from the more traditional 'lecturing' approach improved study skills, since this will only become apparent as students progress through their courses. However, student feedback showed a dramatic improvement over previous years in terms of how relevant students perceived the topic to be.

Assessment Difficulties and Feedback

There are many reasons why we assess the work of students, but a list of the less well

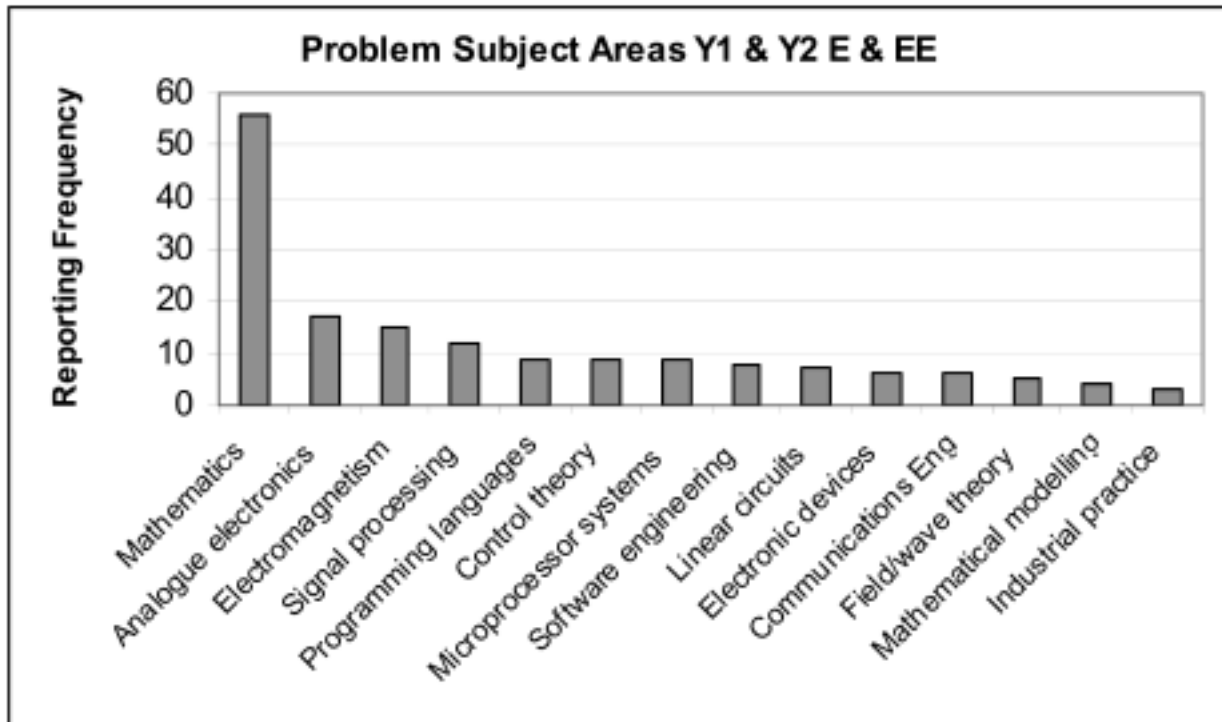


Figure 4: Frequency of a topic's being reported as associated with high failure rate for the range of topics identified by respondents

recognised reasons would be:

- To give feedback to students
- To develop students' self awareness
- To give feedback to teachers on the quantity and quality of learning
- To monitor standards over time.

And some of these aspects may give us hints on how to improve progression.

In considering the first point, feedback to students, it is relevant that lack of feedback was one of the causes of poor progression identified by students in Hull's more recent survey work. Giving students greater detail of their examination performance is, no doubt, helpful, but the ultimate examination feedback seems to be the return of fully marked and corrected examination scripts. As a community, many of us would not feel comfortable with this, yet, and there are, of course, issues of work load to be considered if large numbers of scripts are marked with feedback as a priority.

One alternative is a test with a single 'typical' examination question, perhaps half way through the semester. This could be fully corrected and returned so that students learn

the depth required in a typical answer as well as the necessary standard of presentation. Assigning a relatively modest assessment to this test encourages students to revise earlier in order to have 'marks in the bank' before the full examination, while allowing them to make mistakes associated with poor revision and examination technique with only a modest penalty.

Assignment based assessment is, traditionally, viewed as giving the ultimate in scope for feedback. However, as workloads increase it is increasingly difficult to give sufficiently full feedback to students soon enough after the work has been handed in for the students to form an association between the mark, the feedback and their approach to the assignment. It is amazing how many final year project reports reveal that, despite writing numerous laboratory reports and other assignments, the student has still not learned rudimentary skills in describing their work, presenting and analysing results, and evaluating them using simple but appropriate language. This is worrying for two reasons:

1. we are producing honours graduates who lack these basic skills

2. a student may have been penalised repeatedly for lacking basic skills and will, therefore, have lost marks on a whole sequence of assignments and reports.

If we use continuous assessment to enhance progression, then we must make sure that students are not repeatedly penalised for the same errors; this means that we must require them to engage with appropriate feedback early in their university careers.

Another difficulty with assignment based assessment might be reflected in the relatively high failure rate associated with programming languages and shown in **figure 4**. We, as engineers, appreciate the importance of work being done on time, so we penalise late submission by deducting marks. So, if students are to achieve good marks for their coursework then, early in their courses, they need the habit of submitting reports on time. This can usually be covered in study skills teaching, but it needs to be consistently reinforced from the first piece of coursework, if students are to develop good habits. Reinforcement in this context not only means consistent enforcement of penalties, but discussion with individual students as to why the work was not handed in on time.

Plagiarism also becomes a problem when we introduce more coursework. This also needs to be addressed in study skills teaching and dealt with consistently, and from the outset, in terms of detection and penalty. Although detecting and dealing with plagiarism represents another increase in workload associated with teaching, it is probably less time consuming and more productive to handle plagiarism in a first year assignment than in a final year project report. As with so many other problems there is little to be said for sweeping them ahead of us!

Poor Attendance

Some attendance problems are localised in so far as they are associated with timetabling (9.15 on Monday, 5.15 on Friday, lunchtime) or with particularly unpopular topics, or with individual students. However, sometimes poor attendance becomes part of the culture of a student group and can rise to an alarming

level. To some extent, no doubt, small, localised problems grow into bigger difficulties.

Different departments, and individuals within departments, probably have different perceptions of what constitutes an attendance problem. However, once attendance has been acknowledged as a problem in any department, attendance monitoring and 'chasing' of students by some means or other becomes attractive. Walter Middleton's booklet 'Communication for Retention' presents several case studies involving currently available software for use in attendance monitoring systems. The overall message is that such software is helpful, but that attendance monitoring does, notwithstanding, involve an additional administrative burden.

Having monitored students' attendance, the question arises as to what we do when they fail to attend or, for that matter, when they do attend. It seems that in some institutions, quite a modest reward in terms of assessment marks serves to encourage attendance whereas, elsewhere, the avoidance of quite heavy assessment penalties does not provide sufficient incentive. Local culture seems important here, but if the carrot can work better than the stick, perhaps a visit to the green grocer is called for.

Between the two extremes of reward and penalty lies intervention in terms of counselling; students who fail to attend adequately receive a letter or email asking them to discuss the situation with their tutors, and the pastoral system 'kicks in'. At the other end of the spectrum, persistent failure to attend could trigger a formal University warning. It is noticeable, here, that the milder the problem with any particular student the greater the inconvenience to colleagues; discussing poor attendance with a student takes considerably longer than issuing a letter, although most institutions require procedures to be fulfilled before formal letters can be issued. The point is, however, that early detection and counselling, although labour intensive may forestall academic failure of individual students; once the habit of lying in bed is established it is unlikely that any letter will bring about the motivation needed to make up for lost ground.

Everything said about attendance monitoring probably applies equally to monitoring of the

submission of coursework and this, perhaps, offers a more conveniently implemented means of monitoring students' working.

CONCLUDING REMARKS

In thinking about attrition rates I can't help being reminded of an advertisement by a major supermarket chain. This advertisement claims that the supermarket offers low prices (no surprises there) and goes on to say that they keep checking to ensure that the prices stay low. I have an image in my mind of a deserted supermarket in the dead of night, and of the numbers on price tags clicking up, rather like those on a cricket score board, first slowly and then with increasing speed. Large 'price guards' emerge from the shadows, in bullet-proof vests and holsters, truncheons in their hands. They scowl menacingly at the offending prices and say 'Now then, lads, we'll have none of that.' (They are Yorkshire price guards.)

In many ways the same image could apply to rising failure rates: if we don't keep up our efforts, each successive year seems to have a higher failure rate, and they really do seem to increase all by themselves. Progression is not as issue to be solved once and for all; ensuring appropriate progression, by whatever means is appropriate to the case, is an aspect of Higher Education that needs to become deeply embedded in our culture.

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