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that problems with student diversity and decreasing enrolments in engineering can be attributed to negative and outdated perceptions of engineering in students, teachers and parents.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 re-development 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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