Promoting Vocations in Engineering Amongst Secondary School Students

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Synopsis

In Australia, as in many parts of the world, the engineering profession is struggling to attract a sufficient number of young people to service the needs of local communities. There are many reasons for this. One is a mistaken impression that engineering is a male-dominated institution suited to those lacking creativity and social skills. Another is the community perception that it deals with the dull and mundane tasks of society, that are mostly carried out in the dirtier, more unpleasant industrial environments. This paper explores the reasons why engineering careers are so often overlooked by eligible young people at both primary and secondary school level. It then discusses approaches to dispelling these misconceptions, before presenting the Science and Engineering Challenge as a case study of a successful initiative that has been developed to introduce applied technology to high-school students in an interesting and appealing way.

The Science and Engineering Challenge, developed as a joint initiative of the Faculties of Science and Information Technology, and Engineering and the Built Environment at the University of Newcastle, introduces applications of science and engineering to year 10 students, using an approach that appeals to the competitive nature of young Australians. The Challenge is a kind of science competition, in which school teams of around 30 students compete regionally, for the privilege of representing their region in the "Super Challenge", contested by the best teams in the state, and in 2005, the nation. The Challenge is based on a series of simple half-day or one-day activities, that are each formulated to demonstrate an application of science or engineering in the modern world.

A number of aspects of the Challenge are identified as being essential to its success. These include a basis formulated in competition; a philosophy implicit in the sporting arena, and clearly one that most Australians find appealing, if not addictive. Another aspect is in the selection of simple activities that demonstrate the obvious importance of science and technology in the world around us. It incorporates teamwork, creativity and innovation which appeals to both girls and boys so it is not gender selective. Also important, is the supervision of Challenge activities by enthusiastic volunteers, enlisted from the ranks of research students, academics and professional engineers. Perhaps the most important aspect is the community support offered by Rotary International, who facilitate the staging of Challenge events in local communities in remote regions, and who, through the raising of local community support, enable so much to be achieved for such a relatively small cost.

In conclusion, the paper provides some discussion on the role that the Challenge provides in encouraging vocations in engineering, in the context of the educational process of young people, and it identifies the need for other initiatives to both supplement and complement the achievements of the Challenge.

Introduction

Over the past 10 years or so, Australia has enjoyed unprecedented economic prosperity and growth. This has included strong growth in the industrial, commercial manufacturing and housing sectors, with an increasing awareness of associated environmental issues. As a consequence, the demand for graduate scientists and engineers has grown at an increasing rate.

The supply of engineering graduates has not kept pace with the increase in demand. In a 2005 media release by Engineers Australia (EA, 2005), it was noted that, on the basis of current trends, the number of engineering graduates from Australian universities in five years time will not have increased from the number of engineers graduating a decade ago. Throughout this time, the number of engineering graduates has remained at about 5000 per year, which is a very low replacement rate of professional engineers, when compared with other countries. Even more alarming, was the recognition that an increasing number of these graduates (around 1000 out of 5000 in 2004) were international students, of whom many return to their country of origin after graduation. In real terms, this constitutes an increasing reduction in graduate numbers at a time when demand for engineering professionals is increasing.

There are several contributing reasons for this failure to supply enough graduates to meet professional demands. One reason is that there are insufficient university places being funded by the Federal government to train engineers in Australia's higher education system (EA, 2004a).

Insufficient university places in engineering can be addressed by a shift in government policy and funding strategies. There is, however, an overriding factor, that is less easily remedied. This factor is a shortage of eligible school-leavers choosing to pursue education and careers in engineering and technology. "The latest OECD data shows Australia ranks near the bottom in the percentage of university students in engineering, physics and mathematics." (EA&FASTS, 2004). In most cases, career choices are made prior to entering senior high school, and they are usually formalised by the selection of Higher School Certificate subjects that will *enable* school-leavers to enter professions in the fields of science and engineering. Engineers Australia and the Federation of Australian Scientific and Technological Societies have warned that declining numbers of students in the enabling sciences and advanced mathematics is a key element in declining vocations in science and engineering. (EA&FASTS, 2004).

It is suggested that this problem must be addressed by programs aimed at engendering an interest, in Australian school children, in obtaining the basic skills for specific tertiary qualifications (EA&FASTS, 2004). The Science and Engineering Challenge, an initiative of the Faculties of Science and IT, and Engineering and the Built Environment at the University of Newcastle, is an ideal approach to address this problem. This paper outlines the key elements of the Challenge, and discusses the factors behind its success in inspiring engineering vocations in students at a critical point in the K-12 pipeline.

Worrying Trends

The trend toward reduced enrolments in engineering schools can be seen in data from the University of Newcastle, where the number of commencing students in Engineering

Disciplines has reduced from 277 in 1999, to 228 in 2003. Even more worrying, is the low representation of female students, the numbers of which have not increased significantly over the past 10 years. Clearly, women are under-represented in the profession, and yet they are a potential source of additional graduates who might help to meet the increasing demand.

There are many reasons why young people are not choosing careers in Engineering. Perhaps the most worrying is the lack of appreciation of the engineering profession in the wider community. It appears that there is a significant proportion of society who have never considered engineering as a possible vocation, for themselves or for their children, because they have no real appreciation for what engineers actually do. The authors are involved in the promotion of science and technology amongst school students, and in the selection of school-leavers for engineering industry scholarships. In these roles, they have ample opportunity to enquire of students and school-leavers, the basis for their interest in engineering. In their experience, it appears that

- there is a disproportionately large number of prospective students who are interested in engineering only because they have had some personal interaction with engineering professionals; that is, they have an engineer as a family member or as a close family friend.
- a relatively smaller percentage are encouraged to consider engineering as a vocation by school careers advisors, and it is considered that the lack of appreciation of the engineering profession is widespread amongst careers advisors.
- many school leavers not included in the two groups identified above, choose to study engineering only because they are relatively good at mathematics and science, and they expect that this should qualify them for study in a technological field. In many cases, these students have no real appreciation of the career implications of their choice, and they may become disillusioned when they are exposed to the reality of the first year of a university engineering course.

In Australia, engineering has a low public profile, and often, a poor public profile. As a rule, Australians take the contributions of the engineering profession for granted, with little recognition of the achievements of the profession, or the crucial role that engineering plays in their standard of living. Engineering is thought of by many as a male-dominated institution, and engineers are stereotyped as “nerds”, or louts, lacking in social graces and cultural interests. Engineering is perceived as being too hard, too technical, too dirty and not as a profession that leads to personal affluence and prestige. Unlike other professions such as medicine, law and even finance, engineering is not readily glamourised in television dramas, and so the wider community is not exposed to a perception (accurate or otherwise) of what their profession does, and what a career in engineering could be like. In the everyday lives of a large number of Australians, engineering doesn’t really exist, and so, it is not surprising that many young Australians do not ever consider that they could become engineers.

Ironically, there is a trend for Australians to increasingly embrace new and emerging applied technologies as consumers, but to be less interested understanding or developing these technologies. From the information provided by applicants for scholarships in engineering, it appears that traditional hobbies, such as model planes, trains and boats, chemistry sets, electronics kits, go-karts and bicycles have given way to web-pages, net surfing chat rooms and play stations. Sport has also become a consuming passion of young Australians, and it seems to hold greater appeal than other “hands-on” interests. Unfortunately, the traditional craft and technology based hobbies have been out-competed by the wonders of the internet and the allure of the world wide web. There appears to be a correlation between the decline in vocations to science and technology, and the demise of traditional hobbies. This is not surprising, as the careers of many of today's scientists and engineers were born out of dabblings in things interesting and practical as children, often in family situations where there were no other scientific or technological influences.

What is Needed

It is clear that, through ignorance in the wider community, many potential engineers are not considering a career in engineering. It is also apparent that the proportion of society excluded through this ignorance is increasing. What is needed, is an increased community awareness of the importance of engineering to society and the environment, and an appreciation of the wonderful career prospects that engineering offers. Unfortunately, community-wide education of this type is easier to propose than it is to achieve. Realistically, the required change in community understanding cannot occur in a time frame sufficiently short to avert the looming crisis posed by a shortage of engineers.

A more realistic goal is to instill an appreciation of the engineering profession in those most able to participate in its recovery: the youth of Australia in the K-12 pipeline. Traditional mechanisms for achieving this are through improved education at primary and secondary school education, and through more informed advice from careers advisors. Whilst these are achievable goals, any significant improvement will require substantial government investment in school education. In a press release in 2004, the National President of Engineers Australia, Mr Doug Jones pointed out that "virtually nothing is being done at the primary school level to excite an interest in technology concepts" and that "there is very little commitment to engendering an interest in our school children to provide them with the basic skills for specific trades and tertiary qualifications". "Our current and future generations of school kids are not being given enough encouragement and resources to pursue an interest in mathematics and sciences, because the schools funding debate is all about the overall amount, rather than how the funds should be allocated across the curricula" (EA&FASTS, 2004) In the same statement, the President of FASTS, Professor Snow Barlow, said "Australia's future prosperity is at risk if the low numbers of students in mathematics, physics and chemistry continue. These subjects are the creative engine underpinning engineering and all sciences. If we want future budget surpluses then rebuilding enabling maths and science participation through investment in high quality teachers and teaching is an absolute priority."

Without government support on the scale suggested above, the task becomes considerably more difficult. If any improvement in the perceptions of school students is to be effected without the substantial funding support from the government at the school level, then clever strategies are needed to focus interest in school students at strategically optimized times during their educational process. For example, it is essential that every student, continuing on to senior secondary school studies, be given an insight into the fascinations of science and technology, and the subsequent range of career opportunities that these can lead to. As the opportunities to provide such insights are precious and few, the delivery must be efficient and effective, and in a manner that makes students receptive to new ideas and possibilities. Also, it must be provided at a time when students are about to make decisions about their future career options. The Science and Engineering Challenge, a program developed by the University of Newcastle, is one such initiative.

The Science and Engineering Challenge

The Science and Engineering Challenge was described in detail in Nelson et al. (2004). In summary, it is an outreach program conducted in cooperation with the community, aimed at providing secondary school students with a better insight into the world of engineering, science and technology. The program commenced in 2001, and encouraged by widespread community support, it has grown strongly, so that in 2004 it involved almost 6,000 students from over 200 schools in four of Australia's seven states. With the help of major sponsorship from Energy Australia and the Federal Government Department of Education, Science and Training, the Challenge has expanded to employ three independent teams in 2005, to accommodate over 330 schools and provide more than 12300 positions for students in Challenge events. The Challenge attracts the enthusiastic support of over 500 volunteers who offer their assistance year after year. About one third of the Challenge's operating budget comes from donations by local communities and businesses in regional areas.

A typical Challenge is conducted as a competition between school teams from up to eight different schools, and it is open only to students who have not yet reached senior high school level. The winning school is determined on the basis of the highest total score achieved for the Challenge, calculated as the sum of all scores achieved in the individual 'events' or activities in the Challenge. This means that each school team is subdivided into smaller teams or groups (usually 2 to 4 students) to represent their school in a number of different activities that are run concurrently.

The Challenge is conducted in two sessions during a normal school day: one in the morning and one in the afternoon, and eight different activities run concurrently in each session. Some activities are half-day activities, and others are full-day activities. Groups of students assigned to full day activities will spend all day working on that activity, and will not participate in any of the other activities being undertaken. Groups assigned to half day activities will complete 2 different activities during the challenge; one in each session. The same half-day activity will run in both sessions, and so, each school team must nominate two different groups of students to contest each half-day activity.

At the most basic level, the Challenge is organized into "Regional Challenge" events, where groups of up to 8 schools in a particular geographical region compete to become regional champions. Where the region has more than 8 schools, a Challenge may be conducted for two separate groups, on two successive days. Regions are further grouped into zones, with winners of Regional Challenges going on to compete to become their zone champion, in a "Super Challenge". In 2005, Super Challenge events will be conducted in Newcastle, Sydney/ACT, Queensland and Victoria, with the super Challenge winners going on to compete in the "National Grand Challenge", to be held in Newcastle in October.

The activities that make up the Challenge are fundamental to the quality of the program. Each activity calls on the students to use their innovative and creative skills to solve a problem. Many activities are structured so that prototype solutions can be completed and tested early in the activity, and then evolved according to basic experimental principles. To achieve maximum benefit, the students are given enough time to refine their approach and they are encouraged to test their solutions and to think logically about the outcomes in order to understand the underlying behaviour and to explore various possibilities for improvement. There is no single 'right answer' when it comes to solving a challenge activity: and as in real life students often have to find a compromise between important factors such as strength, cost and weight. In other more intellectual and theoretical activities students are also required to find a compromise between accuracy and speed. Also, the scoring of some activities requires students to develop a strategy to achieve the maximum score

In some activities this concept of comprise is taken even further. In “Escape from the Lost World” students are required to build and fly an airship using balsa-wood for the frame, helium balloons to achieve lift and electrically powered propellers to deliver thrust. The aim is to build a craft that can be effectively maneuvered to negotiate a 3-dimensional obstacle course, and this is the ultimate test used to gauge their success in the activity. Students realize that they must compromise between the time taken to build an elegant, functional craft, and the time they have to perfect their flying skills. This activity thus illustrates one of the important principles in our technology-based society, that it matters little how good the machinery is, if there are no skilled and capable people to operate it.

Each activity is carefully designed to demonstrate the diversity of possible solutions to any given problem. The activities are also designed to ensure that all students meet with some measure of success, so that a degree of satisfaction is achieved, even for the least successful participants. A good activity will inspire students and leave them with a sense of achievement. It will absorb them in the fascination of exploring the variables and understanding how they contribute to a solution; it will excite them with the prospect of using their knowledge in a constructive way to achieve a tangible and rewarding outcome.

Why it Works

There are a number of key aspects to the Challenge that make it an effective tool in inspiring school students to pursue careers in science and technology. The principal aspects are presented, in turn, below.

Mode of Delivery

For an initiative such as the Challenge to be successful, it must be delivered in such a way that it overrides the stereotypical perceptions of science and academia, held by typical teenagers. Science is officially “un-cool” to all but the steadiest of teenagers, so trying to glorify science by pointing out how clever or fascinating it is, is unlikely to leave much of impression. The Challenge overcomes this difficulty by exposing science and technology to students through competition. Australians of all ages respond well to competitive situations, and this is the underlying reason why sport is such a large part of the everyday lives of so many Australians. It has been found that in almost all cases, the opportunity to compete against other schools is a sufficient inducement for students to drop their social defenses and indulge themselves, whole-heartedly, in projects involving creative thought, scientific principles and the completion of hands-on tasks. In all cases, the success of involvement in an activity is evaluated by testing the solution, and this usually involves activities such as controlling vehicles, propelling projectiles or making profits. Consequently, students not only get the satisfaction of competition; they also get to do so in a way that most of them consider to be inherently good fun.

Structure of Tasks

Challenge tasks are selected to represent applications of science and technology to real-life problems. The tasks are structured so that students can develop successful solutions to the specified problem without needing to solve equations or understand higher level scientific concepts. The tasks, and the approach to solving them, mostly involve an initial stage of prototype development, where the students make a first attempt at a solution, followed by stages of design refinement, leading to improved solutions. This embodies the basic scientific approach to problem solving, of performing trials or experiments to test an initial solution, and then making improvements based on the observations and outcomes of the tests performed. In most cases, the necessary refinements are intuitive, and workable solutions can be identified through iterations of “cause and effect” tests or trials. Although the underlying concepts are not explicitly examined or explained quantitatively, interpretation of the characteristics of a particular solution, with identification of appropriate improvements, will usually elicit a qualitative appreciation of an important principle. The end result is that many students are able to realise, for the first time in their educational experience, that they can apply what they learn to make a difference to something that has real-life significance, and that this can involve a considerable amount of personal satisfaction.

Timing

The Challenge targets students at year 9 and year 10 level, at a time when they are called upon to make subject choices that will enable them to follow particular educational opportunities and career paths. To facilitate a smooth transition into university engineering courses, higher level maths and physics are essential, and engineering studies and chemistry are desirable. The Challenge is intended to provide inspiration at the time when students must make one of their most important educational choices. The primary goal is to ensure that they keep their options open to include a potential career in engineering or science.

University Involvement

The Challenge is staffed by a small crew of University volunteers, made up from undergraduate students, research students and academic staff. Whilst this has the potential to be intimidating for some participants, it has a positive effect in that students who are unfamiliar with, and perhaps daunted by, university people, are able to see that they are really not so different, and that ordinary people have a place at university.

Rotary International Involvement

Rotary International play an indispensable role in the running of the challenge series. By coordinating the logistics of the regional challenge events, local Rotary groups enable the university-based teams to service a wide area with great efficiency. Also, by providing a team of willing and capable helpers for each challenge event, they allow the Challenges to be conducted with a minimum university support, thus keeping costs to a minimum.

Most importantly, the cohort of Rotary volunteers are drawn from senior, influential people within the local community, with good connections throughout the wider community. In many cases, their involvement in the challenge is their only exposure to applied science and engineering, and they too are inspired by the event. An important consequence of this is that they take a new respect for science and engineering back out into the community with them. In this way, they become disciples of science and engineering, raising the awareness of engineering in the community, and spreading the message that engineering is a challenging and rewarding career option for the youth of Australia.

Discussion and Conclusions

The Science and Engineering Challenge is an innovative attempt to change the perceptions of school students in regard to vocations in science and engineering. With its strategically developed approach, it has the potential to expose a large proportion of Australia's eligible student population, to the challenges and satisfactions of technology, for a modest investment of resources.

The Challenge has been embraced enthusiastically by Australian secondary schools, as is apparent from its continually increasing popularity. It is important to appreciate, however, that the Challenge is not intended to be a marketing tool for the University of Newcastle, but rather, it is intended to be a mechanism to increase the pool of eligible students seeking to study engineering and science in Australia, for the benefit of all universities, and technological professions.

At this stage, there is only preliminary data to demonstrate the success of the Challenge. Statistics presented by Nelson et al. (2004) suggest that the increase in students enrolling in mathematics and sciences in the Higher School Certificate between 2003 and 2004, was between 3 and 14% greater for students in schools that had participated in the challenge in the preceding years.

In another example, the University of Newcastle has seen a significant increase in enrolments in the Engineering disciplines in 2005. Indeed, for the first time in more than 7 years, it met its target for new students in these areas. This correlates well with the expansion of the Challenge in 2002, to include most of the area from which it traditionally derives most of its student intake. Increases have been most significant in civil engineering, which is well represented in the activities used in the early years of the challenge. It will be interesting to observe the trend in enrollments in electrical engineering in 2008, as the first electrical power activity was introduced into the challenge this year.

Whilst it is clear that a considerably greater investment of resources is urgently required to raise the appreciation of engineering in the wider community, there is no suggestion that this will be forthcoming in the near future. Without an improvement in community perceptions, the popularity of engineering as a vocation is unlikely to increase in a way that pervades the wider community. The short-term objective of increasing vocations in engineering can be achieved by ensuring that science and engineering are given due prominence in the K-12 educational process. This, however, will also require a substantial commitment by governments, and this is also unlikely. Hence, the Science and Engineering Challenge offers one of the few systematic and coordinated opportunities to engender an appreciation of science and technology in school students. It offers great promise as a means of increasing the number of students choosing to study engineering, and hopefully the number of graduates from Australian Universities.

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