The Engineering Link Project:
Learning about Engineering by Becoming an Engineer

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Abstract

There has been a greater emphasis over the past few years of encouraging high school students to take up engineering as a career. This is due to a greater need for engineers in society, particularly in areas that are suffering a skills shortage. Both the engineering profession and universities across Australia have moved to address this shortage, with a proliferation of engineering outreach activities and programs the result.

The Engineering Link Group (TELG) began the Engineering Link Project (ELP) over a decade ago with a focus on helping motivated high school students make an informed choice about engineering as a career. It also aimed at encouraging more high school students to study maths and science at high school. From the start the ELP was designed so that the students became engineers, rather than just hear from or watch engineers. Real working engineers pose problems to groups of students for them solve over the course of a day. In this way, students experience what it is like to be an engineer.

It has been found that the project does help high school students make more informed career choices about engineering. The project also gave the students real life and practical reasons for studying sciences and mathematics at high school.

Introduction

The Engineering Link Project (ELP) was founded in 1994 by The Engineering Link Group (TELG) on two basic premises:-

1. Enrolments in science and mathematics subjects at high schools are decreasing[1].
2. The average school student knows very little about engineering.

The lack of interest in science among secondary school students in general has been particularly demonstrated by a decline in enrolment in physics classes over the past two decades[1]. Between 1980 and 1998, the percentage of the Year 12 cohort in Australia enrolled in physics dropped from 29 to 18 percent[1]. While the diversity of subjects offered has increased during this period, Goodrum *et al*[1] argue that it is unlikely that this large reduction in enrolments can be fully explained by this increase in diversity. In order to reverse this trend, they recommend that schools need to make the current science subjects more inclusive of both males and females, and of the wider interests and abilities of students. The ELP was formed with recognition of this diversity, developing activities that tried to be as inclusive as possible while providing real to life engineering experiences.

The second premise, that few secondary school students know much about engineering, is reflected throughout society. High school students may very well not be choosing engineering as a career simply because they don't really know much about it. "Encouraging high school students to go into engineering, when they have only heard science throughout their school lives does not assist in their choice of university courses."[2] A recent review of Science, Engineering and Technology in Australia suggested that students need to be encouraged at an early stage to pursue careers in these areas[3]. It further suggested that new ways of making science and engineering subjects more appealing to students need to be developed with partners outside the school system, and that these partnerships could also provide students with valuable insight into science and engineering careers. The ELP aimed to fill this gap, by offering an experience outside of school for students to experience engineering in a fun environment.

One of the main difficulties inspiring students about careers in engineering is that their main sources of information, their teachers, are usually not much better informed than the students themselves. A recent report by the Prime Ministers Science Engineering and Innovation Council suggested that more needs to be done to provide teachers the support and professional development activities to inspire their students about science and engineering[4]. The Engineering Link Projects helps teachers in this respect, not only by showing possible students from their classes what engineering is all about so they can tell their fellow school mates, but also allow the teachers to help with the camp, providing them a chance to gain an understanding of what engineering is.

These premises were developed by TELG into three educational aims for a new type of project, the Engineering Link Project:-

1. To teach science and mathematics as a problem solving activity
2. To develop student insight into the activities of practicing engineers
3. To develop higher-order mental practices such as problem solving, critical analysis, synthesis and evaluation.

The first two objectives were met by developing a method of demonstrating to students that science is a valid course of study, and that it can lead to exciting and rewarding careers. The hands on, practical, problem-solving approach characteristic of engineering was chosen as the vehicle, as it was thought that the separation and abstraction of theory and experiment in school was one possible reason for the decline in student enrolment in science subjects[1].

It has been understood for a while that those students who have definite career paths in mind tend to do much better academically, since they can see reasons for studying their subjects[5]. Further, engineering is poorly served in schools as a career choice, since few students, or their teachers, have any knowledge of the field other than vague impressions that 'engineers build things'. This attitude, it was felt by TELG, was not adequately addressed by the usual site visits and talks from engineers in schools. A new approach was required.

> "We felt there was a need to offer a new approach, that is to allow students to <u>be</u> engineers, rather than just <u>watching</u> engineers"[6]

The third aim of developing higher order mental practices, has always been important, and is now vital in today's society. The ability to function at these levels is sought more and more by employers, who accept that change is occurring more and more rapidly[7].

Engineering Outreach Activities

This section reviews other programs similar to the Engineering Link Project, including past and present activities. The review focused on projects or events where students were active participants, rather than just passive observers.

The Engineering Link Project was started in 1994 in Townsville, Queensland. At this time, there were very few similar projects being run in Australia or indeed around the world. The only group working directly in this area was the Smallpeice Trust of the United Kingdom with whom the Project had well-established contacts[8]. Another similar group was Shad Valley, in Canada, but their focus was on problem-solving with a business approach as the vehicle[9]. Both of these groups were discovered after the Project had started, and the Smallpeice Trust has since offered very enthusiastic support, with reciprocal visits made.

Since then, a number of programs have been started to encourage more students to pursue engineering as a career, both in Australia and overseas. Some programs target primary school students, with contests or activities that have an engineering flavour[10]. Others focus on high school students, showing them what engineering is like, giving them the opportunity to talk to graduates and giving them some experiences[11-13]. Some programs also focus on encouraging more women[14] or students from minority groups[15] to pursue engineering as a career. One of the most widely recognised programs developed in the past few years to encourage students into engineering and science is the University of Newcastle's Science and Engineering Challenge[16]. It provides year ten students the opportunity to solve problems with a science and engineering flavour, developing teamwork and other skills and encouraging them to take up science and maths subjects at school.

The Underlying Pedagogy

This section presents a brief overview of the prevailing pedagogy used in the project to teach students about engineering, that of experiential learning. Experiential learning is a pedagogical approach that defines learning as "the process where by knowledge is created through the transformation of experience"[17]. The process of experiential learning can be thought of as a four stage cycle with four adaptive learning methods[17]:

- Concrete experience
- Reflective observation
- Abstract conceptualisation
- Active Experimentation

This basic learning cycle, as seen in Figure 1, was first put forward by American social psychologist Kurt Lewin and has since been adapted by David Kolb[17]. Kolb compared this cycle to models of the problem solving process proposed by Pound[18] and found that the stages were very similar. In selecting the problem, and developing alternative solutions, the students are moving from reflective observation to abstract conceptualisation. The evaluation of the solutions and the consequential selection of a solution parallels the move from abstract conceptualisation to active experimentation. Turning active experimentation into concrete experience involves testing or executing the solution. Finally the process of evaluating the solution and identifying problems and possible changes closes the loop from concrete experiences to reflective observation. Thus, taking a problem solving approach to help students learn re-enforces the experiential learning approach, so long as the loop is closed and the students can test the solutions they devise.

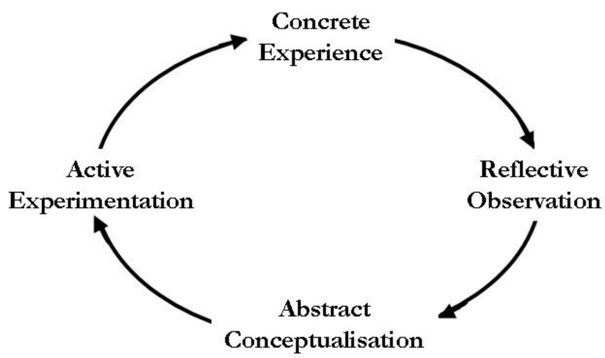

Figure 1: Experiential learning cycle[17]

By basing the Engineering Link Project on an experiential learning model, and using a problem solving approach for each of the days activities, the students learn not just the theory and skills related to the specific activities they are involved with, but more generally about the process of engineering itself.

Overview of the Engineering Link Project

The Engineering Link Project is a four day, in-depth course for Year 11 and 12 students throughout Queensland, who are either considering engineering as a career, or who are undecided about their futures and want to find out more. Three Projects are conducted each year, one in Townsville, Rockhampton and Brisbane, hosted at a local university. The actual course is broken down into three, day long engineering activities, with the final day left for a tour of the university campus and facilities. After an initial safety briefing, each day consists of either two or three different engineering disciplines, including mechanical, electrical, space, chemical, civil, military and mechatronics. The students nominate the type of engineer they wish to become each day, and are thus divided into groups.

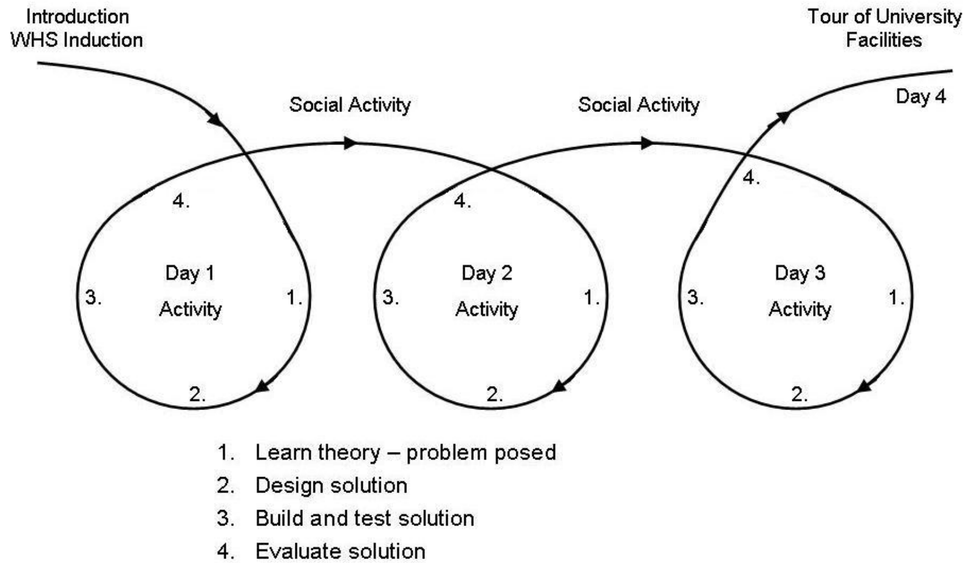

Figure 2: Engineering Link Project Overview

Each day of the Project is similar, as can be seen in Figure 2. Engineers speak to their group of students about themselves and their disciplines, why they chose engineering as a career, what was involved in their course of study to become an engineer, and what they do from day to day. They finish by touching on the sorts of problem they encounter in their daily work, and then they present one of these problems to the students in the form of a contract calling for tenders. The engineers then cover come basic theory that the students will need to solve their problems, and lists the materials available for the construction of the solution. It should be noted that the engineers involved do not get paid for their time; they volunteer their services for the day.

Students then break into groups of four or so and begin to consider the problem. They have access to samples of the materials and can test these, under the general guidance of the engineer. This stage allows the engineer to ensure that the groups have absorbed the theory needed, and to guide those groups that need help. This guidance is kept to a minimum, in order to ensure maximum student input and ownership of the solutions. An interesting development is that the students, having very little engineering knowledge, also have no idea of what can not be done, and this often leads to novel solutions to the problems.

Having settled on their materials, the student-engineers design their solutions and prepare working drawings, construction instructions, cost analyses, environmental impact statements and workplace safety reports. These are presented to the engineer, as their client, for their consideration. Once these are in the client's hands they are examined and commented upon, and then returned to the groups.

After the client's approval, the plans are handed back to their owners and the groups get their materials list filled from the Project's stock. Tools are also available on request. The materials are charged for, with excess being purchased back at a much reduced price, while extra requirements are available at an exorbitant cost. At the end of each day's work, a range of criteria are considered. These criteria are things like meeting design specifications, economy, the elegance of the solution and the ease of construction.

There is sometimes a set time for construction, but generally the students have ample time. After construction the original submissions are examined to make sure that no major departures from design have occurred, and the constructions are tested, initially to design specifications, and then usually to destruction. This is, naturally, a very popular part of the event.

A major consideration was the choice of age group for the students. Initially the ELP was set up to run as early as possible in Year 11 to allow students the chance of changing subjects. It had been envisaged that students from any background who thought that engineering might be worthwhile would be accepted. After the first trial project in 1994 it became clear that a reasonable understanding of mathematics and physics was needed, and that students who lacked this background found engineering and the necessary maths difficult and distasteful. Further, feedback from the Future Engineers Australia Management Project (FEAMP), a course that was developed to follow the ELP for year 12 students, suggested both that most students attending FEAMP were not aware of the ELP but would have very much liked to attend. Thus as of 2005, the Engineering link Project is aimed at both Year 11 and 12 students, primarily studying maths and science and who are either interested in becoming an engineer, or just would like to know more.

Evaluation

The Projects have been assessed in two ways. Firstly the students completed an evaluation of the program, covering each day's activity, as well as the whole Project. The main indicators used to evaluate the project were:

1. Did you enjoy the camp?
2. Was the camp good value for money?
3. One of the goals of The Engineering Link Group (TELG) is to give students real-life applications and practical reasons to study Maths and/or Physics. Have we achieved that goal with you?

There were three responses for each question, yes (Y), not sure (S), and no (N). Table 1 shows the evaluations from the previous four years' projects.

From the data, 92% of students enjoyed the camp, 92% of students thought it was good value for money, and 82% of students thought that TELG had achieved its goal of providing real life and practical reasons for studying science and maths.

	2001	2002	2003	2004
Townsville	NA	n = 46	n = 54	n = 51
Q 1		Y(45) / S(1)	Y(45) / S(8) / N(1)	Y(49) / S(2)
Q 2		Y(42) / S(4)	Y(31) / S(17) / N(5)	Y(49) / S(2)
Q 3		Y(45) / S(1)	Y(45) / S(8) / N(1)	Y(41) / S(9) / N(1)
Rockhampton	n = 48	n = 53	n = 43	n = 43
Q 1	Y(44) / S(4)	Y(52) / S(1)	Y(22) / S(21)	Y(42) / S(1)
Q 2	Y(46) / S(2)	Y(52) / S(1)	Y(38) / S(5)	Y(43)
Q 3	Y(38) / S(7) / N(3)	Y(46) / S(6)	Y(36) / S(7)	Y(34) / S(9)

Brisbane	n = 43	n = 81	n = 71	n = 61
Q 1	Y(41) / S(2)	Y(79) / S(2)	Y(66) / S(5)	Y(59) / S(2)
Q 2	Y(38) / S(5)	Y(80) / S(1)	Y(70) / S(1)	Y(60) / S(1)
Q 3	Y(35) / S(7) / N(1)	Y(62) / S(14) / N(5)	Y(52) / S(9) / N(10)	Y(52) / S(3) / N(6)

Table 1: Evaluations of Engineering Link Project, 2001 to 2004

The final question asked of the students was "Has this camp helped you in deciding on your future career?" The student responses can be seen in Table 2.

Project	T01	R01	B01	T02	R02	B02	T03	R03	B03	T04	R04	B04	%
I was already going to be an engineer; this camp confirms it	NA	12	15	18	12	32	30	7	23	14	10	21	33
I *think* engineering's for me, but still not 100% sure		21	23	19	28	27	22	21	26	19	21	22	42
I'm still not sure what I want to do		10	5	7	10	17	2	11	10	16	8	15	18
Enjoyed the camp, but engineering's not for me		5	0	2	3	5	0	4	12	2	4	3	7
This camp hasn't helped me at all		0	0	0	0	0	0	0	0	0	0	0	0
Total		48	43	46	53	81	54	43	71	51	43	61	100

Table 2: Has this camp helped you in deciding on your future career?

Some typical comments include:

- Great spending time with people with the same interests as myself and I learned much more than I would learn at school.
- I came here to get an idea of what I would like to do after school. After this camp I decided that engineering is definitely the way for me.
- I'm never going to ask my teacher where to use [Maths & Science] any more because now I know.

A more informal assessment is the financial support the Project receives from the Australasian Institute of Mining and Metallurgy, Engineers Australia, Comalco, Stanwell Corporation, Central Queensland University, the University of Queensland, the Australian Army, Queensland Nickel, Education Queensland, Queensland Transport, BHP Cannington and many others.

We are also supported by some twenty practising engineers who are prepared to find time to work with our students, and to involve themselves in considerable planning and preparation. To the profession's credit, we have never been refused by an engineer.

Conclusion

Australian universities are not producing enough engineers to cope with the current demands from industry. A recent article in The Australian's Higher Education Section pointed out that

Australia has a "dire shortage of engineering graduates that, by all accounts, must be addressed immediately"[19]. More high school students need to be encouraged to pursue engineering as a career.

The Engineering Link Project is helping enable students to make a more informed career choice in the engineering field, and so is meeting one of its major aims. Eighty-two percent of students that have attended the project over the past four years felt that the ELP had given them real life and practical reasons for studying sciences and mathematics at high school. This more than exceeds the initial goal of TELG to encourage more students to pursue science and maths at high school by providing context for the students. The project also provides the students with an interesting cross section of engineering and its associated disciplines, helping those interested in undertaking engineering at university a more informed choice of discipline, and, more importantly for TELG helping those students who were undecided more of an appreciation of what engineering is.

The application of an experiential learning pedagogy to the actual engineering activities does help the students to develop higher-order educational aims as the evaluation and synthesis of ideas and problem solving skills.

The Engineering Link Project has been running since 1994, encouraging over a thousand high school students to pursue engineering as a career. This work was recognised in 2004 with The Engineering Link Group receiving one of Education Queensland's inaugural Peter Doherty Awards for Excellence in Science and Science Education[20]. With the continuing support of those organisations that provide help and support, the Engineering Link Group hopes to continue the Engineering Link Project into the future, with the engineering profession only benefiting from this valuable and worthwhile initiative.

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Biographical Information

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PAUL RICHARDS is a retired science teacher. He holds a Bachelor of Science in marine biology from the University of Wales, Aberystwyth, and a Master of Education from James Cook University. He has worked in the Solomon Islands and has taught in the UK and Queensland. He is now developing ways to encourage school students to take up the sciences and mathematics.

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