Final Report of the ARC Linkage Project

engineering choices
engineering futures

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'Students engaged in engineering activities during the Science and Engineering Challenge'

Report of the ARC Linkage Project LP0562653

"Identification and Development of Strategies for Increasing Engineering Enrolments"

This report is part of an Australian Research Council Linkage research project involving the University of Newcastle, Engineers Australia and AmpControl Ltd. The support of all the parties is gratefully acknowledged.

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EXECUTIVE SUMMARY

In many Western nations such as Australia it has proved difficult to attract sufficient numbers students into engineering to meet national needs. Over time there has been a decline in the number of students enrolled in *engineering* at universities and in the *enabling subjects* (science and mathematics) in schools, despite strong career prospects in engineering. In an audit conducted in 2006 by the Australian Department of Education, Science and Training, it was projected that the demand for science professionals would increase by around 55,000 by 2012, and demand for engineering professionals would rise by over 46,640 in the same period (DEST, 2006). However, in 2006, fewer than 10 per cent of commencing enrolments were in the natural and physical sciences, six per cent were in engineering and related fields (Ainley et al., 2008). It is suggested that such a shortfall in scientific and technical capabilities will 'compromise Australia's potential to be at the forefront of global scientific and technologic development' (DEEWR 2008, p.5).

The research presented in this report was undertaken in direct response to the need to identify directly what will capture and build young people's interest in Engineering and to unlock what is necessary for an effective communication strategy to stimulate enrolments in university engineering programs. The project, *Engineering choices, Engineering Futures* was funded through an ARC Linkage Grant (2005-2008) with partners *Engineers Australia* and *AmpControl.*

In broad terms the project sought to address the question: What do we need to know to understand young people's choice of a career in engineering? What factors come into play, in what combination, and when do they become important? The literature directed attention to a number of possible components:

- young people's knowledge of what engineers do and who they are, i.e. what identifies an engineer
- how they feel about, and the extent to which they like and choose subjects and engage in activities important for engineering.
- the environment in which they learn STEM subjects including the location of the school, and any exposure to counselling, or special programs such as the Science and Engineering Challenge
- family background and gender.

When other studies have examined reasons for low engineering enrolments they have rarely looked at these components in combination.

Another unique feature of the study was the design which allowed us to explore in an increasingly focussed way the characteristics of those who took up engineering against the potential population of young people who showed an interest in engineering type activities and relevant STEM subjects. A randomised, cross-sectional sampling design was developed that became increasingly focussed on 'attachment to engineering' (from primary children who had not yet exercised subject choice, through science students in secondary schools; first and final year engineering students and finally engineers). This allowed an exploration of stability in preferences, interests and predispositions relating to engineering across age cohorts, gender, school type and location and family background, and to identify which of these had the most potential to lead to engineering as a career. The design allowed for the identification of 'generational differences' to see if popular assumptions about who becomes, or might become an engineer, had support. The 'potential' population of interested young people, the stability of attachment characteristics ('PIP', i.e. preferences, interests and predispositions) across groups, and the relevance of generational differences were all determined as important to guide an effective communication strategy to attract young people into engineering. The study also sought information from school science teachers/counsellors to gain a perspective on the nature of information and level of understanding about engineering as a career. Engineers too were asked to reflect on barriers, and issues facing recruitment in engineering

One of the most striking findings in relation to ‘potential’ was that 13% of primary school participants indicated that they would like to become engineers when they grow up. Extrapolating this fact to the total number of Year 5 students in Australia, 269,300, there is a potential pool of 35,009 students who would consider engineering as a possible career option. This alone, especially if sustained throughout the secondary years of schooling, would go a long way toward addressing the engineering shortage, and indicates how vitally important it is to keep students interested in the enabling sciences and mathematics and to address any misunderstandings or gaps in information about engineering that may reduce early interest and orientation toward engineering.

Main Findings of the Study

Primary and secondary school students were generally satisfied with school and school subjects, although slightly less satisfied with science and mathematics. An exception was their relative satisfaction with computing: primary students were very satisfied while secondary students (and engineering students, at university) were less satisfied with computing than most other subjects.

At different levels of sophistication, most primary students can identify engineering-type tasks and the secondary students had a reasonably good grasp of engineering tasks and careers. Both groups also had positive personal perceptions of engineers and engineering, indicating that their perceptions, at least, were not a problem

Family members were the major sources of information about careers for primary students, but for secondary students sources ranged from careers’ advisors, TV/Internet and teachers. Primary students believed that males (especially father and brothers) were more likely to be knowledgeable about engineering, and secondary students believed that males generally would be more interested in engineering.

University engineering students differed by discipline for interest in and importance of mathematics, science, computing, perceptions of engineering and liking for engineering activities, with mechatronics students generally being the most positive and computer/software students being the lowest. A large proportion of students indicated that a natural inclination towards mathematics and science was behind their choice of a career in engineering, as was also the case for the practising engineers. About half the sample of engineers recognised a need to address gender imbalance in the profession, a third thought that further effort towards achieving gender equity in engineering was either not warranted or would be ineffectual.

Three themes covering the full range of the student experience emerge from the study’s findings. These are: *enriching* the primary school experience, *enthusing* secondary school students, and *encouraging* intending tertiary students to enrol in engineering degree programs.

***Enriching* the primary school experience** of young Australians was identified by this research as the key to a successful long-term solution to the engineering skills shortage currently experienced in Australia. The three most important actions can be summarised as follows:

1. Enriching the mathematics and enabling sciences experience for students by providing high-level thinking problems in a contextualised curriculum.
2. Tapping into ‘urge to invent’ at an early age, by introducing engineers in the classroom who can ably explain the joys and intricacies of their profession, thus debunking existing stereotypes.

3. Addressing the perception that engineering is a male dominated profession by providing young girls with role models they can be inspired by.

A long-term solution can only occur if the society as a whole changes its perception of mathematics and science, the importance of the work of engineers, and gender roles.

***Enthusing* secondary school students** already taking high-level science and mathematics subjects to pursue the engineering field is a task that could be accomplished to help ease the engineering skill shortage in the medium term. The results of this research indicate that the following four points should be taken into consideration in any action aimed at increasing enrolments in the medium term:

1. Better informing teachers and careers advisors of the range of opportunities arising from a career in engineering.
2. Promoting community perceptions through the media, particularly using internet-based promotion could lead to better engagement with secondary students.
3. Increasing students' exposure to this science outreach programs, including visits to schools
4. Clarify the nature of engineering and its crucial role in society through proactive initiatives.

Increasing student numbers in the enabling subjects of mathematics and science in the senior secondary school is paramount to the success of increasing tertiary engineering enrolments at a level that reduces or eliminates the skills shortage.

Encouraging intending tertiary **students into engineering degrees** and retaining those who have already started these studies is an approach to tackling the skills shortage in the shorter term. A number of actions could be taken to accomplish this:

1. Ensuring that students are not discouraged from studying high-level mathematics, physics and chemistry by misinformation about prerequisite options as this effectively hinders their possible future pursuit of engineering studies.
2. Creating scholarships, in particular industry-sponsored scholarships and subsidising HECS fees for engineering studies.
3. Encouraging more women to undertake engineering studies.
4. Facilitating the upskilling of engineering sub-professionals by appropriate articulation arrangements between TAFE and Universities to assist transition from engineering trades into the engineering profession.

Because of the intrinsic links between engineering and school mathematics/science, creating a strategy to effectively combat the skills shortage involves first answering the question:

> *How can the predisposition of students to continue with mathematics and the enabling sciences, leading to increased enrolments in engineering degrees be improved?*

The overwhelming message of this and many preceding studies and reviews is that action needs to be taken to address this issue and a piecemeal approach should not be attempted. While short, medium and long term steps have been identified, it is essential that the solution is seen as a continuum of action from preschool to the end of secondary school and beyond. A plan of action needs to be in place which addresses the quality and inspiration of mathematics and science teaching and curricula from K-12. Only through a holistic approach can we ensure that a similar report to this one will not be written again in ten years time.

Recommendations – Short Term

Recommendation 1:

Creation of Industry-University partnerships to provide scholarships to students entering engineering degrees.

These scholarships should have a strong work experience component, provided by the companies sponsoring the students.

A main focus of the scholarships should be encouraging women to become engineers.

Recommendation 2:

HECS subsidisation in order to attract more students to engineering degrees.

This should be done in conjunction with better information for students of the essential and desired prerequisites to enter engineering studies

Recommendation 3:

Facilitation the upskilling of engineering sub-professionals by appropriate articulation arrangements between TAFE and Universities

This should be done by providing clear pathways from the engineering trades to technologists to professional engineers.

Recommendations – Medium Term

Recommendation 4:

We recommend improving students' understanding of engineering as a profession by the involvement of the engineering profession in general, and Engineers Australia in particular in:

1. Organising visits to Year 12 students from professional engineers
2. Organising a media campaign to promote engineering as a profession debunking current myths and misconceptions
3. Creating a more modern web-based approach to engineering promotion highlighting the status and rewards of the profession
4. Providing mentoring and role models to schools as required.

Recommendation 5:

Investment should be placed on Science and engineering Outreach Programs which:

1. Improve students' awareness of engineering and engineers' work
2. Improve students' understanding of the enabling sciences leading to engineering careers

These Outreach Programs should be co-ordinated at a national level and organised to reach all Australians

Recommendation 6:

Careers advisors play a very important role in shaping young people's occupational choices. It would be advisable to improve their awareness of engineering choices and rewards. This can be achieved by:

Mobilising the resources of Engineers Australia to provide regular information and site visits for Careers Advisors in all of its Divisions throughout Australia

Recommendations – Long Term

Recommendation 7:

We recommend the development of an intervention strategy suitable for wide-scale implementation to enrich mathematics skills at primary school in order to increase the possibility of choice of a career in engineering. The goals of the intervention would be to:

1. Improve awareness of engineering and engineers' work within the school community
2. Increase children's interest in taking engineering in the future through an enriched maths experience
3. Enhance teachers ability to teach mathematics at a level that enables transition to secondary school maths

Recommendation 8:

The resources of Engineers Australia be mobilised to:

In conjunction with a Primary School Mathematics Intervention Strategy, develop a voluntary mentorship scheme for appropriately motivated and skilled engineers to assist in the classroom in relating mathematics to the real world in general and engineering in particular.

Develop strategies to more clearly clarify and define the term “engineer” in the eyes of the general community

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PREAMBLE

A continuing nation-wide decline in high school student enrolment in higher level mathematics and science is leading to a reduction in the number of students undertaking university engineering programs in Australia. The project “Engineering Choices, Engineering Futures” is directed toward a better understanding of the reasons behind this trend and the development of strategies to reverse it. The project therefore aims to determine the factors that contribute most to enrolment in engineering courses, and utilise this information directly to develop an optimised national strategy for promoting mathematics and science studies to students in order to increase enrolments in engineering at university level.

The project was divided into five different phases:

1. The identification of existing studies which address the decline of enrolment in the enabling sciences and engineering. Through these studies the potential factors that contribute to school student awareness of science and engineering could be determined.
2. The development of a better understanding of the causes leading to the decline in enrolment. A cross section of engineers and engineering students were surveyed to identify the factors which led them to undertake studies in engineering.
3. A nation-wide survey the design of which was directed by the factors identified in the first two phases. This survey was not only aimed at high school students but also at their teachers. It was focused on three main areas:
   a. What is the Australian primary/secondary school student understanding of engineering mathematics and science?
   b. How does primary/secondary school interest in engineering develop so that it leads to participation in tertiary studies?
   c. What strategies have proven most effective in increasing and developing interest in, and understanding of, engineering?
4. The assessment of the impact that the wide range of existing outreach programs on students, what the programs offer, how effective they are, and why.
5. The development of a national communication strategy for promoting engineering studies to school students.

The report presented here is divided into two parts. Part 1 describes the background to the study and shows and analyses the survey component of the study. In Part 2 of the report, the main conclusions are extracted and recommendations presented for future implementation.

PART 1 – INTRODUCTION, DATA COLLECTION AND DATA ANALYSIS

Part 1 of this report presents the background to the survey component of the study. In Chapter 1 a synthesis of the findings of recent reports dealing with what factors influence engineering enrolments is detailed.

Chapter 2 explains the methodology and sampling strategy used to survey a wide range of stakeholders.

Subsequent chapters – Chapters 3 to 8 – present the data obtained by the project for primary, secondary and tertiary students, professional engineers, teachers, and comparative results for all groups combined, and provide an overview of analysis and results.

CHAPTER 1 - Factors influencing enrolments in engineering degrees

In colloquial language the term engineering has multiple meanings and the wide range of contexts in which engineering takes place can frequently lead to misconceptions, mystification and misunderstandings among the young, their teachers, careers advisors, parents and even the media they access. The persistence of misunderstandings about what engineers do, and their relative invisibility as a profession (Gallup, 2004; Reid & Denley, 2003) are some of the reasons offered for the decline in university enrolments in Engineering in Western nations, but this is just the tip of the iceberg. There have been at least 30 major reports that have investigated this decline and a great many more that have studied the allied issue of enrolments and achievement in science and mathematics subjects at secondary school level. The sheer number of reports is often noted and their lack of influence deplored, but it is rare that reports of this size and scope are brought together in a way that can inform research directions. This chapter undertakes the task of synthesising the findings of reports directed specifically at enrolments in tertiary engineering degrees to identify the main influences that result in enrolments or work against such enrolments.

'Engineering' as it is commonly employed by professional engineering associations, refers to the application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems.[1] An engineer is a professional who practises engineering in this discipline. In addition, the term 'enabling sciences' as used throughout this report refers to the science subjects taught at secondary school which enable students to undertake tertiary engineering studies at universities or technical colleges. STEM refers to Science, Technology, Engineering and Mathematics.

There is considerable evidence to show that despite of strong career prospects, there has been a decline in the study of *engineering and the enabling sciences* in universities and schools in many western nations such as Australia, the United States and the United Kingdom. This is confirmed by OECD statistics (OECD, 2001 to 2006) and Australian, British and American publications which reveal that the percentage of graduates in engineering is in the lowest quartile for OECD comparison countries. Furthermore the continuing drop in high school student enrolments in higher level mathematics exacerbates the situation. In the United States, from 1993, the number of engineering enrolments decreased by 6.1% (Kukreti et al, 2005). In Australia, similar trends and projections of enrolment in tertiary engineering studies suggest a shortfall in scientific and technical capabilities which will 'compromise Australia's potential to be at the forefront of global scientific and technologic development' (DEEWR 2008, p.5). The United Kingdom and some countries in continental Europe suffer similar shortages and the reasons, despite of the differences in educational systems and national strategies and policies, seem to be comparable across the United Kingdom, Australia and the US (van Langen & Dekkers, 2005).

In their study of 589 Australian secondary school science teachers and 3759 Year 10 students who had recently chosen their subjects for Year 11, Lyons and Quinn (2010), found three factors that were likely to be the greater contributors to the decline of science enrolments in Year 11. They were the difficulty many students have in picturing themselves as scientists; the decrease in the utility value of key science subjects relative to their difficulty; and the failure of school science to engage a wider range of students. However, the authors of this study believe that declines in the proportions of students taking physics, chemistry and biology are part of a broader phenomenon which has seen similar falls in many traditional subject areas such as economics, geography and history.

[1] engineering. (n.d.). The American Heritage® Dictionary of the English Language, Fourth Edition.

Interestingly, Lyons and Quinn found that other factors that were traditionally linked to science enrolments for Year 11 are unlikely to have contributed significantly to falling enrolments. These are:

- declines in the level of interest in science among today's young people;
- students' perceptions that science careers attract relatively low pay;
- students' perceptions that it is difficult to find a job in science;
- students' experiences of primary school science.

The literature review provided in this chapter is the result of an investigation into the current climate in both research and policy-making publications in the area of engineering skill shortage in countries such as The United Kingdom, The Netherlands, The United States and Australia. The research forms part of a larger Australian project, *"Engineering Choices, Engineering Futures",* directed toward a better understanding of the reasons behind the decreasing trend in engineering enrolments and the development of strategies to reverse it. The first stage of this project entailed the identification of existing studies which address the decline of enrolments in the enabling sciences and engineering. Through these studies the potential factors that contribute to school student awareness of science and engineering could be determined. The research questions that study were the following:

a. What is children's understanding of engineering, mathematics and science?
b. How does primary/secondary school interest in engineering develop so that it leads to participation in tertiary studies?
c. What strategies have proven most effective in increasing and developing interest in, and understanding of, engineering?

The review presented in this chapter is focused on the second of these research questions and set out to identify existing literature dealing with student's interest in mathematics/science/engineering leading to undertaking of university engineering studies

The methodology utilised to obtain these reports was based on searches on educational, engineering and governmental databases. The major focus was on reports that had been produced since the year 2000, although a historical review of significant reports was also conducted. For the main report of this project a thorough examination of academic work on the subject was performed, and some of the results of that examination appear in this chapter.

The issue of attracting young people to the engineering profession has a long history. Reports about the shortage of a technically qualified workforce and the perception that schools ought to play a pivotal role in addressing this weakness emerged early in the twentieth century as the modernisation of industry and commerce proceeded apace (Heywood, 1978). One of the first government reports about engineering education in the United Kingdom dates back to 1931 (Clerk, 1931). By the 1940s government reports dealing specifically with the issue of engineering shortages and their link to education provision began to appear in continental Europe, the United States and Australia. Even at that stage it was stated that "the failure to secure the fullest possible application of science to industry is partly due to deficiencies in education." (Percy, 1945, p.1). In the United States the Grinter report (Grinter, 1955) highlighted curriculum and teacher training as two main contributing factors to engineering enrolments:

> "As preparation for engineering education there is no substitute for scholarly levels of instruction in high school with adequate emphasis upon developing both interest and reasonable proficiency in mathematics, English, physics, and chemistry. […]In order to encourage high school-college articulation, […]each university engaged in teacher training and having a college of engineering, [should determine] ways of providing advanced study as part of high school teacher education that would make such

> teachers more proficient instructors in the subjects necessary for admission to engineering.” (Grinter, 1955, p. 87)

In the United Kingdom from the mid 1950s several projects which implemented teaching of engineering related topics at the school level appeared. Several schools submitted pre-college syllabi for examination and scholarly articles appeared evaluating the effectiveness of such curricula. In 1956, the first white paper on Technical Education was commissioned in the United Kingdom (Robbins, 1956), and it pointed to the role private industry and government funding could play to boost science and engineering enrolments in universities. However, these endeavours did not cause a substantial influx in the numbers entering university departments (Heywood, 1978).

From the 1930s and into the 1950s government reports dealing with increasing enrolments to tackle skill shortages coincided with periods of high demand for trained engineers. Key themes in the reports of the period were the capacity of tertiary education institutions to prepare engineers for future skill demands and the impediments facing students. Three main factors identified as impediments were level of national investment (both from governments and private industry), capacity to educate recruits (i.e. quality, expertise and motivation of teachers, and issues with curriculum); and widespread misconceptions about the engineering profession (encompassing knowledge of what engineers do and about the financial rewards of engineering as a profession).

From the 1950s other influences on enrolments start to emerge in the literature, among them perceptions about the personal characteristics of engineers and what it was about the job that would discourage interest among the young. By the 1960s gender had emerged as a strong theme in this regard and, although by 1960s tertiary institutions were seeking female enrolments, opportunities for their advancement in the profession were known to be limited (SWE, 2006).

Availability of sources of information about engineering for secondary students, the accuracy and competence with which these sources were produced and disseminated, and the influence of parents, teachers, careers advisors, media and industry were also identified as impacting on intention to enrol prior to the 1980s. Since that time many academic institutions, government bodies and engineering corporations have provided external programs to increase engineering enrolments. These programs are commonly known as engineering outreach programs

The attitudes of young people to technology was another theme that emerged In the early 1980s as computer-based technologies began to exert a powerful influence in industry and academe. Jan Raat, Marc de Vries and other researchers in the Netherlands questioned why people chose careers in technology. They developed an attitude instrument and found that the pupils thought about technology within a limited frame of reference as machines and equipment (Wolters, 1989). The same group initiated the PATT (Pupils' Attitude Towards Technology) project that now spans 15 countries and has delivered 18 conferences on related topics

So by the late twentieth century the key themes in reports could be classified into the four main areas of National Investment, Sources of Information, Education and Perceptions of engineering. *National investment* has public and private components which vary internationally. *Sources of information* refers to the major persons and organisations with which students have experience. *Education* includes the roles of teachers and the curriculum in all its aspects including professional interests and selection. *Perceptions of engineering* include community perceptions experienced by students regarding the nature of engineering and engineers, and the rewards (see Table 1).

In the 21st century the growth of university education, the improved collection of statistics and internationalisation of education further served to highlight the relative decline in engineering, mathematics and physical sciences enrolments in many institutions. Dire predictions about the shortage of engineers have prompted a new round of reports and inquiries. But when looking at reports overall, especially those produced since 2000 it is found that they still largely focus on symptoms (i.e. enrolments are low, shortages are imminent, and that too few students are taking science and mathematics in secondary schools). Only a very small number push further and seek to address reasons behind the problem. For example, in some Australian States, it has been pointed out that the non-compulsory nature of mathematics at a Year 12 level or the wide range of courses offered in high school detracting from "core" subjects such as the enabling sciences may be prime causes (Engineers Australia, 2006, p.24), but this does not explain the global nature of the phenomenon. Most recent reports, however, do acknowledge the multidimensionality of the problem and, in addition to the four key themes or strands i.e. national investment, sources of information, education, and perceptions of engineering, they also identify some common sub-themes that bear on the problem of engineering enrolments (see the two levels of elements listed in Table 1).

Table 1: INFLUENCES HAVING A BEARING ON ENGINEERING ENROLMENTS

Influence	Element	Sub-element
National Investment	1. Government 2. Private	
Sources of Information	• Parents (and relations) • Teachers • Careers advisors • Media • Industry	
Education	a. Teachers	- Quality - Expertise - Motivation
	b. Curriculum	- Trajectory - Education Opportunities
	c. Effectiveness of Outreach Programs	
Perceptions of Engineering	a. Nature of engineering	
	b. Personal characteristics of engineers	- Gender - Ethnic Minorities
	c. Financial rewards	

From this point the discussion in this paper will elaborate more fully on the themes presented in Table 1, based largely on information contained in more recent reports (2000 onwards) from the UK, USA and Australia.

1.1 – National Investment

National investment features in all the recent reports on engineering enrolments. The reports typically close with a set of recommendations to governments, government agencies and industry stakeholders to address the declining interest in engineering studies at a time of 'increased business need' (Johnson & Jones, 2006). Many of these recommendations advocate more private-public interaction; seek an increase in funding in certain areas of the education system and an increase in government investment in promoting enabling sciences in the mainstream education system, in ways that involve all sections of society. A report by Engineers Australia emphasised that:

> "The government [needs to be] willing to influence the education system to encourage more students into SETM careers […] and increase partnerships between all SETM stakeholders, schools, teachers, students, government, professional associations and universities." (Engineers Australia, 2006, p. 29)

Several reports point out that private investment from industry in collaboration with government agencies could be a determining influence in the effort to draw young people into engineering as an occupation. In particular it is suggested that the interaction between schools and industry could be decisive in fostering the interest of students:

> "More industrial mentors need to be involved with schools as they play a pivotal role in influencing pupils to take engineering up as a career." (West Midlands Education and Training Department, 2004, p.20)

> "Our study suggests that there is now a priority need for integrated and integrative leadership regarding engineering in schools, within and across sectors, which synthesises existing knowledge and best practice, and makes them available to ongoing initiatives." (Reid et al, 2003, p. 81)

Many reports point out that collaboration between industry and universities in the promotion of engineering is crucial if there is to be an impact on the number of university enrolments. The link between funding 'relevant' research activities at tertiary level and attracting students to engineering degrees is one suggestion (Johnson & Jones, 2006, p. 8); another is the link between current industry engineering practices and university curricula. In one report this is referred to in terms of 'targeted collaboration' (Raison, 2006, p. 47). Moreover, as the Australian Chief Scientist points out, "Alliances with industry [...] can demonstrate the real applications of science and technology to students and teachers." (Batterham, 2000, p. 51)

1.2 – Sources of information

The way students acquire information and the variety of sources they use to do so, profoundly affect the image they have of the engineering profession and subsequently their career decisions. Teachers are clearly one source, however, in a 2004 study in the United Kingdom it was found that almost 48% of students pointed out that their most influential information came from their parents, followed by other family relations (11%) and the school careers advisor (10%) (West Midlands Education and Training Department, 2004). Furthermore, a USA study found that parents' early gender-typed occupational expectations for their children were highly related to the actual occupational decisions made by their adult children (Jacobs, Chhin & Bleeker, 2006).

Given the importance of parents and family, the authors indicate that "engineering education initiatives need to incorporate parental/guardian involvement, because parents/guardians play a significant role in influencing overall career choice" (p.23). The implication is that the importance of informing parents as well as children cannot be underestimated. Consequently, when determining how sources of information influence enrolments in science mathematics and engineering, not only students but the entire population needs to be considered. In the Australian context it is known from the Australian Council for Educational Research (ACER) Longitudinal Surveys of Australian Youth program, a project that has been following three cohorts of students since 1995, the importance of parents and parents' occupation and education in influencing students' decisions to undertake enabling science subjects:

> "Those students with parents with a high occupational status are more likely to be enrolled in advanced mathematics, physics and chemistry." (Fullarton et al., 2003, p. 47)

> "Those students whose parents did not complete secondary school are significantly less likely to be enrolled in intermediate level mathematics than either those students." (Fullarton et al., 2003, p. 50)

The adequacy of knowledge of careers advisers is also targeted in the reports, and this is part of a general theme linked to the adequacy of information generally. The National Science Foundation and the National Science Board in the United States conduct a biennial review of trends and attitudes towards science and engineering called the *Science and Engineering Indicators*. In the most recent of these surveys, it is reported that the media and in particular, the Internet and television play a predominant role in configuring opinion about science and technology:

> "In the United States and other countries, most adults pick up information about S&T primarily from watching television, including educational and non-fiction programs, newscasts and newsmagazines, and even entertainment programs. […] The Internet is having a major impact on how the public gets information about S&T. In 2004, the Internet was the second most popular source of news about S&T, up from fourth place in 2001." (National Science Board, 2006, chapter 7, p. 3)

Since the media is such an important influence on the general population (and subsequently on students), incorrect or inaccurate information delivered through this medium "by failing to distinguish between fantasy and reality and by failing to cite scientific evidence when it is needed." (National Science Board, 2006, chapter 7, p. 3) is a concern for those interested in enrolments in engineering. As Johnson and Jones (2006) note, the manner of reporting, i.e. if the emphasis is unduly negative, can also impact on the perception of engineering as a desirable career:

> "The offshoring of technical jobs, as reported often in the media, transmits an aura of instability in the engineering profession – including the spectre of unemployment. Potential engineering students and their families see such reports, and are often influenced away from engineering study and employment." (Johnson & Jones, 2006, p. 1)

1.3 – Education

As indicated above Education has always been a key element in discussions on engineering enrolments. There are three aspects of primary and secondary education which are targeted in reports: the role of teachers; the adequacy of school curriculum; and the impact of outreach programs. Each of these is now analysed in turn.

1.3.1 – Teachers

The ability of systems to deliver teachers with the capacity to effectively impart enabling sciences has exercised academics, industry employers and legislators around the world. Many of journals and conferences in the field of Science and Mathematics Education are devoted to this topic and the evidence is drawn on in major reports. Some of the most relevant issues arising in this area in the different reports relate to teacher qualifications, initial training and further professional development, resourcing, and remuneration:

Teacher qualifications

The consensus here is that qualifications are inadequate. It is repeatedly reported in the literature that "college graduates who become teachers have somewhat lower academic skills on average than those who do not go into teaching" (National Science Board, 2006, chapter 1, p. 6). It is also reported that many teachers are not qualified to teach enabling sciences because they majored in other subjects at university:

> "Many of those who teach middle school math and science lack an undergraduate or graduate major or minor in the subject they teach. Among middle school teachers, 52.5% of those who taught math and 40.0% of those who taught science did not have a major or minor in those subjects." (Kuenzi et al, 2006, p. 13)

In 2006, the Australian Ministry of Education, Science and Technology conducted a comprehensive audit of Science, Engineering and Technology skills (SET). The audit incorporated an analysis of existing research on supply of, and demand for, SET skills; a survey of youth attitudes toward studying science, mathematics and technology and toward SET careers; an industry survey on current and future demand for SET skills, together with a series of industry studies for industries reliant on these skills. They also incorporated a study by The Allen Consulting Group on international demand for Australia's science, engineering and technology skills. It was reported that feedback from audit submissions and consultations:

> "highlighted a perception among industry and the vocational and technical education and higher education sectors that many students leaving school were ill-prepared for tertiary study and employment in SET fields. There was also a strong perception that Australia lacks sufficient suitably qualified secondary school science teachers, which impacts adversely on student engagement in SET." (DEST, 2006, p. 11)

Teacher training and professional development

Most reports and papers recognise how critical teacher training is, the crowded curriculum for teacher trainees, and how little time experienced teachers have to undertake adequate professional development education to enable them to keep up with advances in their disciplines:

> "Numerous studies indicate that sustained and intensive professional development is an important factor in influencing change in teachers' attitudes and teaching behaviours (Clewell et al. 2004). For example, the amount of time teachers spent on professional development activities was positively related to their perceptions of these activities' usefulness (Parsad et al., 2001)." (National Science Board, 2006, chapter 1, p. 37).

The Skills Audit undertaken by the Australian Ministry of Education, Science and Technology and the reports of the National Science Board in the United States and the West Midlands Education and Training Department in the United Kingdom all agreed that teacher training should be a priority in any strategy to increase enrolments in engineering degrees.

Despite the common recognition of the central role of teachers, and what they know and can do in science education, much still needs to be done in the area of teachers' professional development. Although specific suggestions continue to be put forward and trialled by researchers, the clear recommendations of van Driel, Beijaard and Verloof (2001) that multimethod designs and approaches are required has not been implemented on any large scale. These researchers suggest two major components: that teachers are central to relationships between themselves, administrators and researchers; and that extended time is necessary for significant and sustained change.

Resources

The issue of lack of, or poor access to, resources amongst teachers in terms of availability of teaching space, science consumables, equipment, curriculum resources and information technology also appears to be one of the major issues to do with teachers' capacity to successfully impart enabling sciences:

> "Limitations in school science budgets and resources detrimentally affect the range of learning experiences and innovations that can be implemented. Important needs are curriculum resources, adequate teaching spaces, equipment and support staff to organise the materials for practical work." (Goodrum et al., 2000, p. 174)

Freedom and flexibility to innovate is also connected to resourcing:

> "Enterprising and creative schools need freedom, resources and support, to develop ideas and strategies, to mobilise resources and to take the kinds of decisions they judge to be in the best interests of students, the community and their staff." (DEST, 2003, p. 53)

The key message arising from the reports is the need for more resources allocated to science teaching and learning.

Economic remuneration.

In Australia "while commencing salaries of teachers compare well to some other professions, salaries plateau quickly and there is little opportunity for increased remuneration through career progression, especially at the mid-level".(DEST 2003, p. 103). Evidence suggests that in other countries such as the United States, teacher salaries play an important role in determining both the supply of new teachers and retention of current teachers (Odden & Kelley, 2002)

1.3.2 – Curriculum

How the enabling sciences and engineering are taught and portrayed at school level has been found to have repercussions on student interest and on career choices. A study in Israel found that secondary students had a 'neutral' interest in physics, but a negative view of science classes (Trumper, 2006). It was concluded that curriculum and organizational changes were needed to address this imbalance by improving the students' school science experience. A comprehensive study carried out by the University of Bath in the United Kingdom also found that curriculum and assessment issues can undermine effective teaching in science and engineering:

> "(a) teachers felt pressured to deliver National Curriculum results and grades […], (b) assessment requirements and demands blocked effective STM teaching, and (c) there was little time available for developing and supporting non-syllabus topics associated with engineering."(ETB, 2005, p. 66)

In the United States, research conducted by a working group of the American Society for Engineering Education, pointed to school curriculum as one of the factors influencing the decrease number of students undertaking tertiary studies in engineering:

> "With little chance to learn in school how science and math skills might translate into professionally useful knowledge, students are unable to make informed choices about further education and work options." (Douglas et al., 2004, p. 2)

More recently in the USA, a small intensive study of participation in secondary school science (Aschbacher, Li & Roth, 2010) found that only about half of the high achievers with an interest in science-based studies persisted with STEM-enabling courses throughout high school. In addition to curriculum, various combinations of factors including communities of practice, socioeconomic status, gender and ethnicity were important for persistence in science.

Australian studies also indicate that the high school curriculum exercises a significant influence on a student's intention to undertake careers in science and engineering and that:

> "Research is needed to cut through broad socio-economic explanations and focus more closely on curriculum and pedagogical practices that make for successful schooling, improved retention rates and increased interest in study of science." (DEST, 2003)

University curricula and teaching approaches also influence student interest in engineering. Danish studies have suggested that increasing the contextualisation of the content of engineering education and other improvements to the learning environment (such as problem-based learning) would increase participation in engineering by larger numbers of more diverse groups, including females (Du & Kolmos, 2009),

Student choices of tertiary courses and subjects at the tertiary level are also related to the curriculum knowledge available and its presentation. The nature of information on offer about engineering, for example, may impact on student choice:

> "High school students looking at various options for university level study often compare engineering to alternate paths – such as computer science – where the curriculum is less formidable." (Johnson & Jones, 2006, p. 2)

1.3.3 – Outreach

There are many 'outreach' programs around the world aimed at increasing school student skills, changing perceptions and particularly at increasing enrolments and retention of students in science and engineering programs. To take just two examples: in Milwaukee (Musto, Howard & Rather, 2005), an intensive one-week mechanical engineering program was carefully designed and applied; and in Australia (Little & de la Barra, 2009), a program that also involved hands-on experiences for students, further teacher education and female engineer mentors was implemented. However, in common with most such programs, it would seem that there were no independent evaluations of student outcomes

Most reports dealing with increasing enrolments in science and engineering point out two main areas where outreach programs could be made more beneficial. The first is the need to fund outreach programs to present the engineering profession in a more engaging way:

> "Knowledge institutions like museums, science and technology centres and their outreach programs engage children and present scientific and engineering principles in an exciting way that makes them "real" and accessible." (Engineers Australia, 2006, p. 9)

The second is to assist teachers and encourage young people to take enabling science courses at high school level, leading to subsequent enrolments in engineering:

> "Statistical analysis of teachers' attitudes and in-depth discussions among K-12 experts, have demonstrated that there is a need for enhanced K-12 engineering education outreach."(Douglas et al., 2004, p. 15)

Most reports indicate the need to evaluate the impact of these programs to prove their effectiveness, but systematic research is rare. The National Science Foundation (NSF) in the USA conducts evaluations of its science, technology, mathematics, and engineering (STEM) education initiatives (Chubin, 1996). They believe that the evaluations should be "primarily guided by three fundamental questions: Is the program under study achieving its goals? Is it making an impact? And are there ways in which the program can be improved?" The NSF also provides a range of tools for outreach providers to effectively measure this (Stevens et al, 1992).

In general. however, when programs around the globe are assessed, the evaluation tends to take the form of a quality assurance exercise. The evaluation is generally not extended to a deeper examination of whether or not the outreach program is making an impact on improving perceptions of engineers and engineering, or increasing enrolments at an undergraduate level. Poole, DeGrazia and Sullivan offer a resource for evaluating this impact and conclude that "Assessment strategies should consist of three key components: 1) assessment of workshop participant feedback (teachers and students), 2) assessment of long-term outcomes (teachers), and 3) assessment tools developed for the teachers' classroom use (i.e., embedded assessment)." (Poole et al., 2003, p. 1)

1.4 – Perceptions of Engineering

As mentioned in the introduction to this paper, the issue of how perceptions of engineering and technology affect the decision to undertake studies in engineering has been in the literature for decades. It is believed that how students perceive engineering, the financial rewards arising from a career in engineering and who can become an engineer has a strong impact on career choice. In the United Kingdom, a comprehensive study commissioned by Sir Gareth Roberts indicates that poor enrolments can be attributed to:

> "[…]Poor experiences of science and engineering education among students generally, coupled with a negative image of, and inadequate information about, careers arising from the study of science and engineering" (Roberts, 2002, p. 2)

There is also the issue of teachers' misconceptions of engineers being passed on to their students. There is evidence in several reports that teachers hold substantial misconceptions about the engineering profession:

> "When asked to identify their own conceptions of engineering, teachers often defaulted to a limited range of stereotypes which their students also appear to hold: "its dirty", "an older man in blue overalls"[…], a "hard hat and white coat", "the man who fixes your washing machine": either overly specialised, or a glorified mechanic."(ETB, 2005, p. 43)

There is a field of academic work dedicated to understanding young people's perceptions of engineering and technology. The studies and conclusions drawn overlap to a large extent with the influences on engineering discussed in the next section. The concept of engineering identity is surrogated in this section to nature of engineering and personal perceptions of engineering, as the authors believe it is a compound of these two factors.

1.4.1 – Nature of Engineering

How well do young people understand what engineers do? Cunningham, Lachapelle and Lindgren-Streicher developed and tested an instrument to look into children's concepts of engineering:

> “When asked to choose what kinds of work engineers do, over half of the students indicated that they thought engineers repair cars (78.4%), install wiring (75.2%), drive machines (70.7%), construct buildings (69.7%), set up factories (67.1%), and improve machines (63.5%). These data support DAET data that students perceive that engineers are auto mechanics and construction workers.” (Cunningham et al., 2005, p.4)

With such overwhelming numbers pointing towards widespread misconceptions about the scope of the engineering profession, it follows that many students who are interested in mathematics and science would not recognise engineering as a career where they could utilise their interests fully. Cunningham et al. found that “Fewer than one third of the students recognised one of the central features of engineering was design.” (Cunningham et al., 2005, p.6).

We should be wary of thinking, however, that the problem of recruiting young people into engineering courses and subsequent careers is solely a case of identifying and correcting their misconceptions. More fundamentally, the view of engineering held generally in society is the more significant issue. One line of research suggests that talented young people correctly note that engineering does not have the the same level of advantages (eg, status and salary) in comparison with alternatives, particularly in developed countries (Becker, 2010). When it comes to choosing a career, many come to the realistic conclusion that engineering is simply not attractive enough.

A different approach to this issue was taken by Taconis & Kessels (2009), in a study of student subject choice across two European countries. This study had students match themselves to science and humanities profiles. In common with some earlier work, science exhibited a culture of non-femininity, a preference for content rather than process, having an emphasis on rational rather than emotional communication, and a lack of emphasis on personal presentation. Looked at another way, science was profiled as ‘dull, authoritarian, abstract, theoretical, fact-oriented … with little room for fantasy, creativity, enjoyment, and curiosity’ (p.1130). Many school students perceived a mismatch between how they saw themselves and the socially- developed science profile, so tended not to select science subjects and careers.

1.4.2 – Financial Rewards

Misconceptions about financial rewards very likely figure in choosing engineering as a career. In a report commissioned by the Minister for Industry, Science and Resources in Australia and conducted by the Chief Scientist, Dr Robin Batterham it is argued that:

> “In the future, students are likely to study science if they know they will receive returns in terms of reward, prestige and salaries commensurate with other professional fields. At the moment, science is paradoxically viewed as being for the elite and regarded to be lowly paid. Students need to be encouraged from an early age to consider taking on a career in science, technology or engineering.” (Batterham, 2000, p. 29)

1.4.3 – Women and Ethnic Minorities

Most of the academic research on low enrolments in engineering degrees deals with the disproportionately low rate of participation of women and minorities in these degrees. Government reports also note this problem. The key issues found in the literature which affect women’s participation in the engineering field are that women tend to face tougher institutional and cultural barriers than their male counterparts (Mau, 2003). Also, for adolescent females, the pressures of trying to balance current and future gender relations in an environment that challenges conventional norms for women creates additional tensions and contradictions (McKinnon & Ahola-Sidaway, 1995). In a study by the Engineering and Technology Board in the United Kingdom it is notes that the problem seems to start as early as Year 9:

> "More boys than girls demonstrated a real interest in studying [Science, Maths and Technology] subjects, whereas girls were more likely to have an instrumental view of the subjects, indicating that they would study them because of their importance in life beyond school."(ETB, 2005, p. 9)

Other researchers have provided evidence that gender differences begin much earlier than this. For example, Patrick, Mantzicopoulos & Samarapungavan (2009) investigated outcomes of a Kindergarten program in Scientific Literacy in the USA, determining that, although boys and girls in the regular program differed in liking for science (favouring boys), there were no gender differences for students in the Scientific Literacy program.

A particular focus of research on gender differences in STEM relates to the study of mathematics at school as an essential enabling discipline for engineering and technology. Questions such as why boys are more interested in mathematics than girls (Watt, 2005), the perception of mathematics as mostly a male domain (Brandell, Leder & Nystrom, 2007; Brandell & Staberg, 2008), and the raft of vexed issues related to comparisons of mathematics achievement between genders (Linver & Davis-Kean, 2005; Nagy, Traulwein, Baumert, Koller, & Garrett, 2006) form three major threads in this research area.

It is not only school experiences that are important for potential entry to the profession that is an issue for females. An Australian study of the importance of engineering competencies, as rated by practising engineers, found that engineers themselves were affected by gender stereotyping when indicating 'typical' engineering competencies (Male, Bush & Murray, 2009). The suggestion was made that university engineering curriculum should address this issue (see also the reference to Du & Kolmos (2009) above). Another Australian study found engineering workplaces to be uneasy environments for professional women, and this represented a challenge for engineering education (Gill, Sharp, Mills & Franzway, 2008).

One thread that has moved through the gender disparity issue in engineering, particularly in the USA, is debate about the relative importance of recruitment and retention of women in engineering courses. A recent major study found that the relatively low number of female engineers is almost entirely a recruitment issue, there being no differential attrition by gender (de Cohen & Deterding, 2009). The authors go on to suggest that school and college outreach programs are needed to address the recruitment problem.

A warning against simplistic explanations and solutions to gender imbalance in STEM is provided by Blickenstaff (2005), based on his survey of 30 years of research and observation of the under-representation of women. He called for multi-faceted solutions and suggested that the most promising initiatives need to come from curriculum designers and the teachers who deliver the programs. Another warning against simple conclusions concerning gender differences in participation and achievement of Australian secondary students in mathematics and science was issued by Cox, Leder and Forgasz (2004). Their study demonstrated that interactions between participation rates at school for different STEM subjects and achievement by gender made for complexity.

1.5 – Conclusions drawn from Literature Review

There have been some very substantial investigations into the decrease in the number of tertiary enrolments in engineering degrees in Australia and other first-world countries. However this work, despite the fact that the problem has been in evidence since the 1930s, is rarely drawn together to investigate outcomes that can contribute to future research programs, and more specifically to find solutions. Four main influences contribute to poor enrolments in engineering degrees, namely: national investment, sources of information, education and perceptions of the profession (see Table 1). Each on their own requires more research, e.g. Are governments spending enough on communicating the possibilities of engineering as a career? Where does the general public get their information from? Why are our teachers not prepared to teach engineering concepts? Why is the image of the engineering profession misguided? Where do misconceptions in this regard come from? In the case of school-aged students, does their information about engineering as a prospective career come from teachers and careers advisors? Is it from their parents?

One of the most striking similarities found in most reports and articles is that they focus on the symptoms of the underlying problem, They canvass but do not move to examine the causes, for example, why it is that not enough students are taking science and mathematics in secondary school. What it is implied from all the reports is the multi-dimensionality of the problem and as the table above indicates a way to conceive of the problem more holistically. We have reached a point in this ongoing debate where it must be established with accuracy the degree to which the different factors influence decision making when it comes to enrolments in engineering tertiary studies and how they are linked. It is essential that all the factors influencing enrolments are drawn together in order to fully understand the phenomenon and address it. Furthermore there is a critical importance of raising the interest of students in mathematics and science, and relating those subjects to the real world, particularly areas such as engineering. Enriching the mathematics and enabling sciences experience for students holds the key to increasing enrolments in engineering studies in the long run. If the students are not stimulated at that stage, the chances of them pursuing an engineering related career are then significantly diminished. Unfortunately, according to the reports reviewed, it is also clear that this is currently not happening in schools in countries such as the United Kingdom, the Netherlands and Australia. It also shows that this enrichment has to be contextualised within the school curriculum, stimulating interest in school mathematics and science using engineering as the vehicle to intuitively convey their usefulness and appeal. An initiative to enrich school mathematics and science in an engineering context is required if the aim is to **permanently** solve the skill shortage currently being experienced in our countries.

CHAPTER 2 – Methodology

This chapter presents the specifics of the sample strategy and instrument construction for the surveys designed in *Engineering Choices, Engineering Futures*.

2.1 – Sampling

The sampling strategy for this study was designed to comply with the requirements for national surveys representing individuals whose schooling had taken place in urban locations, regional centres and rural areas.

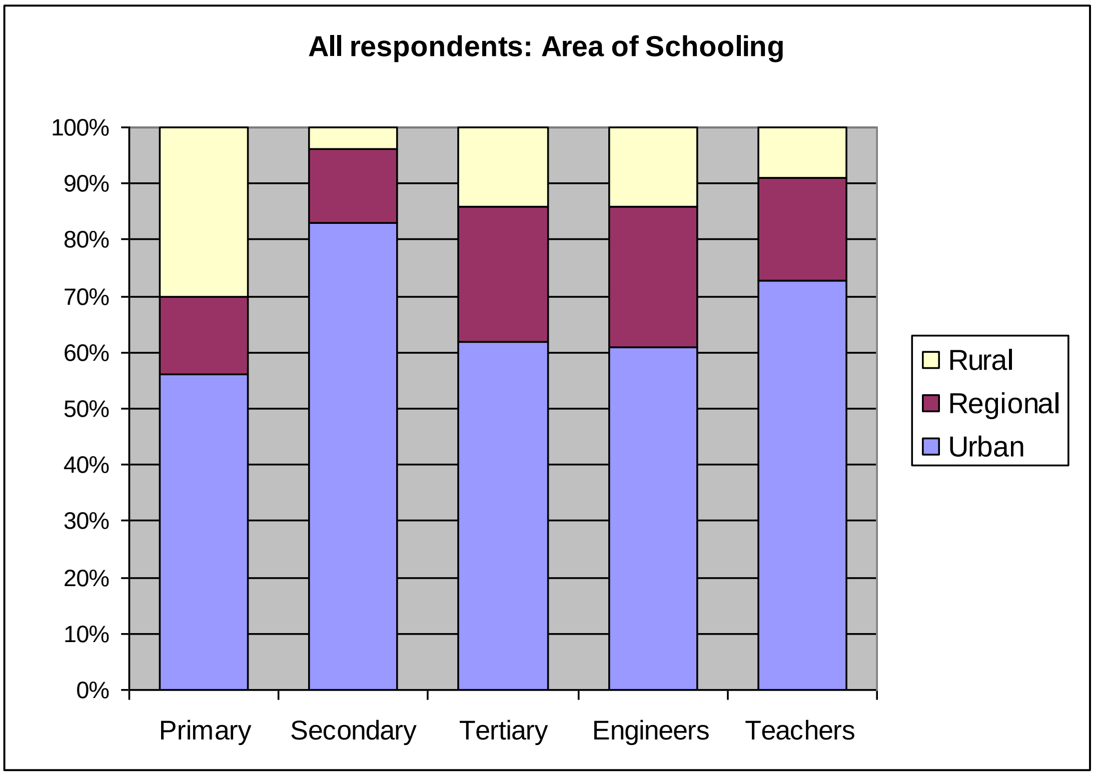


Figure 1: GEOGRAPHICAL AREA OF SCHOOLING

For all the cohorts, individuals were sampled in different States and Territories of Australia. However, as subsequently described, there were some differences between the strategies used for each cohort.

2.1.1 – School Surveys

The selected strategy for this study was of national questionnaire surveys of students in the senior years of both primary and secondary schooling. The rationale behind this sampling choice was that children's ideas of professions and what is required to accomplish them are made around the latter stages of primary schooling. In the case of secondary students, the education choices made by the students have a direct impact in their future career paths, and it was considered important to probe their knowledge of engineering as a career after they had made these subject choices for senior high school.

For practical purposes schools were chosen as the sampling unit and we aimed at obtaining data from 20 students at each school sampled. This approach has been shown to be efficient when obtaining school estimates for clustered samples of this type. Ideally the 20 students should be a random sample of all students in the appropriate year level at the school. The schools surveyed represented students attending government, Catholic and Independent schools. Rather than increasing the overall sample to achieve reasonable representations of non-government schools, it was decided to over-sample the Catholic and Independent systems, by up to a factor of two. For the secondary school science teachers it was considered that the selection of two teachers from each school was appropriate.

Schools in four of the eight States and Territories of Australia were sampled. To represent possible state differences, each state sample needed to be of reasonable size. Also, given the likely disparity in exposure to engineering-type occupations, it was important to distinguish between the responses of students in urban, regional and rural locations. To do so, areas within states were purposefully sub-sampled to ensure a range of area types were included.

As mentioned above, one of the objectives of this project was to evaluate the impact that outreach programs have on students' choices, misconceptions and biases with regard to the engineering profession. For primary students, it was decided to include a very popular outreach program, *EngQuest*, in the design of the sample. Schools participating and not participating in this program were included, to test if students in the participating schools had a different understanding of engineering. For secondary students the programs chosen were *The Science and Engineering Challenge* and *ReEngineering Australia*.

In designing this survey, the difficulty in obtaining adequate school responses was recognised, so when developing the framework for the sampling strategy it was decided to allow for more than 20 students at each school included in the sample to assist in obtaining a larger final sample size. Thus, as making state comparisons was not a high priority, samples of 20 schools at each level for New South Wales, Victoria and Queensland were selected. In the case of Western Australia, with a smaller population, a sample of 10 schools was selected. The total sample size for the four states was thus 1400 primary and 1400 secondary students.

Primary Schools

The designed total primary student designed sample for the four states was 1400 students. The achieved primary sample was a total of 555 students across the four states who provided usable data from the questionnaire (a response rate of 40%). Students from a total of 20 schools participated. This response rate was somewhat disappointing, but increasingly common with respect to research in schools. Response rates were lower in urban areas, reflecting the particularly high demands on schools to participate in various research surveys. The distributions of the achieved sample of schools, students and locations by state are shown in Table 2 and Figure 2.

Table 2: DISTRIBUTIONS OF SCHOOLS, STUDENTS, LOCATIONS AND YEAR LEVELS BY STATE

STATE	SCHLS	STUDS	LOCATION			YEAR LEVEL			
			Urban	Regional	Rural	Yr 4	Yr 5	Yr 6	Yr 7
NSW	6	168	112	-	56	28	124	16	-
VIC	6	117	46	71	-	8	93	16	-
QLD	4	184	72	-	112	-	54	46	84
WA	4	86	80	6	-	2	83	1	-
TOTAL	**20**	**555**	**310**	**77**	**168**	**38**	**354**	**79**	**84**

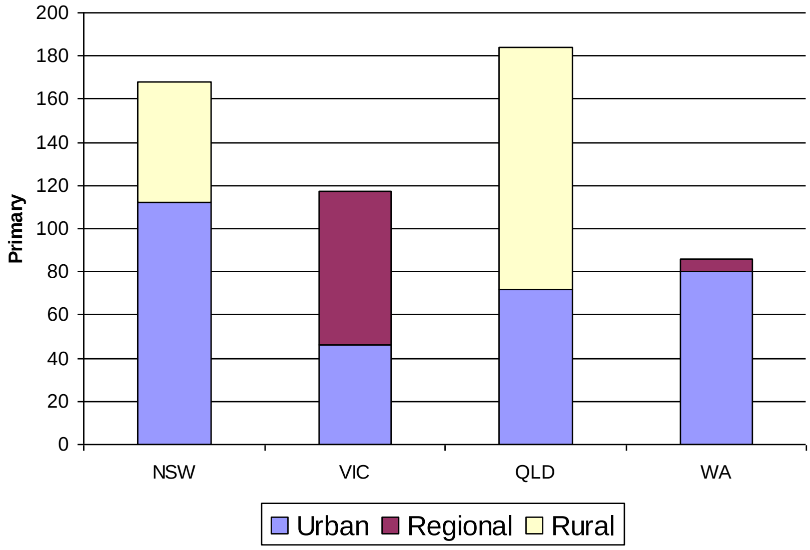


Figure 2: PRIMARY SCHOOL STUDENTS GEOGRAPHICAL LOCATION

With respect to location, the primary sample was composed of 56% of urban students, 14% of regional students, and 30% of rural students. Year levels ranged from 4 to 7, with most students (64%) in Year 5. There were almost equal proportions of students in Years 6 and 7 (14-15%), although all Year 7 students were located in Queensland. This is due to the fact that, in Queensland, students start their primary schooling a year earlier and thus their age in Year 7 is the same as students in Year 6 in the other three States included in the sample.

It will be noted that there were large variations in the distributions of school location and student year level by state. These variations were taken account of when state and other differences were analysed.

The sample was designed to include schools that had participated in the *EngQuest* program, in those states where this was possible, and also to include students in the government, Catholic and independent sectors. These distributions are shown in Table 3.

Students who had participated in *EngQuest comprised 15% of the sample*, all in either NSW or Queensland. Students at government schools constituted 72% of the sample, Catholic school students 17%, and Independent students 11%. Female students made up 54%, and students for whom English was a second language at home constituted 26% of the sample.

Table 3: DISTRIBUTIONS OF PARTICIPATION IN ENGQUEST, SCHOOL SECTOR, GENDER AND ESL BY STATE

STATE	ENGQUEST		SCHOOL SECTOR			GENDER	
	Yes	No	Govt.	Catholic	Indep.	Male	Female
NSW	64	104	93	39	36	57	111
VIC	-	117	67	27	23	54	63
QLD	18	166	184	-	-	80	104
WA	-	86	57	29	-	63	23
TOTAL	**82**	**473**	**401**	**95**	**59**	**254**	**301**

Although the response rate was not high, this distribution of students across school type matches very closely the August 2006 distribution of students across sectors in these four states: 71% at government schools, 19% attending Catholic schools and 10% at independent schools.

Secondary Schools

The secondary student sample for the four states was designed to survey 1400 students who were taking at least one science subject in Year 11. A total of 493 students across the four states provided usable data for the questionnaire (a response rate of 35%). This response rate was somewhat disappointing, but increasingly common for research in schools. Response rates were lower in urban areas, reflecting the particularly high demands on schools to participate in research. Students from a total of 22 schools participated. The distributions of schools, students and locations by state are shown in Figure 3.

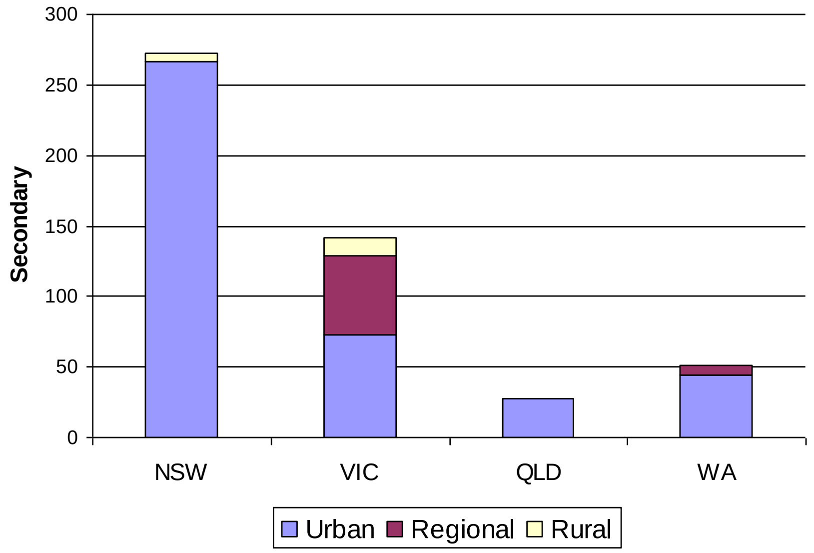


Figure 3: SECONDARY SCHOOL STUDENTS GEOGRAPHICAL LOCATION

The overall distribution by gender of the Year 11 science students was reasonable (slightly more than half the sample was female), but differed by state. The general student distribution of Year 11 students in the four sampled States is given in Table 4. Whereas in NSW almost two-thirds of the students were female, only about 40% were female in Victoria and Western Australia.

Table 4: DISTRIBUTIONS OF SCHOOLS, STUDENTS, GENDER AND LOCATION BY STATE

STATE	SCHLS	STUDENTS	FEMALE %	LOCATIONS		
				Urban	Regional	Rural
NSW	9	272	65	267	-	5
VIC	6	142	39	73	56	13
QLD	3	28	57	28	-	-
WA	4	51	40	44	7	-
TOTAL	**22**	**493**	**54**	**412**	**63**	**18**

With respect to location, the sample was composed 84% of urban students, 13% regional, and 4% from rural locations. It will be noted that there were large variations in the student distributions of school location by state.

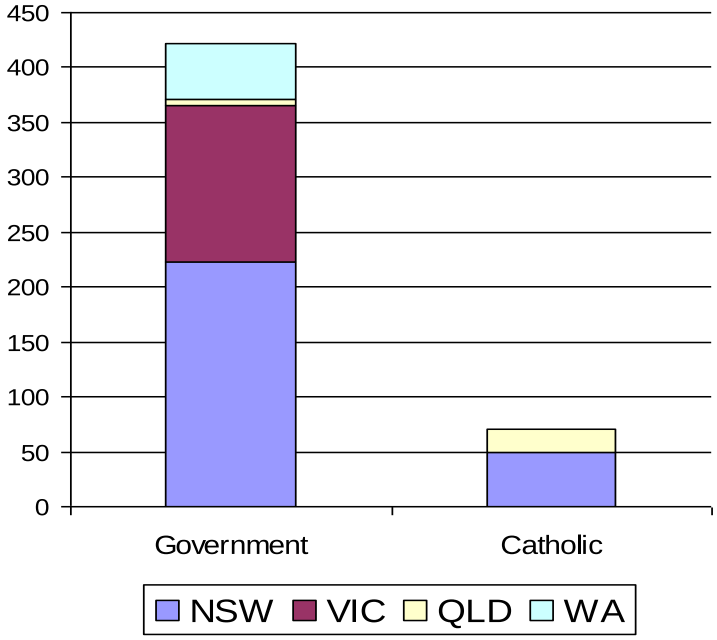


Figure 4: DISTRIBUTIONS OF STUDENT NUMBERS IN 4 SAMPLED STATES BY SCHOOL SECTOR

Responses have been recorded by school type in Figure 4. Despite an attempt at over-sampling non-government schools, none of the independent schools returned questionnaires. The sample thus included 86% of students from government schools and 14% of students from Catholic schools. This compares with the national distribution of secondary students which is 73% government, 17% Catholic and 10% independent schools.

Students for whom English was a second language at home constituted 50% of the sample. This is atypical, in part reflecting the urban bias of the sample of secondary students.

2.1.2 – University Surveys

The sample of university engineering students was designed as a national survey structured to represent students in urban locations and regional areas. For practical purposes universities were used as the sampling unit and the aim was to obtain data from at least 100 students from each university and level sampled. Ideally the 100 students would be a random sample of all students undertaking first and fourth engineering studies at these universities. To achieve this goal, students taking the general engineering courses in two academic years were surveyed.

Given the likely differences in their exposure to Engineering-type occupations at a high school level by location, it was important to be able to distinguish between the responses of students coming from urban, regional and rural locations. Consequently the samples were also designed to sub-sample locations within states with the intent of ensuring a range of region types. It was also important to study gender differences, as traditionally, engineering is a male-dominated profession.

Students were sampled in four states and the Universities chosen were as follows. In New South Wales: University of New South Wales (urban) and University of Newcastle (regional). In Victoria: University of Melbourne (both regional and urban campuses). In Queensland: University of Queensland (urban) and Queensland University of Technology (urban). In

Western Australia: University of Western Australia (urban). Although state comparisons were not a high priority in this study, the sample was designed to allow the results to be checked for possible state differences.

National questionnaire surveys of students in both the first and final years of their engineering degrees were designed. Year 1 engineering students in the first two weeks of their degree were chosen so students would not have any university experience, and thus were similar in that regard to the Year 11 students. It was expected that comparing their responses to those from students on the last year of their degree would provide not only ideas as to what triggers young people to study engineering, but also insight into misconceptions and biases and how they change as the student's professional career advances. The choice of final year (Year 4) students was made to ascertain whether perceptions of the core issues changed as students developed their knowledge of engineering as a profession.

The university engineering students sample for the four states was designed to survey 1200 students who were taking either first or fourth year of engineering studies at one of the six universities. A total of 1,517 students across the four states provided usable data for at least one part of the questionnaire. The response rate from the first year students was higher than expected, and the research team would like to thank the Engineering Departments/Schools at the six sampled universities for providing valuable help to achieve this.

In the overall distribution by gender of the engineering students 19.2% of those surveyed were female. The proportion of females in the sample varied significantly between universities (^{2} = 32.617, df = 5, $p < 0.001$) ranging from 9% at Newcastle (by far the lowest) up to almost 25% at Melbourne, with most universities having about 20% female participation. Out of the total of 65,364 engineering students in Australia, 10,077 are females, that is, 15.4%. The distributions of students contributing to the survey showing gender and year by university are shown in Table 5.

Table 5: DISTRIBUTIONS OF STUDENTS, GENDER AND YEAR BY UNIVERSITY

UNIVERSITY	**TOTAL ENGIN STUDENTS**	**SAMPLED STUDENTS**	**FEMALE %**	**YEAR**	
				Year 1	**Year 4**
UN	2,144	319	9.1	271	48
UNSW	7,189	310	19.0	121	189
UMEL	4,296	224	24.7	224	-
UQ	3,061	330	24.2	236	94
QUT	2,829	118	17.1	91	27
UWA	2,262	199	22.7	162	37
TOTAL	21,781	1500*	19.2	1105	395

* An additional 17 students responded to at least some sections of the questionnaire, but did not indicate their University.

The general student distribution of engineering students in the six sampled Universities is given in Table 6. This indicates that our sample corresponds to percentages of the student population varying between 5 and 20% of the total size of engineering students at these universities.

Table 6: DISTRIBUTIONS OF STUDENT NUMBERS IN 6 UNIVERSITIES

UNIVERSITY	**ENGINEERING STUDENTS**	**STUDENTS**	**%**
UN	2,144	25,114	8.5
UNSW	7,189	39,183	18.3
UMEL	4,296	41,827	10.3
UQ	3,061	37,177	8.2
QUT	2,829	38,527	7.3
UWA	2,262	17,082	13.2
TOTAL	21,781	198,910	11.0

As would be expected, the vast majority (84%) of Year 1 students were aged less than 20 years at the beginning of the academic year when the survey was conducted. More surprisingly, 4% of the Year 4 students were also aged less than 20 years at this time. Most Year 4 students were aged between 20 and 30 years (86%), with the remaining 10% at least 30 years of age.

The majority of students (62%) had attended high school in an urban area, almost a quarter (24%) in a regional centre, and 14% in a rural area. This distribution did differ significantly for students at the two year levels (^{2} = 10.213, df = 2, $p < .01$), with a higher proportion of students in Year 4 having attended an urban high school (67%) compared with Year 1 students (59%), and proportionally less of the Year 4 students were from a regional centre (19%) compared with Year 1 (27%). The proportions of students from rural areas (14%) did not differ between year levels.

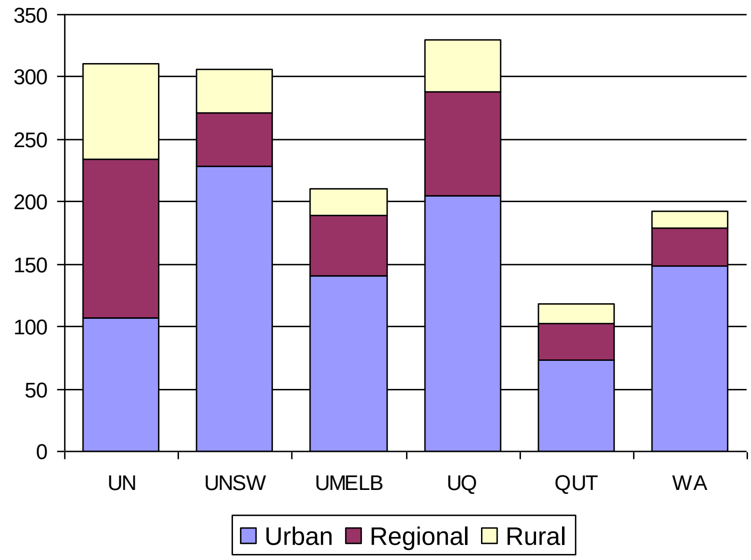


Figure 5: UNIVERSITY STUDENTS GEOGRAPHICAL LOCATION AT THE TIME OF THEIR SECONDARY SCHOOLING

2.1.3 – Professional Engineer Survey

For this survey, 510 engineers were randomly selected out of the *Engineers Australia* database. The sample consisted of 300 Members, 150 Graduates, 50 Fellows and 10 Honorary Fellows.

A total of 153 Engineers responded to the on-line questionnaire, an overall response rate of 30% including 34 females (22% of the sample). The age ranges of respondents indicated a distribution across five age bands weighted towards younger professionals (see Figure 6). Current locations of respondents were Urban (61%), Regional (25%) and Rural (14%). This differs from that of EA membership where urban locations account for 33.8%, regional 46.3%, and rural 19.9%.

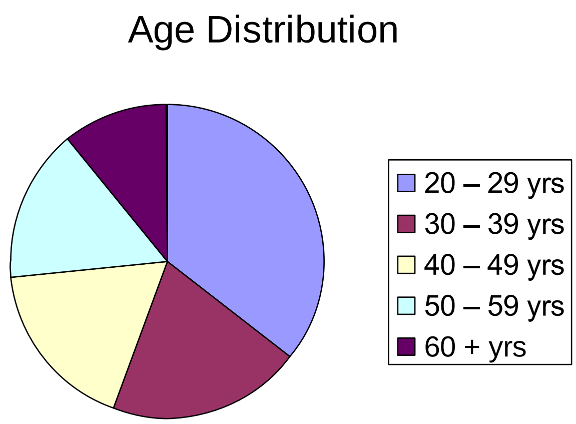


Figure 6: AGE DISTRIBUTION OF PROFESSIONAL ENGINEERS

2.1.4 – Teachers

The sample of teachers included two different cohorts. The first cohort is the Science Teachers from the schools selected in the secondary school sampling. A total of 30 of these teachers responded to the survey, with Table 2.7 showing the distribution by state. The second cohort comprised Careers Advisors from NSW schools in the Hunter Region who attended a field day at *Engineers Australia* Newcastle Division. A total of 24 careers advisors completed a survey immediately after a one-day program of talks and activities aimed at increasing advisors' awareness of the possibilities of engineering as a career for their students.

The gender distributions indicated that 17 (56%) of the science teachers were male, as were 10 (41%) of the careers advisors.

Two questions requested information regarding teachers' years of experience in the profession. The first question asked both cohorts how many years they had been in the education sector as a teacher (experience overall) and the second question asked how many years they had been in their current role (either science teachers or careers advisors). Table 7 below shows the distributions of responses to both questions for each cohort.

Table 7: DISTRIBUTION OF SCIENCE TEACHERS BY STATE

State	No.	Percent
NSW	14	47
QLD	3	10
WA	6	20
VIC	7	23
Total	30	

As might be expected, the careers advisors had more experience overall than the science teachers, as experience is effectively one of the requirements for the role.

It is noted that, in most cases, science teachers had spent the majority of their careers teaching science, whereas many careers advisors previously had other roles. Most careers advisors (59%) had overall teaching experience of more than 20 years.

Table 8: TEACHING EXPERIENCE

Number of years of experience	EXPERIENCE OVERALL		EXPERIENCE IN ROLE	
	Science Teachers	Careers Advisors	Science Teachers	Careers Advisors
Less than 2	1	0	1	6
2 to 5	3	0	3	2
6 to 10	9	6	9	6
11 to 20	8	4	9	6
More than 20	9	14	8	4
Total	30	24	30	24

2.2 – Instruments

As mentioned above the major surveys were of individuals belonging to one of the following categories:

- Primary and secondary school students
- Engineering students at Australian universities
- *Engineers Australia* members

As discussed in the literature review, the main issues influencing student enrolments in engineering degrees were identified as follows:

1. National Investment (both government and private)
2. Sources of Information (parents, teachers, careers advisors, media and industry)
3. Education
    a. Quality, expertise and motivation of teachers
    b. Curriculum (leading to trajectory and education opportunities)
    c. Effectiveness of outreach programs focusing on engineering
4. Perceptions of engineering (what engineers do, financial rewards, and personal characteristics of engineers).

These factors provided the basis for the development of a system of scales and subscales. The instruments were designed with matching items for comparison between cohorts to enable us to develop a quasi-longitudinal picture of engineering interest and development. Each group was tested using substantially the same scales and subscales, although due to differences in age and experience some of the matching items were worded differently. A more detailed explanation of the instruments for each individual cohort follows. For a detailed description of which subjects correspond to each of them please refer to the Appendix.

2.2.1 – School Surveys

The research instruments were compiled and constructed following a rigorous process of selection of questions. The research team was granted access to the data obtained by the Australian Council for Educational Research in their Longitudinal Studies of Australian Youth (LSAY) series (ACER, 1996). The LSAY data comprises a large cohort of students in Year 9 in the years 1995, 1998 and 2003. The total number of students surveyed exceeds 40,000 making LSAY the most comprehensive study about school students and their career pathways after leaving school in Australia.

In the questionnaires, for both levels of schooling demographic information was collected such as the school geographical location, age of each individual student, whether English was the main language spoken at home and also the students' parental occupations. As some of the scales and items differed slightly for the cohorts, they are described separately below:

Primary Schools

In the case of primary school students the scales and subscales devised for the instrument are shown in Table 9.

Table 9: SCALES DEVELOPED FOR PRIMARY AND SECONDARY STUDENTS

Scale/Subscale name	**Description**
- *Attitudinal Scales*	
+ Satisfaction with school	Children's general attitude to school
+ Interest in enabling sciences	Interest in science / maths / computing
+ Interest in other school subjects	Interest in English / art / society & environment…
+ Interest in engineering	Interest in engineering as a profession and engineering-type activities
- *Information Scales*	
+ Understanding of engineering	Children's knowledge of engineering concepts
+ Perception of engineering	- Positive personal perceptions of engineering - Stereotypes held - Perceptions of gender issues
+ Sources of information	- TV, Internet, teachers, parents or other relatives, etc…

The A*ttitudinal Scales* were designed to test the belief that children who show an early interest in mathematics, science and computing are more likely to have a better understanding and liking of engineering. Two subscales were created: *Interest in enabling sciences* (with questions such as "I would like to spend more school time doing science") and *Interest in engineering as a profession* (with questions such as "I would like to be an engineer"). Children's interest in other school subjects was included as a subscale to make sure that it was the liking for the enabling sciences that was linked with a better understanding of engineering rather than a positive disposition to school and school subjects generally. The items in the subscale *Satisfaction with school* were extracted from the LSAY questionnaire. They tested children's general attitude towards schooling with questions such as "I really like to go to school each day" or "I like learning". Those items were used to obtain data that could be used to draw nation-wide conclusions by comparison with the LSAY results.

In the literature it is commonly acknowledged that one of the main issues concerning low levels of enrolments in engineering-enabling subjects at school are the existing misconceptions about the profession. The *Information Scales* were designed to test whether this was the case with Australian children. A link between the children's understanding of engineering and their perception of the profession was sought. Two subscales, namely *Understanding of engineering* (in which students were given a set of skills or activities and asked to decide whether they were engineering-related or not) and *Perception of engineering* (with questions along the lines of "Engineers make people's lives better", "Engineers do dangerous things at work" or "Engineers are geeks") were created. It is commonly thought that science and engineering are male-dominated professions, so another subscale, *Perceptions of gender issues,* was included to ascertain whether children thought that science and engineering were more suited to males than females. Some of the items for these two subscales in the questionnaire were extracted from the existing literature to enable comparisons between this study and international ones. There were also several questions about how they do or would obtain their information about engineering thus creating a third subscale, *Sources of information about engineering.*

To complement the subscale *Perception of engineering*, the item: "Draw an engineer at work" was included for the primary students. A similar item, "Draw an engineer", has appeared a number of times in the literature as a variation of the "Draw a scientist" test. It was considered that the children's drawings would provide a very valuable insight into their images of the engineering profession.

Secondary Schools

The secondary school student survey contains the same scales as the primary school scales described above. However, another scale, *Effectiveness of engineering outreach programs*, was also included to complete one of the study phases presented at the beginning of this chapter, to do with evaluation of existing engineering programs aimed at increasing interest in engineering as a career. The scale was designed to find students' opinions about a range of specific programs such as Programs for Gifted and Talented Students, Science Shows (*SMART*, *Questacon*), Competitions (*The Science and Engineering Challenge*, *ReEngineering Australia*) and Science Workshops (CSIRO, *Zoomobile*).

A survey for science teachers of the sampled secondary schools was also developed. In this survey science teachers were asked for their perception of their students' knowledge and understanding of engineering. A similar, additional survey for careers advisors was also developed subsequently.

2.2.2 – University Surveys

The research instruments for university engineering students were designed to follow the same structure as the school surveys and also based on the information found in existing international studies about university students' enrolments in engineering. In addition to the demographic information collected, the scales and subscales developed for the university engineering student questionnaire are shown in Table 10. All the items in these scales are essentially the same as those in the school surveys.

For the engineering students, a new set of items was also included as a scale, *Communication and national investment*. With these items the aim was to find what university students think should be done in order to enthuse school-aged students to study the enabling sciences and engineering. A range of questions to ascertain what students thought should be done to increase the number of engineers in the country was presented to participants. In particular, students were asked if they thought that a shortfall of engineers in Australia should be made up by skilled migration or by assisting transition from engineering trades to the engineering profession. It was also enquired whether they thought that if more students did mathematics and science there would be more students undertaking engineering degrees.

Table 10: SCALES DEVELOPED FOR THE ENGINEERING STUDENT, PROFESSIONAL ENGINEER AND TEACHER COHORTS

Scale/Subscale name	**Description**
- Attitudinal Scales (past and present)	
+ Interest in enabling sciences	Interest in science / maths / computing
+ Interest in other school subjects	Interest in English / art / society & environment…
+ Interest in engineering	Interest in engineering-type activities
- Information Scales	
+ Engineers in the family	Number of engineers in the family
+ Perception of engineering	- Positive personal perceptions of engineering - Stereotypes held - Perceptions of gender issues - "Geekiness" index
+ Sources of information	- TV, Internet, professional journals, etc…
+ Outreach	- Influence of different outreach programs in degree choice
- Communication and national investment	

2.2.3 – Professional Engineer Survey

The research instrument for professional engineers was designed to follow the same structure as the university engineering student survey and the items in the scales were essentially the same as those in the latter survey.

A number of open-ended questions was also included for the professional engineers with the objective of finding out what engineers think the main issues concerning engineering education are at present. Some of these questions complement the subscale *Perceptions of gender issues* and the scale *Communication and national investment* as described in a previous section of this report.

2.2.4 Teachers

The research instruments for teachers were designed to follow the same structure as the professional engineer surveys and the items in their scales were very similar. The main difference is that the teachers were asked what their students' attitude towards the enabling sciences and engineering were, instead of asking them about their own perceptions.

Two open-ended questions were included with the objective of finding out what teachers think the main issues concerning engineering education are at present. These two open-ended questions asked teachers about the promotion of tertiary studies in engineering to their students. They tap into teachers' views about *Community, outreach and promotion*.

CHAPTER 3 – Analysis of Primary Student Questionnaires

In addition to the demographic information given in Chapter 2 Section 1, information from the scales described in Chapter 2 Section 2 was collected. The analysis of the data is presented here.

3.1 – Parent occupations

Two questions requested father's and mother's occupations.[2] These results are shown in Table 11. For convenience, student occupational intentions are also shown in this table.

Table 11: OCCUPATIONAL CATEGORIES OF FATHERS, MOTHERS AND STUDENT PREFERENCES

OCCUPATIONAL CATEGORY	FATHER %	MOTHER %	STUDENT %
Shop work	8	13	4
Office work	18	12	3
Health care	3	10	13
Services (police, fire)	8	4	1
Armed forces	2	0	2
Information technology	6	5	6
Agriculture	11	4	3
Hospitality	3	5	1
Engineering	11	1	13
Manufacturing	9	3	4
Sports and leisure	0	0	9
Teaching	4	10	8
Art	1	1	11
Other work	4	15	3
Do not know	12	17	17

The most frequent occupation for fathers was office work, with agriculture and engineering also above 10% of responses. The most frequent occupations for mothers were shop and office work, health care and teaching, all at least 10%.

3.2 – Satisfaction with aspects of schooling

As pointed out in Chapter 2, students were asked about satisfaction with their life at school. These questions were taken from the Longitudinal Surveys of Australian Youth, a study running since 1995 aimed at understanding the transitions between education, training and work (ACER, 1996). This section was followed by a set of questions about school subjects and activities, specifically about the excitement, interest, usefulness, importance and difficulty found in science, mathematics and computing. Importance of English was also requested to provide a point of comparison with the other subjects. Several scales were developed from these questions. Four categories of responses were offered, ranging from *Strongly disagree* (coded 1) to *Strongly agree* (coded 4). The mean scores and standard deviations for these scales are shown in Table 12.

[2] The occupational categories used were taken from a survey into the perceptions of secondary students towards careers in engineering, in a report commissioned by the West Midlands Education and Training Department (2004).

Table 12: SATISFACTION WITH SCHOOL AND SUBJECTS

SCALES	MEAN	STAND.DEV.
Satisfaction with school	3.0	0.55
Satisfaction with science	2.7	0.40
Satisfaction with mathematics	2.8	0.38
Satisfaction with computing	3.2	0.71
Interest/excitement of enabling sciences	2.9	0.51
Usefulness/importance of enabling sciences	3.3	0.46
Difficulty of enabling sciences (negative scale)	2.5	0.43
Importance of English (single item)	3.5	0.66

Students generally agreed they were satisfied with school, although slightly less satisfied specifically with science and mathematics. It should be noted that all scale mean scores related to subjects were higher than the mid-point of the scale (2.5) which indicated a neutral response. The students were particularly satisfied with computing activities, however, this scale had a relatively large standard deviation, indicating a wider range in views about computing. These subjects/activities were considered to be more important than they were interesting, although both scales had mean scores at least close to the *agree* response (ie, 3.0). The students neither agreed nor disagreed about difficulty of these subjects, with the difficulty scale having the lowest mean score. Finally, the item concerning the importance of English had the highest mean, located between the *Agree* and *Strongly agree* responses.

Subsequently the questionnaire asked students to indicate whether they liked or did not like each of seven school subjects and subject areas. Responses are shown in Figure 7, in descending order of liking.

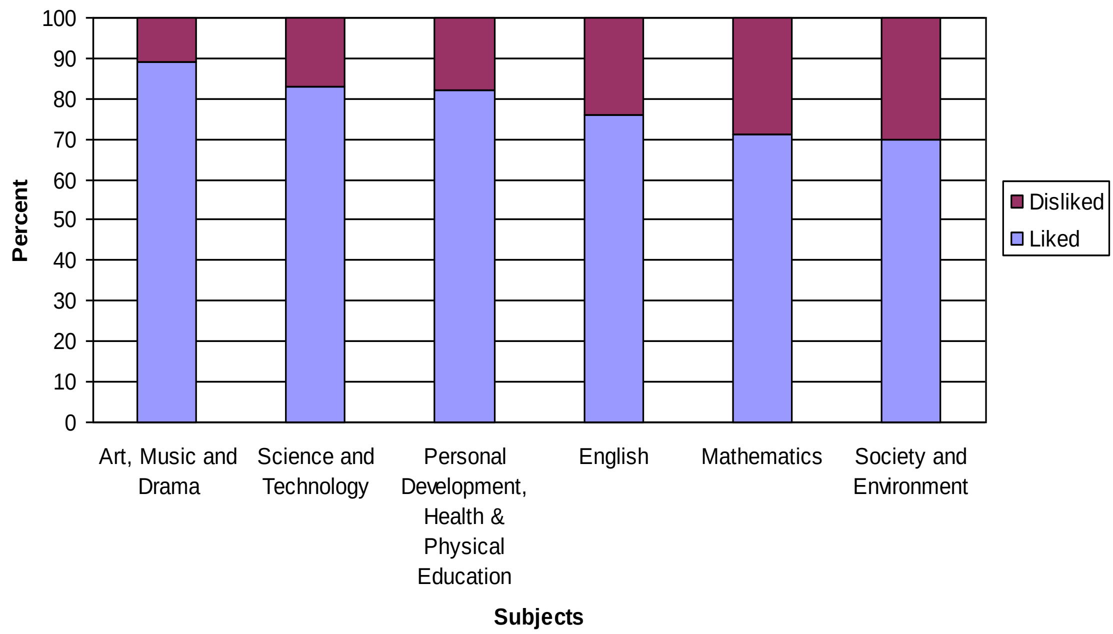


Figure 7: LIKING OF SCHOOL SUBJECTS

Although every subject was liked by a clear majority, it is of interest that Science and Technology was among the most liked subject areas with Art and Physical Education. On the other hand, Mathematics was one of the least liked together with Society and the Environment and Languages other than English. Whereas it is probable that both the mathematics and society subjects featured strongly in the curriculum of primary schools, other languages do not.

It was found that students thought that mathematics and science tended to be interesting (mean 2.9) but were neutral about their difficulty (mean 2.5) The correlation between both scales was not statistically significant, indicating there was no relationship between students' interest in science and mathematics and the perceived difficulty of these subjects.

3.3 – Student occupational interests

When asked whether they would like to be an engineer or to work with computers, almost half the primary students responded 'no' in both cases. Perhaps of greater interest, one-third or more responded 'don't know' to both questions (see Figure 8). The 'don't know' respondents would probably consist of two groups of students – those who genuinely had not 'decided' on an occupation at that time, and those who may have not known (or were uncertain of) what engineering was. These two groups cannot be differentiated here, but a subsequent section of this questionnaire suggests that most students were reasonably knowledgeable about the nature of engineering (see Table 15).

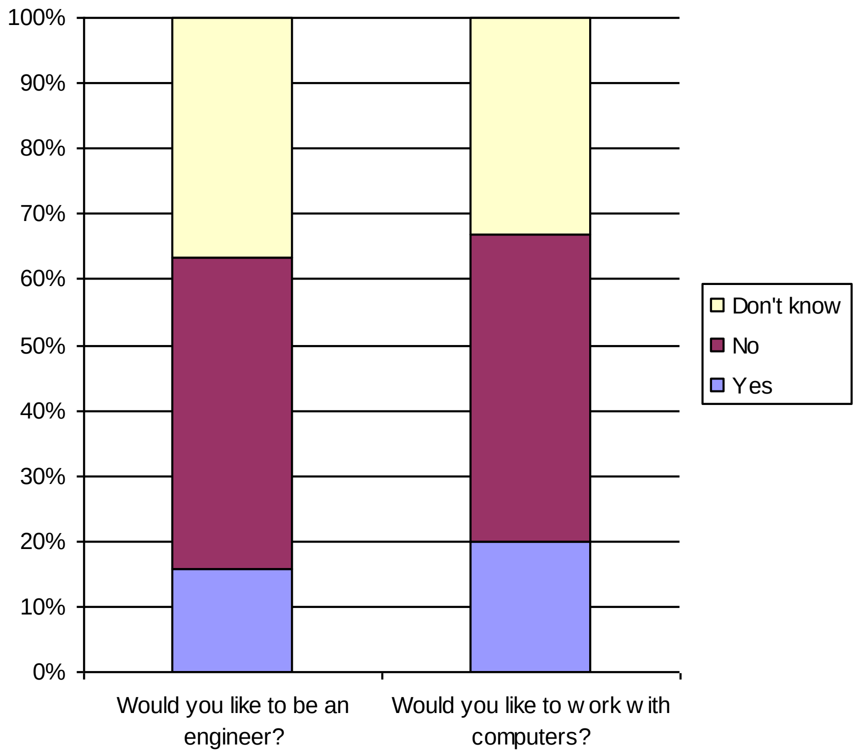


Figure 8: SPECIFIC INTERESTS IN ENGINEERING AND COMPUTING

The following question in the survey asked the students what job they would like to do. Using the same set of occupational categories as used for parents, the students' preferences are also shown in Table 3.1, alongside those for fathers and mothers. There are clear similarities between the existing parental occupations and the student preferences, with exceptions being lower proportions of students showing an interest in shop or office work, and a much higher proportion for an Art occupation. The slightly higher proportion indicating an interest in engineering could perhaps be explained by the students being aware that the questionnaire was focussed on engineering, and that primary-aged students often like to please.

The students were then asked whom they would approach to find out about engineering, with seven specific alternatives offered plus an invitation to name another source of information. Positive responses are shown in Table 13.

Table 13: SOURCES OF INFORMATION ABOUT ENGINEERING

SOURCES OF INFORMATION	%
Dad or brother	73
Mum or sister	23
Any other relative	49
A friend	24
A teacher	49
TV or the internet	62
Science museums or shows	37
Other*	1

*Two other sources written in were ‘an engineer’ (42 responses) and ‘books’ (26 responses).

Clearly the perception existed among the majority of primary school students that males were more likely to be knowledgeable about engineering.

The students’ interests and perceptions about engineering and engineering stereotypes were obtained through a set of 27 statements with codes ranging from 4 for *strongly agree* to 1 for *strongly disagree*. The items were then collected into three scales, with the mean, standard deviation and the percentage of mean responses in the agreement range (ie, with mean scores greater than 2.5) for each scale as shown in Table 14.

Table 14: STUDENT INTERESTS, PERCEPTIONS AND STEREOTYPES

SCALES	Mean	Stand.Dev.	Agree %
Liking of engineering-related activities	3.0	0.53	78
Positive personal perceptions of engineers	3.0	0.46	90
Engineering stereotypes held	2.8	0.33	87

All three scales had mean scores indicating majority agreement. However, the scale mean for engineering stereotypes was somewhat lower than the other two scales and also had a lower standard deviation. Clearly only relatively small minorities of students were in the negative ranges for these scales. Most students liked the engineering-type activities listed, even more had positive personal perceptions of engineers, and most also accepted the engineering stereotype items offered.

When the scale score for liking of engineering-related activities was correlated with the subject satisfaction scales (see Table 3.2 above), it was found that the strongest correlation was with the interest/excitement scale ($r = 0.55$, $n = 553$, $p < .001$). Correlations with science ($r = 0.48$), and with usefulness/importance ($r = 0.42$) were also moderate to strong, and only a little less with mathematics ($r = 0.32$).

Testing the scale usefulness/importance of mathematics and science in everyday life against the item “Engineers make people’s lives better” from the Positive Personal Perceptions scale gave a statistically significant result ($t= 3.2$, $p < .01$). Children who thought maths/science was important in everyday life agreed more (mean = 3.1) with the statement that those who didn’t (mean = 2.6). The same item tested against gender of the participants showed that although students overall were in agreement with the statement ($t = 3.2$, $p < .001$), boys saw engineering as a profession that helped people (mean = 3.3) more so than girls (mean = 3.0).

3.4 – Understanding of engineering

The reliability and usefulness of many of the questionnaire items and scales described above rely on the students having a reasonable understanding of what engineering is and what engineers do. In order to judge the students' level of understanding, a brief scenario of being stranded on an island was set up, and six possible tasks were listed. For each task, the students were asked to indicate whether it needed the skills of an engineer (see Table 15).

Table 15: RECOGNITION OF ENGINEERING TASKS

ENGINEERING TASKS?	Yes %
Building a raft	82
Designing a water pump	78
Testing a radio transmitter	72
Making a fire	32
Catching fish to eat	28
Helping sick people	14

It would seem from the pattern of responses, with majority correct identification of engineering-type tasks (in blue) and much smaller proportions of students (all less than one third) selecting non-engineering tasks (in red), that most students had a reasonable understanding of engineering as an occupation. To test this assertion further, the proportions of students who correctly identified all three engineering activities (53%) and correctly identified all three non-engineering activities (61%) were obtained. In both cases a majority had no errors in making this distinction. In fact more than one third (34%) of the students had a perfect score in identifying these six activities as engineering tasks or not.

When testing students' knowledge of engineering versus the item "Engineers must be strong" it was found that students who had a good understanding of engineering tasks (those who had responded correctly 5 or more of the questions) disagreed with stereotype (mean = 2.40), whereas students who had a poorer understanding agreed with stereotype (mean = 2.79). This difference was found to be statistically significant (t=4.2, p =.000).

Following the question concerned with recognition of engineering tasks, the final item of the questionnaire asked the students to 'create' an engineering task by drawing an engineer at work. Such an item has been previously used in the USA (Cunningham et al, 2005). Almost all sampled students attempted the task (i.e., 549 out of 555), and their drawings were coded across a wide range of criteria: nature of images, gender of the engineer, indoor/outdoor location, nature of activity according to typical engineering activities, attire, positive or negative disposition, whether text was included in the drawing, whether a sequence or story was illustrated, etc. Figure 9 below shows the nature of image that participants chose as a percentage of the total. Proportions of each category that could be coded from each drawing are presented in Table 16.

One notable stereotype that appeared repeatedly amongst children's impressions was the misconception that car mechanics are engineers. This was shown by the high correlation between images of fixing and images of cars. Another stereotype that seemed to appear was the idea of engineers working on their own (70%). Even though only 41% of children clearly represented engineers as male, out of the 50% of the items whose gender could not be clearly ascertained, most of them would be more easily put into the male than the female category.

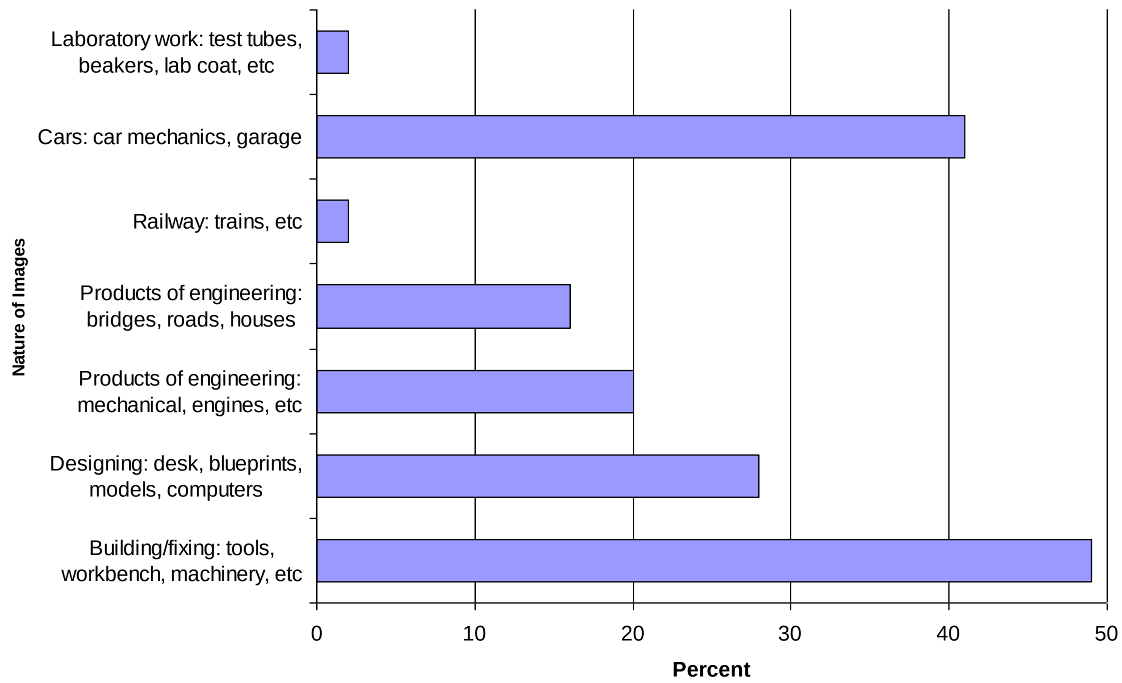


Figure 9: DRAWING AN ENGINEER, NATURE OF DRAWING

The confusion about the tasks associated with assembling cars would seem to be particularly part of an Australian phenomenon where anything to do with cars is likely to be seen as 'engineering' – the term 'automotive engineering' used to describe a garage for repairing cars is common (Holbrook et al, 2007). In the United States the "Draw an engineer test" by Knight and Cunningham (2004) found that students were much more likely to think that a train driver was an engineer (13% of females and 5% of males portrayed train drivers), than for this study, where only 2% of the children's drawings indicated such an activity. Cunningham et al. (2005) found that the top student choices were rooted in activities that focused on construction, building, machinery and vehicles, whereas this study found the top activities to be building and fixing (fixing cars appeared in the majority of cases). They also found that there was a widespread lack of understanding about the breadth of the fields of engineering as children identified engineering almost exclusively with civil engineering, whereas Australian primary school student's drawings showed 20% as products of mechanical engineering and 16% of products of civil engineering. Almost a third of sampled students identified design as an important engineering activity, a very similar percentage to the North American students.

When analysing the responses to this question against the parental occupations, it was found that 36% of students who claimed their father was an engineer drew a car mechanic. For all other professions this percentage was 41%. The group of students that held the car mechanic stereotype most strongly was that of students whose fathers were either "at home" or "unemployed", with 61% of these children drawing a car mechanic when asked to draw an engineer.

Students who drew a car mechanic in response to this question agreed with the engineering stereotype "Engineers must be strong" (mean = 2.75) whereas those who did not draw a car mechanic tended to disagree with the statement (mean = 2.40). This difference was found to be statistically significant ($t=3.5$, $p < .001$).

Table 16: DRAWING AN ENGINEER, OTHER NOTABLE CHARACTERISTICS

CRITERIA	Categories	%
Gender	Male	41
	Female	9
	Cannot tell	50
Location	Indoor	32
	Outdoor	22
	Both	6
	Cannot tell	40
Nature of activity	Interacting with others	4
	Managing others	3
	Not interacting with others	24
	Only one person in the drawing	70
Attire	Formal	4
	Informal	31
	Cannot tell	65
Disposition	Positive	54
	Negative	3
	Cannot tell	44
Text included	Yes	27
	No	73
Sequence or story	Yes	6
	No	94
Humans visible	Yes	92
	No	8

3.5 – Conclusions

This section summarises the most relevant findings of the primary school survey.

- Students generally agreed they were satisfied with school, although slightly less satisfied specifically with science and mathematics. The students were particularly satisfied with computing activities.
- Although all subjects were liked by most students, it is of interest that Science and Technology was among the most liked subjects. On the other hand, Mathematics was one of the least liked.
- There were clear similarities between the existing parental occupations and the student preferences, with exceptions being lower proportions of students showing an interest in shop or office work, and a much higher proportion for an Art occupation. The slightly higher proportion indicating an interest in engineering should perhaps be explained by the students being aware that the questionnaire was focussed on engineering, and that primary-aged students often like to please.
- There exists a perception among the majority of primary school students that males are more likely to be knowledgeable about engineering.
- Most students liked the engineering-type activities (designing, experimenting, testing, etc.). Even more students had positive personal perceptions of engineers. However, most students accepted as facts the engineering stereotype items offered.
- Most primary students can reasonably identify engineering tasks. More than one third (34%) of the students had a perfect score in identifying correctly the six activities given to them as being engineering related or non-engineering related.

- One noticeable stereotype that appeared repeatedly amongst children's impressions was the misconception that car mechanics are engineers. This was shown by the high correlation between images of fixing and images of cars.

CHAPTER 4 – Analysis of Secondary Science Student Questionnaires

In addition to the demographic information already stated in Section 2.1 information in the scales provided in Section 2.2 was collected.

4.1 – Parents' occupations

Two questions requested father's and mother's occupations.[3] These results are shown in Table 17. For convenience, student occupational interests are also shown in this table (see the discussion of student occupational interests Figure 10.

Table 17: OCCUPATIONAL CATEGORIES OF FATHERS, MOTHERS AND STUDENT PREFERENCES

OCCUPATIONAL CATEGORY	FATHER %	MOTHER %	STUDENT %
Shop work	9	15	13
Office work	24	26	36
Health care	5	14	44
Services (police, fire)	5	2	14
Armed forces	1	0	16
Information technology	7	2	20
Agriculture	6	1	7
Hospitality	2	4	14
Engineering and science	14	1	35
Manufacturing	10	4	9
Sports and leisure	1	0	25
Teaching	5	12	22
Creative Arts	1	1	24
Other work	1	2	0
Do not know	11	15	-

The most frequently-given occupation for fathers was office work, with engineering and manufacturing also above 10% of responses. The most frequent occupations for mothers was office work with more than one-quarter of responses, followed by shop work, health care and teaching, all attracting at least 12% of respondents.

It is perhaps of interest that 31% of students indicated their fathers and 7% of their mothers were in engineering/manufacturing/IT occupations. One contribution to an explanation of this relatively high incidence is the fact that most of the students selected were taking physics or mathematics as subjects in Year 11.

4.2 – Student satisfaction with aspects of schooling

First the students were asked about satisfaction with their life at school. In this case, five questions were taken the LSAY surveys. This section was followed by a set of questions about school subjects and activities, specifically about the excitement, interest, usefulness, importance and difficulty found in science, mathematics and computing. Importance of

[3] Again, the occupational categories used were taken from a survey into the perceptions of secondary students towards careers in engineering, in a report commissioned by the West Midlands Education and Training Department (2004).

English was also requested to provide a point of comparison with the other subjects. Several scales were developed from these questions. Four categories of responses were offered, ranging from Strongly disagree (coded 1) to Strongly agree (coded 4). The mean scores and standard deviations for these scales are shown in Table 18.

Table 18: SATISFACTION WITH SCHOOL AND SUBJECTS

SCALES	MEAN	STAND. DEV.	RELIAB (α)
Satisfaction with school	3.0	0.47	0.76
Satisfaction with science	2.8	0.45	0.85
Satisfaction with mathematics	2.7	0.44	0.65
Satisfaction with computing	2.5	0.69	0.81
Interest/excitement of these subjects	2.5	0.52	0.64
Usefulness/importance of these subjects	2.9	0.48	0.72
Difficulty of these subjects *(negative scale)*	2.7	0.47	0.69
Importance of English *(single item)*	3.0	0.90	-

The students generally agreed they were satisfied with school, although slightly less satisfied specifically with science and mathematics, and were neutral about computing. It should be noted that all scale mean scores related to subjects were higher than the neutral mid-point of the scale (2.5) which indicated they were somewhat positive. The satisfaction with computing scale had a relatively large standard deviation, indicating a wider range in views about computing. These subjects/activities were considered to be more important than interesting, with the importance/usefulness scale having a mean score close to the *agree* response (ie, 3.0) while, on average, the students neither agreed nor disagreed that these subjects were interesting/exciting. The mean score for difficulty of these subjects was between neutral and agreement that they were difficult. Finally, the item concerning English had the highest mean score of all the subjects with students, on average, agreeing it was important.

Subsequently the students were asked to state the two subjects they most liked and the two subjects they most disliked. Responses were grouped for the two items and are shown in Table 19, in descending order of the percentage listing each subject as *liked*.

It will be noted that all percentages, for both most liked and disliked subjects were less than 50%. Mathematics and English had high percentages as both liked and disliked subjects, particularly disliked. Slightly more students liked Chemistry and Biology than disliked these subjects, but the proportions were equal for Physics. It is no doubt relevant that the respondents were doing at least one Year 11 science subject to be included in the sample, so one might expect a favourable leaning towards science.

It is important to point out here that a high proportion of students like school but not mathematics or science. Since there is a concern about the possibility of increasing student participation STEM degrees, it is of interest to compare responses to three pieces of information provided above: the scale scores for student satisfaction with the subjects of mathematics and science, and their more general satisfaction with school, and students' relative liking for these individual subjects.

Table 19: STUDENT LIKING, DISLIKING AND DIFFICULTY OF SCHOOL SUBJECTS

SCHOOL SUJECTS	LIKE %	DISLIKE %	DIFFICULT %
Mathematics	33	44	31
Chemistry	22	15	44
English	20	45	21
Physics	19	19	55
History/geography	15	7	16
Economics/law/business	14	10	na
Creative arts	13	3	na
Physical Education	13	4	na
Biology	12	8	17
Design and Technology	7	1	7
Languages other than English	6	6	na
Science (general)	3	2	na
Software/IPT/Computing	3	3	9
Religion	1	8	na

Taking satisfaction with school first, a vast majority of the students (94%) scored at or above the mid-point of the scale (2.5) indicating they were at least not dissatisfied with school. However, by setting a higher criterion for clear satisfaction (3.0 on the 1 to 4 response scale), a somewhat smaller majority (65%) scored at least at this level.

Considering scores on the other measures for this 65% of Year 11 students undertaking a science course who were clearly satisfied with school, it is of concern that 40% of these students did not like or found mathematics too difficult (26% of the total) and 35% disliked science (24% of the total).

Another interesting comparison from these data was the percentage of Year 11 students who showed interest in engineering-type activities (71%) but disliked mathematics or science. The results here were even more worrying: 42% of students who liked engineering-type activities did not like or found mathematics too difficult (this represents 30% of the total), and in the case of science this number was slightly less but still rather sizeable at 35% (representing 22% of the total).

Presumably, students who are satisfied with general aspects of schooling and/or who like engineering-type activities but do not have a liking for mathematics or the enabling sciences (whilst taking these subjects in Year 11), could be a potential target group for any possible initiative to increase enrolments in STEM degrees.

The students were also asked to provide a difficulty rating for each of eight of the 14 subjects (see Table 4.3). The subjects included here were the science, mathematics, and technology subjects, and English and History. While Physics was disliked by only one-fifth, more than a half rated Physics as one of the two most difficult subjects. Somewhat surprisingly, less than a half disliked Mathematics and less than one-third found Mathematics difficult.

4.3 – Student occupational interests and knowledge

Students were asked to indicate their possible interest in each of 13 occupational areas, with multiple selections possible, and even encouraged by the format of the question. Responses are shown in Table 19 above. Health care, office work and engineering were all selected by more than one-third of respondents, with a quarter and a fifth selecting each of sports and leisure, creative arts, teaching and information technology (see Figure 10).

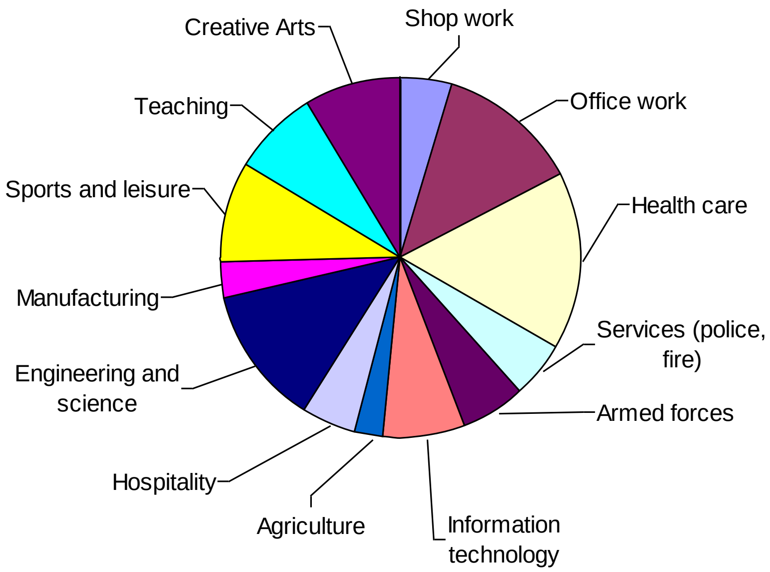


Figure 10: STUDENT'S OCCUPATIONAL INTERESTS

A subsequent set of questions asked students whether they agreed or disagreed with each of 30 statements about their liking of engineering-related activities, perceptions of engineering-type skills, and engineering stereotypes held, with a separate category for perceived "geekiness" of scientists and engineers (see Table 20).

Table 20: PERCEPTIONS OF ENGINEERING

SCALE	YR 11 MEAN	STAND. DEV.	RELIAB. (α)	PRIM. MEAN
Liking of engineering-related activities	2.8	0.48	0.75	3.0
Personal perceptions of engineering	2.9	0.37	0.65	3.0
Engineering stereotypes held	2.6	0.33	0.60	2.8
Perceived geekiness	1.9	0.78	0.78	na

Three of the four scales mean scores indicated agreement. However, most students disagreed with the perception of scientists and engineers as "geeks". The Year 11 means for liking of engineering-related activities and personal perceptions of engineering both approached overall agreement (a score of 3.0), and were only slightly lower than the means for primary students (see Chapter 2). There was less agreement with the engineering stereotypes offered, with the mean of 2.6 only marginally above neutral (2.5). The perception of scientists and engineers as 'geeks' was, on average, not agreed with, the mean indicating *disagree*.

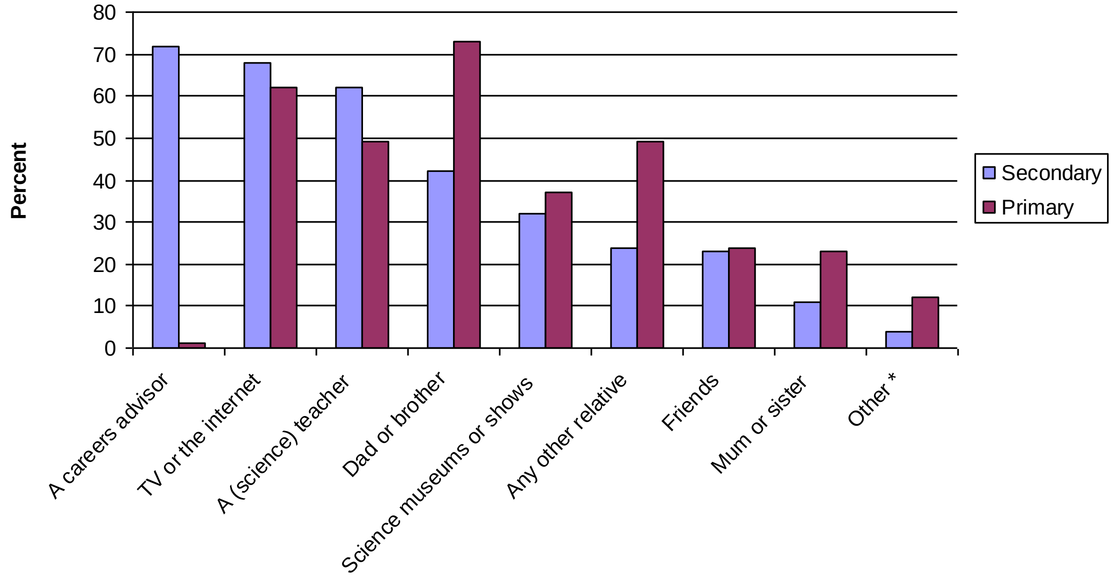


Figure 11: SOURCES OF INFORMATION ABOUT ENGINEERING

^ Two other sources written in by secondary students were 'an engineer' or 'engineering shop' (11 responses), and 'university science shows' (8 responses).
* Two other sources written in by primary students were 'an engineer' (42 responses) and 'books' (26 responses).

When asked if they knew any engineers, 65% of the students said they did, and 40% of these indicated the engineer was a member of their family. They were subsequently given a list of persons in eight categories and asked which they would go to find out about engineering. Responses are shown in Figure 11, together with responses from primary students to the same question, ordered by frequency of response by the secondary students.

Careers advisors, TV/internet and science teachers were seen as sources of information by the majority of secondary student respondents, replacing dad/brother which was the major source for the primary students.

A list of specific careers was given with respondents asked to indicate whether an engineering degree would prepare them for each type of task. The proportions of students indicating 'yes' are shown in Table 21 in descending order of frequency.

By and large, it can be said that the majority of these students had a reasonably good grasp of what types of careers/tasks were related to the engineering profession. The weakest areas were *Assembling cars in a factory* (which was not intended as an engineering example) and *Changing raw chemicals into products* (which was an engineering example), both almost evenly splitting the secondary student sample.

Table 21: RECOGNITION OF ENGINEERING-RELATED CAREERS

CAREER/TASK	ENGINEERING RELATED %
Modelling and overseeing the building of structures such as bridges, dams and towers	81
Constructing and testing aircraft and their components	79
Designing electrical systems for electric generators	74
Developing equipment to monitor and control pollution	69
Devising and testing new medical equipment for hospitals	66
Assembling cars in a factory	49
Changing raw chemicals into products	48
Maintaining children's playground equipment	35
Driving a train	21
Producing music CDs	15
Managing a restaurant	8
Working in the stock market	8

The confusion about the tasks associated with assembling cars would seem to be particularly part of an Australian phenomenon where anything to do with cars is likely to be seen as 'engineering' (see Chapter 2).

Students' scores when answering whether these tasks were engineering related compared with two individual items in the "Stereotypes about engineering" scale: "You need to be physically strong to become an engineer" and "A car mechanic is an engineer". Students were separated into two groups, those with a good understanding of engineering (students with scores of 12 or 11, out of the 12 possible tasks given), and those with a less-good understanding (ie, fewer than 11 items correct) In the first of the two items (concerning physical strength), although both groups disagreed with the statement, students with a good understanding of engineering did so more strongly than those who had a poorer understanding of engineering (with means of 1.9 and 2.1 $t = 3.1$, $p < .001$),. With regard to the second item concerning car mechanics being engineers, students who had a good understanding of engineering tasks disagreed with stereotype (mean = 2.49), whereas students who had a poorer understanding agreed with stereotype (mean = 2.70). This difference was also statistically significant ($t = 3.6$, $p < .001$).

To compare results with the primary cohort, secondary science students were then given a set of six more-specific tasks related to survival on a desert island, and asked which tasks needed the skills of an engineer. The proportions selecting each task, together with responses to the same questions by primary school students, are shown in Figure 12 in descending order of frequency for the secondary students.

With these more specific tasks, there was a high level of correct distinction between engineering and non-engineering activities. Slightly higher proportions of the secondary students responded appropriately compared with the primary students, although the observed differences were not large.

A second, more demanding example explored possible tasks related to Mars exploration, by asking respondents to provide one or two jobs that would be undertaken by an engineer. The descriptions given were classified into 10 areas, and the proportions of students including each area are shown in Table 22 in descending order of frequency.

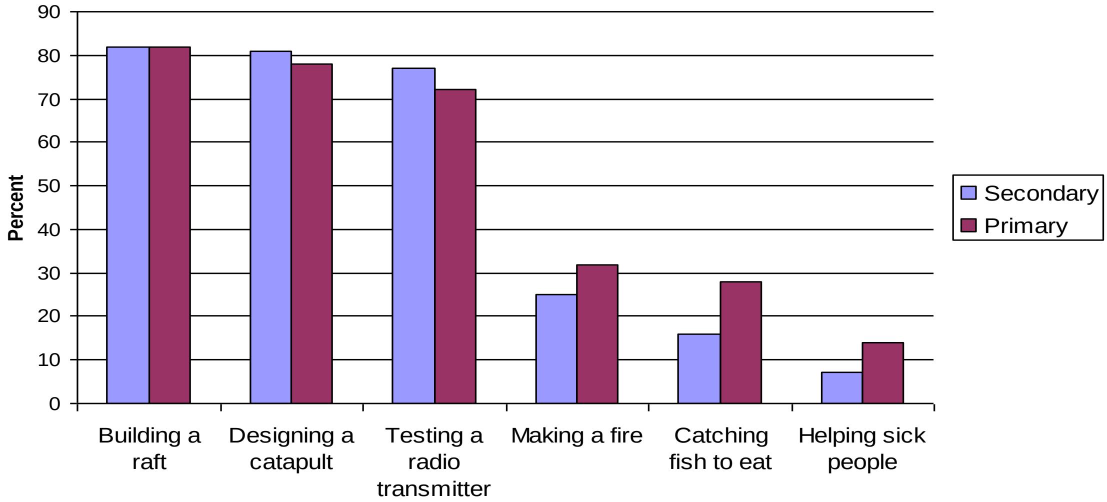


Figure 12: RECOGNITION OF ENGINEERING TASKS

Designing/creating/inventing tasks were the most commonly described, with half the respondents giving at least one such task. Building/constructing tasks were given by about one-third of the students. Other engineering-related tasks were given by few respondents (eg, calculating, studying). Tasks which were less likely to be directly related to engineering (eg, driving, fixing) were also given by only small proportions of respondents, each not exceeding 10%. Tasks more specific to technicians than engineers, such as building, constructing and fixing the rover, were more commonly given (in total 37%). It is perhaps surprising that a total of 37% of Year 11 students in science subjects selected these as engineering-type activities.

Table 22: DESCRIPTIONS OF ENGINEERING JOBS/TASKS

NATURE OF JOB/TASK	%	EXAMPLES OF JOBS/TASKS
Designing/creating/inventing	50	Designing the rover
Building/constructing	34	Building the rover
Testing/monitoring/improving	17	Testing that all components work appropriately
Driving	10	Driving the rover on Mars surface
Fixing	3	Fixing components of the rover if it malfunctioned
Calculating/computing	2	Calculating the trajectory to get to Mars
Studying	1	Studying the theory necessary to implement the rover

4.4 – Outreach programs

Students were offered a set of several outreach programs, divided into four categories: (1) science shows (Questacon and Smart), (2) science workshops (CSIRO, Zoomobile), (3) Science and Engineering Challenge and ReEngineering Australia, and (4) Programs for gifted and talented students. For a description of these programs please see the Appendix. Students were asked two questions. First they were asked to indicate which of the four categories of outreach programs their school had participated in and secondly, whether they had personally participated in any these or any other programs. The involvement of schools and students personally with these programs is shown in Table 23, in descending order of school involvement in each type of program.

Table 23: SCHOOL AND PERSONAL INVOLVEMENT IN OUTREACH PROGRAMS

TYPE OF OUTREACH PROGRAM	SPECIFIC PROGRAM	School involved %	Personally involved %
Science workshops		**29**	
	Zoomobile		11.4
	CSIRO		11.6
Science & Engineering Challenge / Re-Engineering Australia		**28**	-
Gifted and talented programs		**24**	5.4
Science shows		**20**	
	Questacon		9.9
	Smart		-

A significant minority of students (29%) were in schools that had participated in one of the science workshop programs, and most of these (23% in total) had participated personally in one of the two programs listed. With respect to science shows, one-fifth of the sample was in participating schools and half of the sample had participated personally.

It was unexpected that although 33% of the Year 11 students were in schools that had previously participated in the Science & Engineering Challenge[4], and 28% were aware their school had been involved, none claimed to have participated personally. It is possible that they were not in Year 10 when the school participation occurred, so were not themselves eligible (the Challenge being restricted to Year 10). With respect to Re-Engineering Australia, only 4% of the students were in schools that had participated, so it is not surprising that none of the students in the sample had been personally involved.

4.5 – Conclusions

This section summarises the most relevant findings of the secondary school science students' survey.

- Secondary students generally agreed they were satisfied with school, although slightly less satisfied specifically with science and mathematics, and were neutral about computing.
- Mathematics and English had relatively high percentages as both liked and disliked subjects, particularly disliked. Slightly more students liked Chemistry and Biology than disliked these subjects, but the proportions were equal for Physics.
- While Physics was disliked by only one-fifth of sampled students, more than half of them rated Physics as one of the two most difficult subjects. Less than half of the students disliked Mathematics and less than one-third found Mathematics difficult.
- Health care, office work and engineering were all selected as preferred occupations by more than one-third of respondents.
- Year 11 students in the sample liked the engineering-related activities presented activities (designing, experimenting, testing, etc.) and their personal perceptions of engineering approached overall agreement. There was less agreement with the engineering stereotypes offered, with the mean of 2.6 only marginally above neutral (2.5). The comparison with the primary student mean suggests that the secondary

[4] This information was obtained from records of school participation kept by the *Science & Engineering Challenge*..

students had more knowledge about engineering and therefore were less likely to hold a stereotypical view.

- The perception of scientists and engineers as ‘geeks’ was, on average, not agreed with.
- Careers advisors, TV/internet and science teachers were seen as sources of information by the majority of secondary student respondents, replacing dad/brother which was the major source for the primary students.
- By and large, a majority of the secondary students had a reasonably good grasp of what types of careers and tasks are related to the engineering profession.
- A significant minority of students (29%) were in schools that had participated in one of the science workshop programs.

CHAPTER 5 – Analysis of University Engineering Student Questionnaires

In addition to the demographic information already reported in Section 2.1 information in the scales provided in Section 2.2 was collected, and is now decribed.

5.1 – Parent occupations

Almost one-third of the students' fathers (32%) were employed in an engineering or engineering-related field, and 4% of mothers were similarly employed. Other major occupational categories with at least 10% of responses were 'office work' (27% of fathers, 29% of mothers) and, for mothers only, 'teaching' (23%) and 'healthcare' (18%).

5.2 – Engineering studies and membership of Engineers Australia

Year of commencing tertiary study of engineering
The vast majority of Year 1 students (89%) had commenced their study in 2007 (the year of data collection), with most of the remainder (9%) having commenced in 2006. Although two of the Year 4 students had commenced study in 1998, the largest group (35%) had commenced in 2004, and 30% had commenced in the previous year. It would seem that, in the main, the students in Year 4 had been enrolled full-time.

Major area of study within Engineering
Thirteen major areas of study within engineering were identified. The numbers of students responding ranged from 9 in Geotechnical engineering to 399 in Civil engineering (see Table 24). Clearly some of the areas of study related strongly to the university attended with only Electrical, Civil, Computer and Environmental engineering having students responding from all six universities.

Table 24: DISTRIBUTION OF MAJOR AREA OF STUDY AND MEMBERSHIP OF ENGINEERS AUSTRALIA

MAJOR STUDY AREA	NUMBER OF STUDENTS	MEMBERSHIP OF EA %
Materials/Mining	90	37
Mechanical	226	46
Aeronautical/Aerospace	46	46
Electrical/Electronics	152	31
Civil/Structural/Surveying	399	35
Environmental	62	27
Computer/Software	111	19
Chemical	133	39
Photonics	12	0
Biomedical	19	32
Mechatronics	140	36
Telecommunications	16	25
Geotechnical	9	56
TOTAL	1415*	35

* A total of 85 students did not respond to this question.

Membership of Engineers Australia

Of the 97% of students who responded to this question, 35% were members of Engineers Australia – made up of 57% of Year 4 students and 27% of Year 1 students. The proportions of students in each area of engineering who were members of Engineers Australia varied considerably between zero for Photonics to 56% for Geotechnical (again see Table 5.1), and these differences were statistically significant (^{2} = 39.49, df = 12, p < .001).

5.3 – Student perceptions

A range of perceptions of these students was sought relating to science, mathematics and computing, and some more specific aspects of engineering. Two types of comparison of these perceptions are made here, first between the Year 1 and the Year 4 students, and secondly between their recall of these perceptions at high school and now. Significant differences between the mean scores are reported in the following tables. In Chapter 8 comparisons will be made between the responses of these two groups of engineering students, school students and practising engineers.

Table 25 reports the scale mean scores for Year 1 and Year 4 students. The scale range is 1 to 4, with 1 indicating least agreement and 4 indicating highest possible agreement. The mid-point of the scale (2.5) indicates a neutral position. With the exception of the engineering stereotypes scale, the means for all scales were greater than 2.5, that is, they indicated agreement.

Perceptions of engineering between year levels

There were several scales assessing the students perceptions of engineering, related to liking the types of activities involved, personal perceptions, requirements for success in engineering, stereotypes, notions of gender equity in the profession and a 'geekiness' measure.

Table 25: PERCEPTIONS OF ENGINEERING STUDENTS BY YEAR LEVEL

SCALE	YEAR 1 Mean (SD)	YEAR 4 Mean (SD)	SIG.DIFF.
Liking of engineering-type activities	3.28 (0.44)	3.32 (0.45)	ns
Positive personal perceptions of engineering	3.31 (0.41)	3.27 (0.41)	ns
Requirements to become an engineer	2.77 (0.42)	2.85 90.40)	<.01
Engineering stereotypes held	2.19 (0.48)	1.94 (0.43)	<.001
Equality in gender	3.28 (0.58)	3.53 (0.48)	<.001
Geekyness index	2.98 (0.77)	2.83 (0.69)	<.001
Interest in science	3.26 (0.51)	3.25 (0.51)	ns
Interest in mathematics	3.24 (0.53)	3.20 (0.54)	ns
Interest in computing	2.88 (0.71)	2.90 (0.69)	ns
Career importance of these subjects	3.23 (0.46)	3.17 (0.47)	<.05
Everyday life importance of these subjects	3.04 (0.50)	3.11 (0.47)	<.05

Engineering activities and personal perceptions: As might be expected from samples of engineering students, these two scales had among the highest mean agreement levels. Levels of agreement for the two scales did not differ significantly between year levels.

***Requirements for engineering success*:** This scale refers to subject-mater expertise and qualifications necessary to become an engineer. The mean level of agreement was positive but not strong for either year level, although the level of agreement of the Year 4 students was significantly stronger than that of the Year 1 students.

Engineering stereotypes: The stereotypes scale focussed on what were considered to be common misperceptions of engineering (eg, you need to be physically strong to be an engineer), so one might reasonably expect that engineering students would know better. It seems that such learning continues during the engineering course because Both year levels had a mean score below 2.5 for this scale, indicating that, on average, neither group supported the stereotypes suggested It seems that this learning continues throughout the engineering course because the Year 4 students rejected the stereotypes more strongly than the Year 1 students,

Gender equality: Gender equality in the engineering profession was strongly supported by students in both year levels, with those in Year 4 having a significantly more positive view than those in Year 1 for both genders. The gender equality scale mean scores ranged from 3.23 to 3.46 for males, and from 3.48 to 3.78 for females. For both year levels, females constituted approximately 20 per cent of the samples of students obtained.

Geekyness index: Popular adolescent culture often seeks to shun serious pursuits, with studious students being referred to derogatively as 'geeks' and/or 'nerds'. Engineering students are among the more successful at academic work in schools, particularly in maths/science areas, so are likely to have been referred to in this way at some stage during their schooling. It would seem that they accepted the appellations because they generally agreed with the statements in this questionnaire (eg, people who do science are geeks). However, it is notable that there was significantly lower agreement by the Year 4 students compared with the Year 1 students.

Interest in science, mathematics, computing: Both year groups generally agreed with these scales, although interest in computing was lower than for the other two subject areas. There were no significant differences between year levels for any of the three scales.

Importance of the subjects: Two scales for importance of science, mathematics and computing were developed – one related to importance for career, and the other related to importance in everyday life. Although there was general agreement with both scales by both year levels, agreement was stronger with the career scale, particularly for the Year 1 students. Mean differences were significant between the year levels for both scales, although in opposite directions, with Year 4 students having a higher mean for the everyday life scale.

Comparisons between perceptions at high school and now

The students were asked to indicate their agreement or disagreement with statements on two different time frames – first what they believed when at school (a retrospective scale), and secondly what they believed now. Given the differences observed between several of the scale mean scores for current belief (see Table 24), Table 26 reports the 'then' (at high school) and 'now' means for Year 1 and Year 4 students separately.

It will be noted that all mean scores for interest and importance were in the positive range (ie, greater than the scale mid-point of 2.5), with the highest scores for interest in science and mathematics.

Table 26: PERCEPTIONS OF ENGINEERING STUDENTS – WHEN PREVIOUSLY AT HIGH SCHOOL AND NOW

SCALE	HIGH SCHL	NOW	SIG.DIFF.
Year 1 Students			
Interest in science	3.26 (0.51)	3.34 (0.52)	<.001
Interest in mathematics	3.23 (0.54)	3.34 (0.51)	<.001
Interest in computing	2.88 (0.71)	2.88 (0.73)	ns
Career importance of these subjects	3.22 (0.46)	3.05 (0.59)	<.001
Everyday life importance of these subjects	3.04 (0.50)	3.27 (0.46)	<.001
Year 4 Students			
Interest in science	3.25 (0.51)	3.30 (0.53)	ns
Interest in mathematics	3.20 (0.54)	3.23 (0.55)	ns
Interest in computing	2.90 (0.69)	2.92 (0.69)	ns
Career importance of these subjects	3.17 (0.47)	3.09 (0.58)	<.05
Everyday life importance of these subjects	3.11 (0.47)	3.21 (0.50)	<.001

Year 1 students: Interest in science and mathematics was stronger now than at high school, but there was no difference for computing. Year 1 students now also believed that these subjects were more important in everyday life than they recalled believing in high school, but the reverse applied for the career importance of these subjects.

Year 4 students**:** There were no significant differences between recalled interest in the three subjects and interest now. There were, however, significant differences for the importance scales between the recalled and the current beliefs. Again the directions of the difference were opposite – career importance was a stronger belief at high school and everyday importance was stronger now.

5.4 – Engineering area comparisons

Many other comparisons in the data collected from the engineering students are possible, in addition to the intended comparisons with other samples, namely school students and professional engineers.

To illustrate, perceptions of students in the major discipline areas of engineering were compared. The areas selected for comparison were the six for which there were at least 100 questionnaire responses from students (see Table 25), and the comparisons were for the scales shown in Table 26 where year levels were compared.

Six of the 11 scales had significant differences in the mean scores between engineering areas of enrolment (see Table 27). The other five scales did not differ for individual areas of engineering (holding engineering stereotypes, requirements to become an engineer, equality in gender, the geekyness index, and interest in mathematics). The scales for which there were significant differences are now discussed briefly.

Liking of engineering-type activities: Computer/software students had the lowest mean score, although still clearly in the positive range (3.21). Mechatronics students had the highest mean score (3.39) that differed significantly from the former group. Although there was a range of mean scores between these extremes, none of the other groups differed significantly from one another.

Table 27: COMPARISON BY AREA WITHIN ENGINEERING IN ASCENDING ORDER OF POSITIVE SCALE MEAN RESPONSES

LIKING OF ENGINEERING-TYPE ACTIVITIES	**MEAN SCORE ***	**POSITIVE PERSONAL PERCEPTIONS OF ENGINEERING**	**MEAN SCORE ***
Computer/software	*3.21*	*Computer/software*	*3.19*
Chemical	3.24	Mechatronics	3.28
Civil/structural/surveying	3.27	Mechanical	3.31
Electrical/electronics	3.30	Civil/structural/surveying	3.32
Mechanical	3.36	*Electrical/electronics*	*3.35*
Mechatronics	*3.39*	*Chemical*	*3.36*
INTEREST IN SCIENCE	**MEAN SCORE ***	**INTEREST IN COMPUTING**	**MEAN SCORE ***
Computer/software	*3.04*	*Chemical*	*2.80*
Civil/structural/surveying	*3.23*	*Mechanical*	*2.86*
Electrical/electronics	3.32	Civil/structural/surveying	2.72
Mechanical	3.39	*Electrical/electronics*	*3.08*
Mechatronics	*3.41*	*Mechatronics*	*3.12*
Chemical	*3.59*	*Computer/software*	*3.34*
CAREER IMPORTANCE OF THESE SUBJECTS	**MEAN SCORE ***	**EVERYDAY LIFE IMPORTANCE OF THESE SUBJECTS**	**MEAN SCORE ***
Civil/structural/surveying	*2.91*	*Computer/software*	*3.03*
Mechanical	3.01	*Civil/structural/surveying*	*3.19*
Chemical	3.10	Electrical/electronics	3.25
Electrical/electronics	3.20	Mechatronics	3.28
Mechatronics	*3.25*	Mechanical	3.30
Computer/software	*3.30*	*Chemical*	*3.39*

* Areas with means that are significantly different are shown in italics.

***Positive personal perceptions of engineering*:** Again Computer/software students had the lowest mean score (3.19), but still positive. Chemical students (3.36) and Electrical/electronic students (3.34) had the highest mean scores which both differed significantly from the former group. Students in the other areas did not differ from one another.

The Chemical engineering group is interesting in that these students were among the highest in liking of engineering-type activities but were the lowest (and significantly so) in personal perceptions about engineering. The Mechatronics students were the opposite of this, being the lowest (significantly) in liking of engineering-type activities but second highest in positive personal perceptions of engineering.

Interest in science: Computer/software and Civil/structural/surveying students had the lowest mean scores for interest in science, which differed significantly from the Chemical and Mechatronics students who had the highest mean. Again, students in all areas were generally positive, all mean scores being above 3.0.

Interest in computing: Civil/structural/surveying and Chemical engineering students had the lowest mean scores for interest in computing, and differed significantly from students in Computer/software and Mechatronics who had the highest mean scores. These mean scores were not as high as means for science and mathematics, but still in the positive range with the lowest area mean of 2.72.

Career importance of these subjects: The Civil/structural/surveying students had the lowest mean score for career importance which differed significantly from students in the Computer/software and Mechatronics areas who had the highest. Although positive (in the range of 2.91 to 3,30), the importance for careers of these subjects was rated notably lower than importance for everyday life.

Everyday life importance of these subjects: Computer software (3.03) and Civil/structural/surveying (3.19) students had the lowest mean scores for everyday importance of these subjects which differed significantly from students in Chemical engineering who had the highest mean (3.39).

5.5 – Personal life information and choices

When asked why they chose to become an engineer, 1335 students provided usable responses which could be classified into one of nine categories. These are shown in descending order of frequency in Figure 13. It will be noted that an average of 1.4 reasons was given by the respondents.

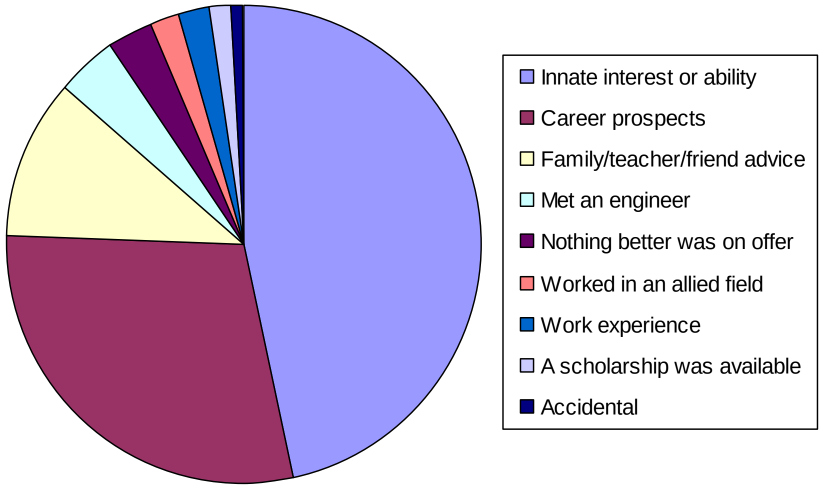


Figure 13: REASONS TO BECOME AN ENGINEER

More than half the reasons indicated were innate to the respondent themselves, either due to a natural inclination towards mathematics and science ('natural ability at science and mathematics' or 'Enjoy solving mathematic problems') or an intrinsic urge to 'invent' (eg, 'I've been interested in cars all my life, since I was 5ish; I wanted to work on cars; when I was about 14-15 I realised I could be smart enough to make the components used in cars and that I don't have to be content to be a mechanic.'). Also, over one-fifth identified advice from one or more of a variety of sources (family, teacher or friend (eg, 'Influence of my father, he is a civil draftsman') was acted upon.

When asked how many other engineers there were in their family, 59% indicated there were none, 27% indicated one, 9% indicated two, with up to eight engineers in the family indicated by three respondents. Slightly over 7% of respondents indicated that there are female engineers in their families.

5.6 – Promotion of engineering as a career

Five reasons were offered as solutions to what is seen as a shortfall of engineers in Australia. There was overall agreement with the first four reasons/solutions, and something approaching disagreement with the fifth solution, that being skilled migration (see Table 28).

Table 28: IMPLIED REASONS/SOLUTION FOR ENGINEERING SHORTFALL

REASONS/SOLUTION FOR SHORTFALL	Mean scores	Stand.Dev.
Assist transition from engineering trades	3.0	0.64
Gender imbalance not being addressed	2.9	0.85
Not enough students doing maths & science	2.8	0.73
Not following the success of other countries	2.5	0.71
Skilled migration	2.3	0.86

As well as the above five statements respondents were asked directly what they thought should be done to promote engineering as a career. Suggestions made were classified into eleven categories (see Figure 14). In this table it is to be noted that 1,329 participants provided 1,479 usable responses with some providing several responses, ranging up to 5.

Two suggestions related to promoting community perceptions through the media, together accounted for over 50% of responses. A typical example of this type of response is '[promotion should be done through] TV shows such as 'what is good for you''. Another two suggestions related to schools ('Hold information evenings for students in yr10-12 in each local government area') accounting for over 40% of responses.

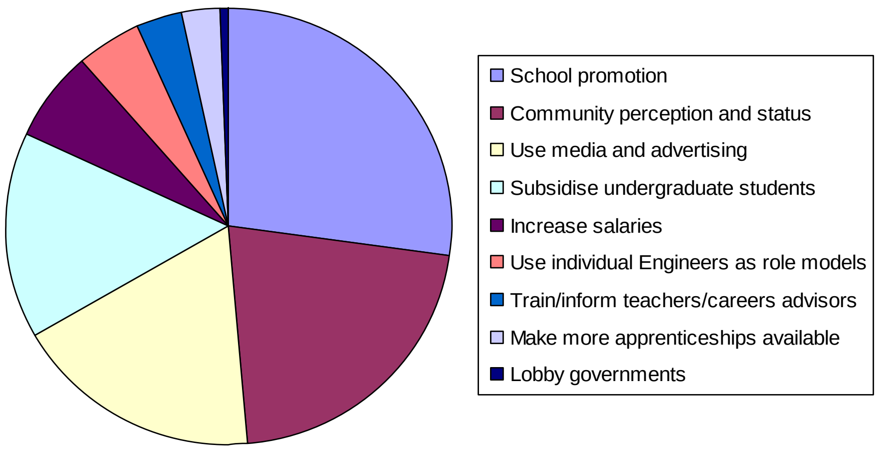


Figure 14: HOW TO PROMOTE ENGINEERING AS A CAREER

5.7 – Conclusions

The sample of engineering students obtained was reasonably representative of the students by gender, location and across specialisations. However, the very high percentage of students whose father was in an engineering-associated occupation, (almost one-third) was marked, if not surprising given what it is known about parental and wider family influences on professional choice.

Although interest in mathematics, science and computing studies did not differ between the Year 1 and the Year 4 students, there were changes in the recognition of importance of these subjects, and in some of their views about engineering and about gender equality over the four-year course. Interest in computing was consistently lower than for the other subjects. The acceptance of being perceived as 'geeks', was interesting, although this seemed to decrease over the four years. Clearly an engineering identity was still in formation.

A brief description of differences in perceptions between when they were at school (retrospectively) and now, provided some interesting differences between the Year 1 and the

Year 4 engineering students. It would seem that the Year 1 students now identified much greater differences from their school views than the Year 4 students recalled. Perhaps the Year 1 students who had left school only months before were consciously making a break.

Perceptions of students in the different engineering specialisations about interest and importance of mathematics, science, computing and engineering differed, with some consistencies. In general the computing science students had the lowest scores except for interest in computing and the career importance of the subjects where they had the lowest scores. The mechatronics students generally had the higher scores than the other specialisations, but did not differ from the other students on the everyday importance of the subjects.

The perceptions reported here for engineering students will be compared subsequently across several of the scales with those of primary and secondary school students and with engineers who are members of Engineers Australia (in Chapter 8). The aim is to map the development of interests from an early age to determine important aspects of what eventually constitutes an engineering identity.

In summary:

- Year 1 and Year 4 students from thirteen major areas of study within engineering responded to the survey with Electrical, Civil, Computer and Environmental engineering having students responding from all six universities.
- Gender equality in the engineering profession was strongly supported by students in both year levels, with those in Year 4 having a significantly more positive view than those in Year 1
- Both year groups had generally positive attitudes towards science, mathematics and computing, although interest in computing was lower than the other two subject areas.
- Year 1 students' interest in science and mathematics was stronger now than at high school, but there was no difference for computing.
- Computer/software students showed the lowest mean score in the 'Liking of engineering-type activities' scale, although still clearly in the positive range. The same tendency was shown with regard to the 'Positive personal perceptions of engineering' scale.
- All students had a fairly positive perception of the importance of enabling sciences in their future career, although these subjects' importance for careers was rated notably less than importance of enabling science for everyday life.
- A large proportion of the students indicated that their reasons for becoming engineers were that engineering was somewhat innate to themselves, either due to a natural inclination towards mathematics and science ('natural ability at science and mathematics' or 'Enjoy solving mathematics problems') or an intrinsic urge to 'invent'. Over one-fifth of respondents identified advice from one or more of a variety of sources (family, teacher or friend: 'Influence of my father, he is a civil draftsman') was acted upon.
- The two most popular suggestions for promoting engineering related to community perceptions through the media, together accounting for over 50% of responses. A typical example of this type of response is '[promotion should be done through] TV shows such as 'what is good for you''. Another two suggestions related to schools ('Hold information evenings for students in yr10-12 in each local government area') accounted for over 40% of responses.

CHAPTER 6 – Analysis of Professional Engineer Questionnaires

In addition to the demographic information already reported in Section 2.1, information in the scales provided in Chapter 2, Section 2 was collected and is reported here.

6.1 – Parent occupations

Two questions requested father's and mother's occupations. The occupational categories used were taken from a survey into the perceptions and attitudes of years 7, 8 and 9 students towards careers in engineering, a report commissioned by the West Midlands Education and Training Department (2004). The most frequent occupational category given was 'Office work' for fathers (26%) and this same category was 27% for mothers, with the second largest occupational category for mothers being 'Teaching' (26%). Other major categories for fathers were 'Engineering' (16%) and 'Manufacturing' (11%). The only other major occupational category for mothers was 'Healthcare' (20%).

6.2 – Engineering qualifications

The majority of the sample held a bachelors degree (70%), 19% held a higher degree and 11% had an 'other' qualification. The year of qualification was pre-1980 for 26% of respondents, post-1999 for 39% with the remainder (35%) having qualified in the 20 years between 1980 and 1999. An Australian qualification was held by 87% of the sample, with 13% having an overseas qualification.

Engineering specialisations were grouped as shown in Table 29. The largest group was Civil/Structural/Surveying (36%) followed by Electrical (23%). This distribution can be compared with the Australia Bureau of Statistics Labour force numbers where these two disciplines are the largest, with Civil Engineering accounting for 26% of the total and Electrical 30%.

Table 29: ENGINEERING SPECIALISATIONS

SPECIALISATION	No.	%
Materials/Mining/Chemical/Power	12	8
Mechanical/Aerospace	31	22
Electrical/Computing	40	27
Civil/Structural/Surveying	52	36
Environmental/Biomedical	9	7
Total	144	

* Of the 153 respondents, 9 did not answer this question.

Length of membership of *Engineers Australia* was reasonably spread across three groupings: 33% had been members for up to 5 years, 39% for between 5+ and 20 years, and 28% for 20+ years. This distribution can be compared with membership numbers of Engineers Australia where 33% have been members for less than 5 years, 36% for from 5 to 20 years and 22% for more than 20 years. Almost all (83%) are members and graduate members, 9% are fellows, 3% are companions and 4% are student members. Again, a comparison with *Engineers Australia* statistics can be drawn: 63% are members, 9% fellows, 1% companions and 13% students (source Engineers Australia's "The Engineering Profession: A Statistical Overview" Fourth Edition March 2006).

When asked whether they were currently practising as engineers, 85% indicated that they were. The nature of their current roles is shown in Table 30.

Table 30: CURRENT ROLES OF RESPONDENTS

CURRENT ROLE	No.	%
Academic	8	6
Project manager	43	30
Designer	14	10
Consultant	24	17
'Straight' engineer	42	30
Retired	4	3
Student	4	3
Not engineering related	3	2
Total	142	

* Of the 153 respondents, 11 did not answer this question.

By far the most common roles were project manager and those who described themselves as a 'straight' engineer (both 30%). Other common roles were consultant (17%) and designer (10%). In this case only 2% of the sample described their roles as not engineering related.

6.3 – Recalled school experiences

Respondents were asked to recall what they thought of different aspects of science, mathematics, computing and English while at secondary school. Perceptions of interest, excitement, usefulness and importance of these subjects were requested, with responses over four categories ranging from *Strongly disagree* (coded as 1) to *Strongly agree* (coded 4). As can be seen in column 2 of Table 6.3, mathematics and science were the subjects viewed most favourably, and English and computing slightly less favourably, but still on the positive side of the scale (the scale mid-point being 2.5). Other scales, also shown in Table 6.3, measured interest/excitement, usefulness/importance of these subjects collectively.

These secondary school perceptions were compared with their recollections of interest/excitement at university and, across all scales, their current perceptions (see Table 31).

Table 31: MEAN SCORES FOR PERCEPTION SCALES OVER TIME

SCALE	SEC. SCHOOL	UNIVERSITY*	AS ENGINEERS
Mathematics overall	3.4		3.2
Science overall	3.4		3.3
English	2.9		3.2
Computing	2.8		2.9
Interest/excitement	3.2	3.0	3.2
Useful/important	3.3		3.2

* In the interest of brevity, only one of the perception scales was covered at university level in the engineers' questionnaire.

Overall, engineers' perceptions of mathematics (interest, excitement, usefulness and importance) would seem to have declined slightly between secondary school and now, while perceptions of the usefulness of English have increased considerably. One of the participants pointed out "My perception concerning the importance of English has gradually changed over time as I realise the importance of communication of ideas to the development of engineering". This same vision is shared by several other participants. There is little difference in the other measures over time.

It must be stressed that the secondary school scale scores result from recollections and are therefore subject to the variable quality and reliability of memory. However, in Chapter 8 a comparison between current engineers' perceptions with those of the samples of current primary and secondary school students and of current engineering students participating in this study will be presented.

Respondents were asked to name the two subjects they liked most and two they liked least while at secondary school. These are shown in Table 32. Both mathematics and physics were very clearly the most liked subjects overall. English was by far the least liked subject, but the relatively high proportion (20%) who disliked chemistry was somewhat more surprising.

Table 32: MOST AND LEAST LIKED SECONDARY SCHOOL SUBJECTS

SUBJECTS	Liked most %	Liked least %
Mathematics	59	12
Physics	51	10
Chemistry	20	20
Science	12	1
English	8	55
Religion	0	5
Other languages	5	19
Biology	3	10
Economics/Law/Business	1	7
Art	3	17
Social Sciences	11	29
Design & Technology	19	2
Physical Education	3	10

* Of the 153 respondents, 11 did not answer this question.

Four science subjects, mathematics and English were listed with the engineers being asked to rank them for difficulty at secondary school. English was ranked as the most difficult by over a quarter of respondents (26%) and mathematics and physics were ranked as the least difficult by similar proportions (26 and 20%, respectively). Table 33 indicates the percentages of respondents selecting each of the six subjects as most difficult and least difficult.

Table 33: RELATIVE DIFFICULTY OF SIX SECONDARY SCHOOL SUBJECTS

SUBJECTS	Most difficult %	Least difficult %
English	26	18
Chemistry	21	5
Biology	19	15
Mathematics	13	26
History	10	16
Physics	10	20

* Of the 153 respondents, 16 did not answer this question.

6.4 – Perceptions of engineering

Professional engineers were asked a series of 30 questions about perceptions of engineering in terms of liking of typical activities (such as 'I like testing and modelling my ideas'), personal responses (such as 'engineers make people lives' better' and 'engineering is a highly respected profession') and popular stereotypes (such as 'engineers spend a lot of time working with machines').The main purpose of including these items in this questionnaire was to enable comparisons of these perceptions with school and university student perceptions of the same engineering-related constructs. Scores on the three scales are shown in Table 34 where most agreement is indicated by a rating of 4, and most disagreement by a rating of 1, with a neutral perception for this scales being 2.5.

Table 34: PERCEPTIONS OF ENGINEERING

SCALES	Mean scores	Stand.Dev.
Liking of engineering-related activities	3.4	0.31
Personal perceptions of engineering	3.1	0.34
Engineering stereotypes held	2.3	0.35

The first two scales indicate agreement with the statements (means are greater than 3.0), although the range was considerable. Differences between all three mean scores were statistically significant. Not surprisingly, the engineers were most likely to agree that they liked engineering-type activities and were least likely to agree with standard stereotypes about engineering. For the third scale, 'Engineering stereotypes held', mean scores indicated disagreement

There were no differences in perceptions of activities or personal perceptions according to age, but there was a significant difference with respect to stereotypes. Older engineers, that is, those who graduated before 1980, were more inclined to agree with stereotypes than young engineers, that is, those who had graduated since 2000.

There were no differences in any of the three scales related to perceptions of engineering with respect to engineering specialisation (as listed on Table 29).

6.5 – Gender-related perceptions

Four questions sought agreement/disagreement with statements that males and females can become excellent engineers and levels of interest in engineering as a profession. The same 4-point agree/disagree scale was used. There was strong agreement concerning excellence, with no respondent who disagreed with either statement. Overall, respondents also agreed with the statements about interest, although less strongly, and small proportions disagreed with both statements. Table 35 shows the mean responses to these statements together with the standard deviations.

Table 35: PERCEPTIONS RELATED TO GENDER

STATEMENTS	Mean	Stand.Dev.
Women can become excellent engineers	3.6	0.56
Men can become excellent engineers	3.6	0.48
Engineering is interesting for men	3.4	0.58
Engineering is interesting for women	3.2	0.69

It is perhaps of interest to note that agreements with the items concerning men were slightly stronger than the same items concerning women in the interest questions. In the following chapter responses to these four questions will be compared with the responses from current engineering students.

All participants agreed or strongly agreed with the question "Men can become excellent engineers", whereas the same statement about women also produced two 'Disagrees' and one 'Strongly disagree'. No males strongly disagreed with the statement about women not being interested in engineering, but one female did.

6.6 – Sources of information about engineering

When asked a preliminary question about how easy it was to obtain information about engineering from the media, only 21% agreed it was easy, 56% disagreed and 21% strongly disagreed. The following question asked how they keep up to date with engineering, and offered four alternatives, with mean responses shown in Table 36 in descending order of frequency.

Table 36: METHODS OF KEEPING UP TO DATE

UP TO DATE THROUGH …	Mean	Stand.Dev.
Professional association	3.3	0.58
Professional journals	3.2	0.67
TV and the internet	2.4	0.76
Newspapers	2.1	0.66

As might be expected, professional journals and professional associations were the most common sources of up-to-date engineering information, with more popular outlets much less so. There was a wide range of responses to the TV/internet as a source, perhaps reflecting that some respondents focussed on TV while others focussed on the internet, and these media differed in usefulness.

Several items in the questionnaire invited extended responses. These are shown in the attachment to this initial report. The overall analysis of these answers follows in the next subsections.

6.7 – Personal life information and choices

When asked why they became an engineer, 132 provided usable responses which could be classified into one of nine categories. These are shown in descending order of frequency in Figure 15.

Just under half the reasons indicated by participants were innate to the respondents themselves either due to a natural inclination towards mathematics and science ('maths was a strong subject in my early life' or 'interest in science on a theoretical as well as on a practical level') or an intrinsic urge to 'invent' ('Since the age of 6 [years] I wanted to design and construct things'). Also, over one-fifth identified advice from one or more of a variety of sources (family, teacher or friend) was acted upon.

When asked how many other engineers there were in their family, 61% indicated there were none, 24% indicated one, 7% indicated two, with up to five and six engineers in the family indicated by four respondents. Slightly over 6% of respondents indicated that there are female engineers in their families.

It is important to note here that 8% of participants said that they chose engineering as a career because a scholarship was available as opposed to only 1% of current university engineering students.

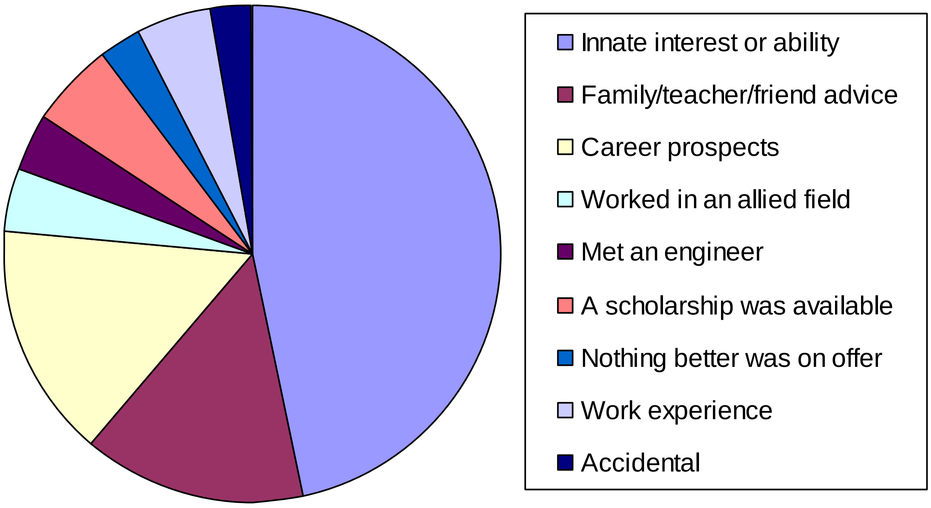


Figure 15: STATED REASONS FOR BECOMING AN ENGINEER

6.8 – Community awareness

Respondents were asked how well informed they thought the community was about aspects of engineering. The response categories offered ranged from *very well* informed (coded 4) to *not at all* informed (coded 1). The mean responses are shown in Table 37.

Table 37: COMMUNITY AWARENESS OF ENGINEERING

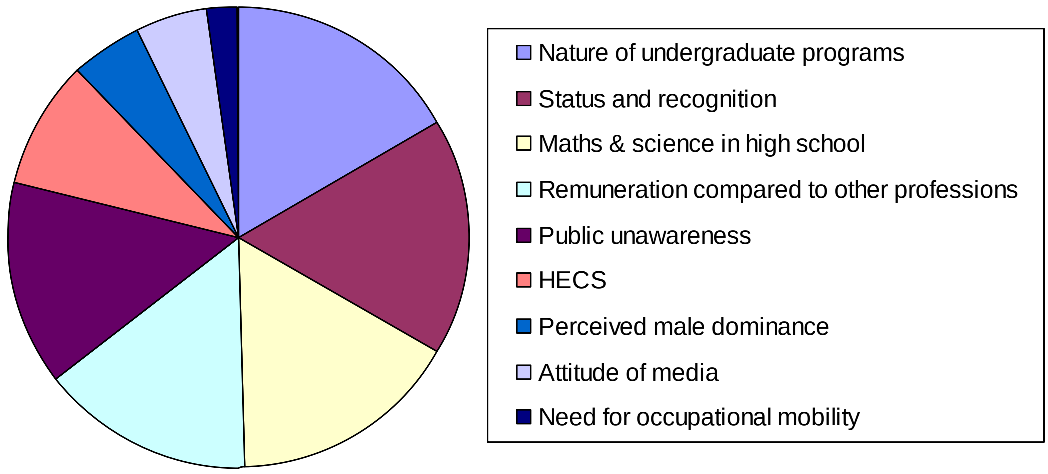
COMMUNITY IS INFORMED ABOUT…	Mean scores	Stand.Dev.
Current engineering projects of national importance	2.2	0.68
How to become an engineer	2.0	0.75
What engineers do	1.9	0.62

The engineers thought that the community were only a *little* informed about what engineers do, and slightly more informed about how to become and engineer and about current engineering projects. In all cases means were below the midpoint of the scales (2.5).

6.9 – Barriers to becoming an engineer

An open-ended question asked respondents what they saw as key barriers to becoming an engineer. Replies were classified into nine categories (shown in Figure 16) and also listed in order of descending frequency, together with the numbers and percentages for each category.

Two of the most prominent barriers related to status/rewards of engineering, together accounting for 57% of the barriers cited. Examples of this type of response range from 'lack of profile and recognition' to 'inequality in the pay between Engineers and tradespeople'. Two other reasons relate to problems with university studies (30%). The relative difficulty of mathematics and science at high school accounted for 29% of barriers. Note here that some respondents answered with more than one category to these questions and thus there is some overlap in the percentages.



*Of the 153 respondents, 33 did not answer this question

Figure 16: PERCEIVED BARRIERS TO BECOMING AN ENGINEER

6.10 – Promotion of engineering as a career

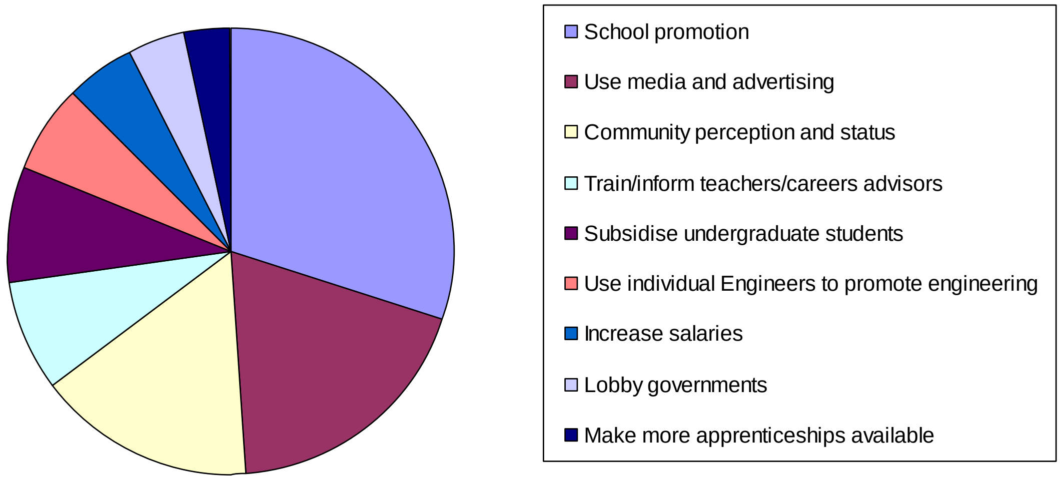
Five reasons/solutions were offered as to what is seen as a shortfall of engineers in Australia. There was overall agreement with the first four reasons/solutions, and something approaching disagreement with the fifth solution, that is skilled migration (see Table 38).

Table 38: REASONS/SOLUTIONS FOR ENGINEERING SHORTFALL

REASONS/SOLUTIONS FOR SHORTFALL	Mean scores	Stand.Dev.
Not enough students doing maths & science	3.0	0.72
Not following the success of other countries	3.0	0.70
Gender imbalance not being addressed	3.0	0.77
Assist transition from engineering trades	2.9	0.79
Skilled migration	2.3	0.72

In contrast with the above five statements that could be implied as reasons for the engineering shortfall, respondents were asked directly what they thought should be done to promote engineering as a career. Suggestions made were classified into ten categories (see Figure 17). It is notable that 120 participants provided usable responses and most provided several responses, ranging up to 5.

Two suggestions related to promoting community perceptions through the media, together accounting for over 60% of responses. A typical example of this type of response is 'CSI has done wonders for Forensics - maybe an action show with the protagonist as an engineer...'. Another two suggestions related to schools ('Educate high school students about all aspects of engineering including the diversity, pay, working conditions, opportunities for service overseas, etc.') accounted for over 60% of responses.



* Of the 153 respondents, 33 did not answer this question

Figure 17: HOW TO PROMOTE ENGINEERING AS A CAREER

When asked which of six agencies should promote engineering as a career, a total of 623 positive responses were received, an average of almost 4 responses per engineer (see Table 39). A wide range of agencies were indicated by at least half the respondents – *Engineers Australia*, governments, industry, schools and universities. The "other" reason most frequently given (10 respondents) was "Individual engineers". TV networks were also mentioned as a potential agency. One respondent claimed that there was no shortage.

Table 39: WHO SHOULD PROMOTE ENGINEERING AS A CAREER?

PROMOTION BY…	No.	%
Engineers Australia	125	79
Governments	118	74
Industry	109	69
Schools	103	65
Universities	99	62
Parents	57	36
Other	12	7
TOTAL NUMBER	623	

* Of the 153 respondents, all answered this question

6.11 – Gender imbalance

One item recognised gender imbalance in the profession, and asked what inroads have been made and whether greater effort should be made. As might be expected, comments ranged widely – nine categories have been recognised with responses recorded in Table 40. A total of 117 participants responded to this question.

More than one-third of responses recognised the need to address gender imbalance (48%), while a smaller, yet sizeable proportion (33%) thought that further effort was either not warranted or would be wasted. Some participants stated that they thought it was an important issue, however, many of them were sceptical as to how much effect any effort in this direction would have (‘If the recruitment is increased, more women will be interested, but I suspect the ratio will still be biased towards men’).

Table 40: ADDRESSING GENDER IMBALANCE

GENDER IMBALANCE RESPONSES	No.	%
Effort needed/important issue	57	48
Recognised a need to support female entry	45	38
Effort is currently being undertaken	24	20
Noted that engineering is male dominated	23	20
Women are inherently not interested	22	19
Do not know what should/can be done	11	9
Gender imbalance is not an issue	11	9
Effort has not been successful	9	8
Young males need more assistance than females	8	7
More effort will be wasted	7	6
TOTAL NUMBER	217	

* Of the 153 respondents, 117 answered this question

6.12 – Advice about engineering as a profession

Advice related to a career in engineering that would be offered to young persons was able to be grouped into nine categories – see Figure 18.

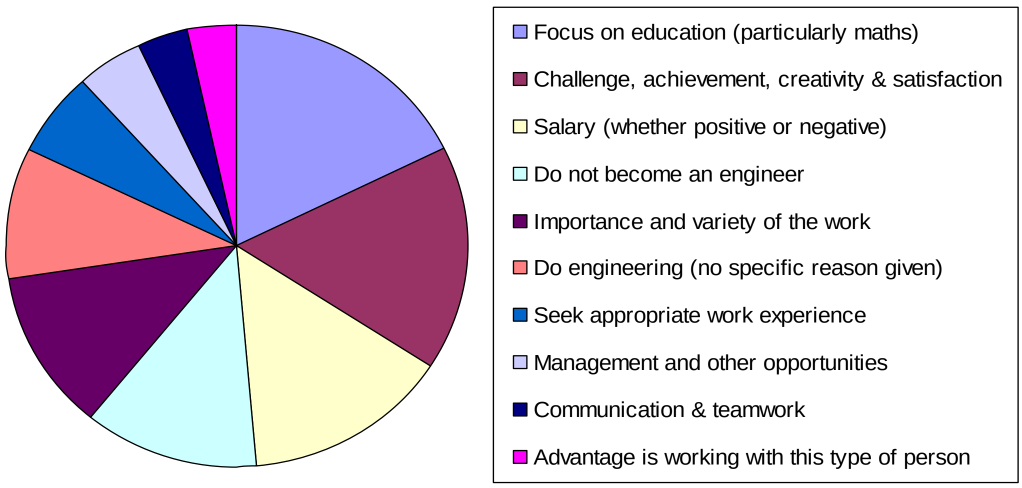


Figure 18: ADVICE ABOUT BECOMING AN ENGINEER

* Of the 153 respondents, 122 answered this question

Many of the responses were encouraging (challenge, importance, opportunities, communication, type of people you work with, and unspecific), in total 72%. Typical responses of this type were: ‘You will be working in an area where you can make a difference in the life of society, and can turn your ideas into a real product’ or ‘I would advise them that it is an excellent and challenging career with decent remuneration and plenty of opportunity for travel and new work’. A proportion (26%) gave specific advice (focus on maths and seek experience: ‘Study engineering if you enjoy maths and science, and are creative’), and a small proportion (14%) would discourage young persons from following an engineering career. The most common negative answers concerning advice to a young person about becoming an engineer recommended studying construction management or medicine, or moving to a country (like the U.S.A.) where engineers are well respected. Note here that some respondents answered across more than one category to these questions and thus there is some overlap in the percentages.

6.13 – Further Comments on the Extended Responses by Engineers

At a recent conference in the United States a group of Engineers reported that they had come to the conclusion that the perceived need for advanced mathematics was not justified. They would have some firm supporters among some of the engineers who responded to the open-ended questions in the present study, *Engineering Choices: Engineering Futures*. While it is clear from the survey that for a number 'enjoyment of maths' is a key factor in identifying those who will find engineering interesting, for some of those who elaborated on this theme, mathematics as studied at university has little place in the 'reality' of engineering. More pressing might be the need for technical, communication and other skills. The findings overall suggest tension between university subjects and professional perceptions. There is also some polarisation between inherent interest in mathematics and science and the 'need' to use mathematics and science, especially mathematics. The need to have skills in mathematics, especially at school level, was not questioned by any of the respondents.

A clear message from the extended response data (Question 25) is that a general predisposition is the strongest reason for becoming an engineer. It seems some individuals are just keen to do engineering whatever the options, and they will be attracted to engineering over all other areas. However, 'advice' would appear to be quite powerful for a larger number. In terms of a communication strategy to increase interest in engineering, parents and friends feature as the key group to target, rather than teachers and professionals. However, some respondents pointed out the potency of industry-sponsored scholarships as a possible solution to the enrolment shortage in engineering degrees.

Those who responded to the question on what are the key 'barriers' to becoming an engineer (Question 28) generally used terms and forms of emphasis that showed how intensely they felt. It would be safe to say this question tapped deeply into concerns. The concerns are multiple, but centre on three core themes: lack of status (both professional and remunerative), lack of information (contributing to community ignorance about engineering and lack of profile), and academic issues, primarily at tertiary level, which ranged from course difficulty through to cost of undertaking a degree. Some deep disappointment and frustration emerged through responses to this question.

Question 31 about what agencies or groups should promote engineering drew a significant number and variety of responses, but they did tend to coalesce around two forms of suggestion, image promotion usually through advertising, for the general population and young people, and secondly educational (usually school-level) solutions that increase exposure to information. Image and professional identity feature in other responses as well.

When respondents were asked what they would advise if someone wanted to enter engineering (Question 33), a handful were negative. But the value in the responses, and indeed the intent of the question, was to see how respondents would describe engineering, a pertinent exercise given the strong response to earlier questions that information about engineering is sparse. The results are detailed in Figure 19 below (and include some responses to the general invitation to add comments at the end of the questionnaire). The two columns represent job and individual characteristics with the bottom section of the table covering comments with a negative emphasis.

JOB CHARACTERISTICS	INDIVIDUAL CHARACTERISTICS
Good people to work with Very exciting projects Make a difference/projects of benefit Make real products/see outcomes Travel Most integrative in that it can lead to creation of huge projects involving lots of people Requires communication skills Requires technical skills Requires maths and science Solve problems Dynamic, not boring Flexibility in thinking	Leadership opportunities Management opportunities Positive career prospects Be creative OK remuneration Variety Challenge Interesting /rewarding/accomplishing Exciting/ fulfilling Valuable Contribution Job satisfaction Meet people Ongoing learning
High responsibility Workload high Tough to get into, academic requirements Takes quite some time to get good at	Busy with minutiae Poor remuneration/exploitation Need to sell yourself Not for loners Poor office accommodation

Figure 19: DESCRIPTIONS OF ENGINEERING

One thing that strikes the reader is the generic nature of the characteristics except for the term ‘integrative’. Most characteristics could apply to any occupation and not only professional ones. This must give some pause regarding communication of what engineers do. Are the respondents deliberately trying to be general as opposed to ‘mechanical’, or just to be brief? One can only note with interest the lack of reference to most of the sub-categories of engineering, and it was learned from earlier questions that mechanical or building stereotypes were connected with a non-professional trades image. In these lists the engineering, *per se*, is invisible. However, a number of responses about improving image included strategies for providing illustrations of engineering achievement.

It is important to note that 8% of participants said that they chose engineering as a career because a scholarship was available as opposed to only 1% of current university students (Question 25). The fact that 23% of the university students suggested that subsidising HECS fees would be a way to promote engineering as a career and 16% of professional engineers thought that HECS fees were a key barrier to becoming an engineer (in response to Question 28) could together imply that the current university HECS system may be one of the reasons behind the current shortfall of engineers.

6.14 – Conclusions

This section summarises the most relevant findings of the professional engineers’ survey.

- The majority of the sample held a bachelor degree (70%), 19% held a higher degree and 11% had ‘other’ qualifications.
- Overall, engineers’ perceptions of mathematics (interest, excitement, usefulness and importance) would seem to have declined slightly between secondary school and now, while perceptions of the usefulness of English have increased.
- Both mathematics and physics were very clearly the most liked subjects by engineers when they were in secondary school. English was by far the least liked subject.

- Older engineers, that is, those who graduated before 1980, were more inclined to agree with stereotypes about the engineering profession than young engineers, that is, those who had graduated since 2000.
- All participants agreed or strongly agreed with the question “Men can become excellent engineers”, whereas the same statement about women also produced two ‘Disagrees’ and one ‘Strongly disagree’.
- Professional journals and professional associations were the most common sources of up-to-date engineering information, with more popular outlets (TV and the internet) much less used.
- Equally as university students, professional engineers indicated that their reasons for becoming engineers were innate to themselves, either owing to a natural inclination towards mathematics and science (‘maths was a strong subject in my early life’ or ‘interest in science on a theoretical as well as on a practical level’) or an intrinsic urge to ‘invent’ (‘Since the age of 6 [years] I wanted to design and construct things’). It is important to note here that 8% of participants said that they chose engineering as a career because a scholarship was available as opposed to only 1% of current university students.
- Two of the most prominent barriers to becoming an engineer stated by the professional cohort related to status/rewards of engineering, together accounting for 57% of the barriers cited. Examples of this type of response range from ‘lack of profile and recognition’ to ‘inequality in the pay between Engineers and tradespeople’.
- The two most popular suggestions for promoting engineering related to promoting community perceptions through the media, together accounting for over 60% of responses. A typical example of this type of responses is ’CSI has done wonders for Forensics - maybe an action show with the protagonist as an engineer...’.
- Almost half the respondents (48%) recognised the need to address gender imbalance in the engineering profession, while a smaller, yet sizeable proportion (33%) thought that further effort was either not warranted or would be wasted.

CHAPTER 7 – Teachers

In addition to the demographic information already reported in Chapter 2, information on the scales provided in subsection 2.4 was collected. All teacher information is now described. There were two groups of teachers identified as having particular relevance for this study - science teachers and careers advisors. Small samples of both groups were obtained.

7.1 – Teaching qualifications

Teachers' qualifications consisted of degrees and diplomas/certificates, with degrees being shown in Table 41. The majority of the sample of science teachers held a bachelor degree in science (77%), 10% held a bachelor degree in education and two teachers (7%) held engineering degrees. Most careers advisors (75%) had an education degree, with only 12% having a science degree. Almost 80% of the science teachers held a Diploma of Education and 48% of careers advisors had a graduate diploma in Careers Advising.

Table 41: TEACHER DEGREE QUALIFICATIONS

Degree	Science Teachers	Careers Advisors
B. Education	3	18
B. Science	23	3
B. Social Science	0	1
B. Arts	1	2
B. Engineering	2	0
Total	30	24

When asked what subject they majored in, 27% of careers advisors selected history and geography, 18% industrial arts and 13% majored in science. Science Teachers majored mostly in either Biology or Chemistry (60% combined). Other major areas for science teachers were physics (16% of participants) and mathematics (10%).

7.2 – School students' interest in Mathematics/Science/English

Respondents from both cohorts were asked to indicate what they thought their students' attitudes were towards different aspects of science, mathematics, computing and English at school. Their perceptions of student interest in, excitement with, and usefulness and importance of these subjects were requested, with responses over four categories ranging from *Strongly disagree* (coded as 1) to *Strongly agree* (coded 4). On these scales codes of less than 2.5 indicated negative perceptions, 2.5 indicated neither positive nor negative perceptions, and codes greater than 2.5 indicated positive perceptions.

As can be seen from the first two columns of results in Table 42, teachers thought that mathematics and science were the subjects viewed most favourably by their students. The science teachers thought that English was viewed as marginally negative, although the careers Advisors did not share this opinion. The other two scales, also shown in Table 42, measured teacher perceptions of student interest/excitement and usefulness/importance of these subjects collectively, and teachers responded positively, although barely so for usefulness/importance. The teacher responses, on behalf of students, can be compared with the actual student responses to the same scales, shown in the last column of the table.

Table 42: MEAN SCORES FOR PERCEPTION SCALES COMPARED

SCALE	Science Teachers	Careers Advisors	Secondary Students
Science overall	2.8	2.9	2.8
Mathematics overall	2.7	2.9	2.7
Computing overall	2.6	2.9	2.5
Interest/excitement	2.9	3.0	2.5
Useful/important	2.6	2.9	2.9
English (item)	2.4	2.8	3.0

Overall, careers advisors' perceptions of their students' attitude towards all enabling sciences, individually and collectively, was very positive, whereas science teachers seem to have a less optimistic perspective on their students' liking for some of these subjects. For comparison purposes, in the final column of Table 42 the actual perceptions of the sample of secondary school students undertaking at least one science subject has been included. The teachers' perceptions were, in the main, reasonably accurate, but there were two notable exceptions – interest/excitement was generally lower than both cohorts of teachers suggested, and student liking for English was much higher than was perceived by the science teachers.

7.3 – School students' difficulty understanding subjects

Seven science subjects plus history were listed with teachers being asked to state how their students would rank them in order of difficulty. History was included to provide a basis of comparison with the science subjects. Physics was ranked as the most difficult by almost two-thirds of respondents (65%) and design and technology was ranked as the least difficult (45%). Table 43 indicates the percentages of respondents selecting each of the eight subjects as most difficult and least difficult with a comparison for student responses shown in the final columns. On average, students and their teachers agreed that physics was the hardest subject, and this was particularly true for teachers where a majority (65%) considered physics to be the most difficult subject. Physics was followed by mathematics and chemistry for both teachers and secondary students, with English and biology following behind. Both groups agreed that design and technology was the easiest subject, and computing the second easiest.

Table 43: RELATIVE DIFFICULTY OF EIGHT SECONDARY SCHOOL SUBJECTS

SUBJECTS	Teacher perceptions about students %		Student perceptions %	
	Most difficult	Least difficult	Most difficult	Least difficult
Physics	65	2	30	3
Mathematics	15	0	18	10
Chemistry	7	0	19	2
English	7	6	13	13
Biology	2	11	6	7
Computing	2	18	4	23
Design & Technology	2	45	4	33
History	0	18	6	9
TOTAL	100	100	100	100

7.4 – Perceptions of engineering

The teachers were asked a series of 19 questions about their perceptions of engineering in personal attitudes (such as 'engineers make people lives' better' and 'engineering is a highly respected profession') and popular stereotypes (such as 'engineers spend a lot of time working with machines' or 'you need to be physically strong to become an engineer'). The main purpose of including these items in this questionnaire was to enable comparisons of these perceptions with professional engineers' perceptions of the same engineering-related constructs. Scores on the two scales are shown in Table 44 where most agreement is indicated by a rating of 4, and most disagreement by a rating of 1, with a neutral perception for the scales being 2.5.

Table 44: PERCEPTIONS OF ENGINEERING

SCALES	Mean scores Teachers	Mean scores Engineers
Personal perceptions of engineering	2.9	3.1
Engineering stereotypes held	2.4	2.3

Teachers had fairly positive perceptions of engineering, but, not surprisingly, professional engineers had an even more positive view of the profession. For the second scale, 'Engineering stereotypes held', mean scores indicated slight disagreement in both cases, with professional engineers having slightly less misconceptions and stereotypes about the engineering profession than teachers.

There were no differences in either scale according to teacher gender (*t = .003, p = 0.998)*, but there was a slight difference by teacher experience. Teachers who had been teaching for more that 10 years, agreed with stereotypes (mean = *2.7*) more than younger teachers that is, those who have been teachers from 1 to 9 years (mean = *2.4*) (*t = 2.19, p = 0.003*). There is also a difference in the stereotypes scale when looking at the division by degree qualification. Teachers or careers advisors who had a degree in science (be it Chemistry, Physics or Biology) were less inclined to hold stereotypes (mean = *2.3*) than their Bachelor of Education counterparts (*mean = 2.5*) (*t = 2.85, p = 0.007*). However, the latter group had a more positive view of the engineering profession (*t = 1.75, p = 0.086*).

7.5 – Engineering gender-related perceptions

Four questions sought agreement/disagreement with statements that males and females can become excellent engineers and levels of interest in engineering as a profession. The same 4-point agree/disagree scale was used. There was strong agreement concerning males and females becoming excellent engineers, with no respondent who disagreed with either statement. Overall, respondents also agreed with the statements about male and female interest in engineering, although less strongly, and small proportions disagreed with both statements. Table 45 shows the mean responses to these statements together with the standard deviations.

It is perhaps of interest to note that agreements with the items concerning men were slightly stronger than the same items concerning women for both excellence and interest. It is notable that the standard deviation was quite high compared with other scales, indicating a greater diversity of opinion on these items. There were no significant differences between the male and female teacher respondents for these questions.

Table 45: PERCEPTIONS RELATED TO GENDER

STATEMENTS	Teacher		Engineer Mean
	Mean	Stand.Dev.	
Women can become excellent engineers	3.3	0.68	3.6
Men can become excellent engineers	3.4	0.60	3.6
Engineering is interesting for men	3.2	0.78	3.4
Engineering is interesting for women	3.0	0.90	3.2

When comparing the responses of teachers with those of the professional engineers, it was found that the latter cohort has a much better perception of how women can excel in the engineering profession than teachers do. Engineers also consider both men and women to have a greater interest in on engineering than teachers do.

7.6 – Awareness

Respondents were asked how well informed they thought the community was about three aspects of engineering. The response categories offered ranged from *very well* informed (coded 4) to *not at all* informed (coded 1). The mean responses are shown in Table 46.

Teachers thought that the community generally and parents were only slightly better than a *little* informed (coded 2) about all three scales. In all cases means were below the midpoint of the scales (2.5). The engineers generally agreed with the teachers, indicating that both parents and the community were barely *a little* informed, exhibiting even lower mean scores than the teachers for two of the three items.

Table 46: COMMUNITY AWARENESS OF ENGINEERING

How well informed do you think…	Teacher Means	Stand.Dev.	Engineer Means
the community is about current engineering projects of national importance	2.2	0.64	2.2
parents of your students are about opportunities for their children to study an engineering degree	2.2	0.50	2.0
the community is about what engineers do	2.1	0.50	1.9

Both cohorts were also asked to report about their knowledge of different engineering fields. The question gave a list of areas within engineering – Civil, Electrical, Mechanical, Chemical, Environmental, Aerospace and Biomedical Engineering – and asked teachers to say how much they knew about what each of them involved. The response categories offered were *a lot* (coded 4), *a little* (coded 3), *some* (coded 2), and *nothing* (coded 1).

The mean of scores for science teachers was 2.5 with Environmental, Aerospace and Biomedical ranking lower than the others. The mean scores for careers advisors was 2.9, with as many as 5 out of 24 respondents acknowledging to knowing nothing about Aerospace or Biomedical Engineering.

7.7 – Outreach programs

Both cohorts were asked about existing outreach programs created to promote Science and Engineering to secondary school students. They were asked if their schools had participated in programs which were divided into the following categories: Science Shows (e.g. Questacon, Smart program), Programs for Gifted and Talented Students, Science Workshops (e.g. CSIRO, Zoomobile), Competitions (Science and Engineering Challenge, Re-engineering Australia). Table 47 shows the responses for the combined two cohorts.

Table 47: OUTREACH PROGRAMS

TYPE OF PROGRAM	Yes (%)
Science Show	37
Programs for Gifted and Talented Students	44
Science Workshops	52
Competitions and Challenges	68

Perhaps owing to the extensive influence of the Science and Engineering Challenge in the Hunter region, the number of careers advisors whose school had participated in Competitions and Challenges was almost 80%, substantially higher than the 60% of science teachers who had participated in that category of programs.

Science teachers and careers advisors were also asked if they would welcome more of these programs in their schools, and whether they thought it would be beneficial. Although participants agreed that the programs are effective (mean = 3.2, std = 0.60), only 46% would like a greater implementation of such programs at their schools.

7.8 – Promotion of Engineering to Secondary Students

Two open-ended questions were asked of teachers regarding the promotion of tertiary studies in engineering to their students. A total of 44 out of the 54 participants responded to the questions, providing 91 comments in total. The first question asked teachers “What would most help students become interested in engineering”. As might be expected, comments ranged widely – ten categories have been recognised with responses recorded in Table 7.8. Proportions in both Tables 48 and 49 are given as a percentage of respondents making each suggestion.

Clearly direct exposure to engineering, whether to the job or to a person was the most common suggestion for increasing student interest in engineering, accounting together for one half (51%) of all responses.

Table 48: WHAT WOULD INCREASE STUDENTS' INTEREST IN ENGINEERING?

SUGGESTIONS	No.	%
Exposure to engineering jobs	23	42
Meeting engineers	20	37
Community profile of engineers (salary!)	12	22
Visits from university lecturers	9	17
Media and advertising	6	11
Help with subject decision early	5	9
Good teachers	5	9
Early intervention	4	7
Promotional material	4	7
Work experience	3	6

The second question, "How would you give encouragement to a bright student to become an engineer?", also had a variety of answers and the 86 responses have been recoded into the 11 categories shown in Table 49. Again exposure to engineering and engineers were most frequently given, providing the first three categories and accounting for slightly more than half (53%) of all responses.

Table 49: HOW TO ENCOURAGE ENGINEERING AS A CAREER

METHODS OF PROMOTING ENGINEERING	No.	%
Exposure to engineering jobs (including status)	23	52
Talks by engineers	12	27
Work experience	11	25
University open days	11	25
Maths/science encouragement	8	18
Personal interview	6	11
Competitions and challenges	6	13
Information about scholarships	5	11
Inform parents	2	5
Engineering VET courses	1	2
I wouldn't encourage my students to do engineering	1	2

7.9 – Conclusions

Although based on reasonably small cohorts of science teachers and careers advisors, a number of useful results were obtained from this section of the overall study.

- The teachers had a wide range of experience, with a preponderance in the sample of those with more than 10 years, particularly if their role was now careers advisor. In general, teaching experience was not linked to perceptions about engineering or school subjects. However, teachers who were careers advisors and who had greater teaching experience were more inclined to agree that women can become excellent engineers than the less-experienced science teachers.
- The teachers mainly had one of two basic qualifications. The science teachers tended to have a science degree and the careers advisors tended to have an education degree. There were few differences in the perceptions of these two groups of teachers. However, the teachers with a science degree were less inclined to hold engineering stereotypes than teachers with an education degree. And the science degree group thought that the community was less well informed about the

importance of large engineering projects of national importance than the education degree group, the latter made up principally of the careers advisors.

- In general, the careers advisors had more positive perceptions of their students' interests in school subjects than the science teachers. Given that the science teachers would be in more constant direct teaching contact with students, perhaps their perceptions were more realistic for most subjects of interest in this study. This would seem to be reinforced by the student responses – although not for English.
- In general, the teachers did not have an accurate view of the relative difficulty levels of school subjects for students, when these were compared with the responses of the secondary science students.
- Overall, the teachers differed little from engineers in perceptions of engineering, although they had less positive views of women in engineering.
- The teachers had similar views to engineers about community perceptions of engineering, if a little less negative than the engineers.
- On average, both teachers and careers advisors acknowledged to know somewhere between "a little" and "some" about different engineering areas of specialisation. In the case of environmental engineering (one of the most popular degrees amongst engineering students) this knowledge was lower than the average.
- The exposure of the teachers' schools to at least one kind of engineering outreach program was reasonably high, and perhaps higher than the national average.
- Although perhaps not surprising, the two cohorts of teachers focussed on exposure to engineering and to engineers as the most likely to be productive in interesting their students in engineering and encouraging them towards that possible career choice.

CHAPTER 8 – Combined Views of the School and University Students and Professional Engineers

8.1 - Introduction

This chapter extends some of the results reported in chapters 3, 4, 5 and 6 for four of the 5 cohorts reported. Here we specifically present a comparison of views about science, mathematics, computing and engineering of students in primary school (Year 5) and secondary school (Year 11), and university Engineering students in their first and final years.

This project was designed so that direct comparisons between the samples would be possible in a number of areas by including some identical questions in the school and university questionnaires. The relevant areas are shown in Table 50.

Table 50: ATTITUDE AND PERCEPTION SCALES

Attitudinal Scales	Interest in science
	Interest in maths
	Interest in computing
	Liking of engineering-type activities
Perception of Engineering Scales	Positive personal perceptions of engineering
	Holding of engineering stereotypes
	Geekiness index
	Equality in gender

8.2 – Subjects and activities: likes and dislikes

The mean scores in each of the attitudes and perceptions listed above are shown first in Table 51 for each sample. There will be some differences between the means reported here and the mean scores reported in earlier chapters because not all items in every scale were used for all samples. Only the common items are used in this chapter. It should be recalled that the possible scale scores range from 1 to 4, with a score of 2.5 being neutral, ie, representing neither agreement nor disagreement.

When interest in science and mathematics within cohorts was compared, using paired-sample t-tests, there were differences at the 5% significance level for the primary, secondary and final year engineering cohorts. For primary, mathematics was more interesting than science, but the reverse was the case for the secondary and university student cohorts. It should be noted that the primary students in Year 5 would have had minimal exposure to science as a school subject, so perhaps felt more comfortable with mathematics.

Between-cohort comparisons

Each comparison of scale means here used an ANOVA and a Scheffe post-hoc test to determine differences between specific groups at the 5% significance level.

In considering differences between the samples, it is worth noting that the samples are progressively specialised in that the Year 5 primary students are not at all self-selected, whereas the Year 11 secondary students are doing a science subject, presumably by choice.

In most cases these students would have elected to do science because they like it, and/or because they see it as necessary or at least important for their further post-school studies and consequently their career. The engineering students have gone much further in self-selection, having chosen to study for a career where the course relies heavily on mathematics and science.

Table 51: MEAN SCORES FOR THE QUESTIONNAIRE SCALES

SCALE*	SCHOOL STUD.		UNI ENGIN STUD.	
	Primary	Second	1st year	4th year
Interest in science	2.74	2.76	3.26	3.25
Interest in mathematics	2.80	2.70	3.24	3.20
Interest in computing	3.18	2.55	2.88	2.90
Like engineering-type activities	2.96	2.83	3.28	3.32
+ personal perceptions of engineering	2.94	3.03	3.31	3.27
Hold engineering stereotypes	2.82	2.60	2.19	1.95
Geekiness index	1.74	1.92	2.02	2.17
Equality in gender	3.11	3.10	3.28	3.53
No. OF STUDENTS	555	493	1111	424

* **Reading horizontally, mean scores that do not differ are in the same colour. The lower means are shown in red, the higher in blue, and green is used for all the medium-level scores, except in one case (Hold engineering stereotypes) where all four sample means differ significantly.**

8.3 - The scale mean scores and proportions of negative responses

It should first be noted that none of the mean scores for any of the positive scales for interest in science, mathematics, computing and engineering activities was less than 2.5, ie, all were in the positive range. This indicates that, on average, there was an overall agreement, at some level, that the subject areas listed were interesting and perceived positively.

In the cases of the engineering stereotypes scale and the geekiness index, a higher score indicates a stronger holding of stereotypes, ie, an undesirable outcome, so scores lower than 2.5 are desirable and this was generally the case. In fact, all student groups had a mean of less than 2.5 for the geekiness index, indicating a quite strong disagreement with the proposition that those who do science and engineering are geeks.

Table 52: PERCENTAGES OF STUDENTS WITH NEGATIVE RESPONSES TO SCALES FROM THE QUESTIONNAIRE

SCALE	SCHOOL STUD.		UNIV ENGIN STUD.	
	Primary %	Second %	1st year %	4th year %
Interest in science	23	19	5	6
Interest in mathematics	22	25	6	8
Interest in computing	12	**46**	19	17
Like engineering-type activities	16	**22**	3	3
+ personal perceptions of engineering	10	6	2	3
Hold engineering stereotypes	**87**	**62**	16	5
Geekiness index	11	15	16	**25**
Equality in gender	8	3	5	0

Although the scale mean scores indicate generally positive responses from all four samples of students, there were minorities of students who had negative views about the subjects listed and negative general perceptions about engineering. The proportions of these students are shown in Table 52 by scale for each sample. Percentages that are particularly notable are shown in red.

8.4 – Summaries of individual scale results

Interest in science

As might be expected, both groups of school students had the lowest mean scores, although marginally positive, for interest in science. Many of the primary students would have had little exposure to science, so one can understand that their generally positive responses would not be strong. At the secondary level, a proportion of students are less likely to strongly support positive statements about school subjects in any circumstance, reducing the overall mean score. The university students in both year levels gave higher and uniformly positive responses.

The proportions of students who disagreed that science was interesting were about four times higher for the two samples of school students (approximately 20%) than for the university students (approximately 5%). Clearly there are issues here that should be addressed.

Interest in mathematics

The secondary students had the lowest mean score for interest in mathematics, although it was marginally positive, and the mean for the primary students was significantly higher. The means for both samples of university students were significantly higher again and did not differ from each other.

The proportions of students who disagreed that mathematics was interesting were similar to the pattern but slightly higher than those for science. A proportion approaching 25% of the school students, particularly secondary students and 6-8% of the university students did not find mathematics interesting. Perhaps it is surprising that the Year 11 secondary sample had chosen to do a science course, but apparently did not like mathematics.

Interest in computing

The secondary student sample again had the lowest mean score (and only very slightly positive), but the primary students had the highest mean. Between these two groups were the university students which did not differ between year levels. With the exception of the primary students, interest in computing was lower than for science and mathematics.

The proportions of Year 5 primary students and both groups of university students who disagreed that computing was interesting were all less than 20%. In contrast, the fact that almost half the Year 11 students did not find computing interesting is a matter of some concern, perhaps requiring further investigation of the nature of computing experiences in the secondary school.

Preferred Subjects

Chapter 3 presented the most liked subjects at a primary level. The other three cohorts' choices are comparable and Figure 20 shows which proportion of secondary/university students and professional engineers preferred them. Figure 21 shows which subjects were the least liked across the three cohorts.

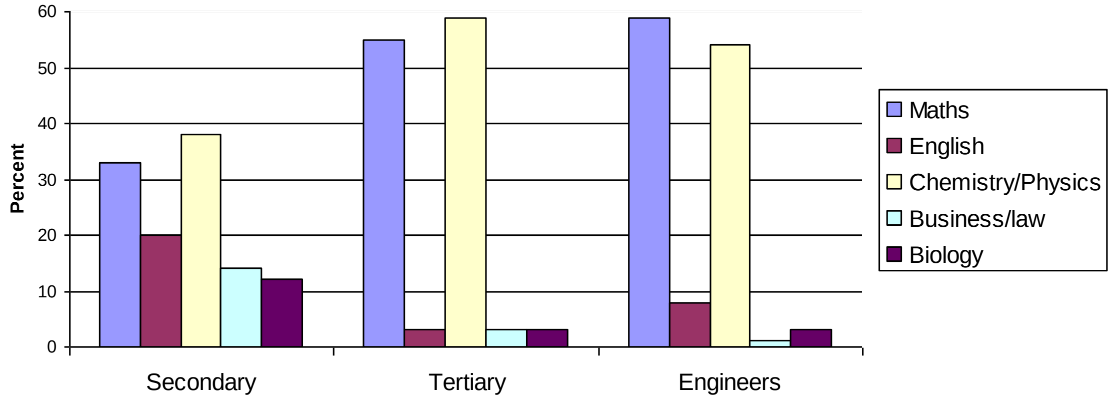


Figure 20: MOST LIKED SUBJECTS (SECONDARY/TERTIARY/ENGINEERS)

It is notable here that Mathematics, Chemistry and Physics are a clear preference amongst engineering students and professional engineers, whereas the secondary students rank them also high, but not as high as the other two cohorts. English ranks much higher as a preferred subject with secondary students (20%) than it does amongst university students (3%).

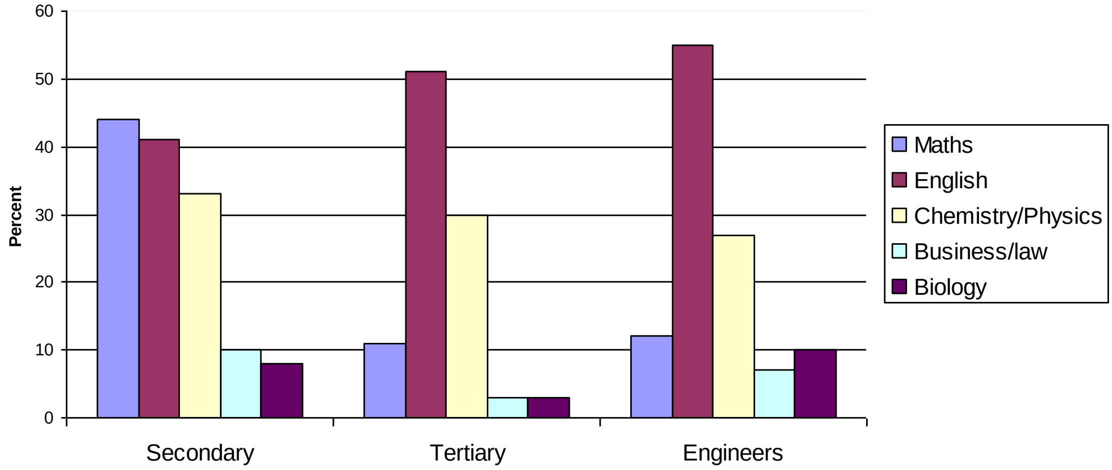


Figure 21: LEAST LIKED SUBJECTS (SECONDARY/TERTIARY/ENGINEERS)

The proportion of engineering students who chose English as their least preferred subject when they were at school was relatively high (51 and 54% respectively) compared to the proportion of secondary students who chose English as their least preferred subject at school (42%). Mathematics ranked high as a non-favourite in secondary school (44%), but only a small proportion of engineering students and engineers (11 and 12% respectively) chose it as a least liked subject in their recollection of school subject preference.

Like engineering-type activities

Although all groups had a positive mean score for this scale, again the secondary students had the lowest mean score, with the primary students significantly higher. The university student scores were significantly higher, and did not differ from each other. The scores were similar to those for interest in science and mathematics, indicating moderate agreement.

The proportions of students who did not like engineering-type activities (see Table 8.2) were of the order of 20% for the two school samples, and, understandably, quite small for the samples of university engineering students. It is useful to follow-up on some of the individual items forming this scale to investigate specific areas which might be pursued in fostering positive perceptions of engineering as a career at school.

Like designing things. The primary students responded very favourably to this item, and this was true even for students who, overall, responded negatively to this scale. The mean item score was 3.4 for the total, primary group, and 3.2 for the generally-negative sub-group. The total secondary group also responded favourably to this item (mean = 3.0), but the secondary students who were negative overall had a mean for the item not significantly different from the neutral point of 2.5. Certainly at the primary level, and to a lesser extent at the secondary level, an increased emphasis on designing things may well be successful in encouraging students towards engineering-type interests, and possible careers in that area.

Like creating and constructing things. The primary and secondary students responded favourably overall to this item, although not as positively as for the designing item (above). The primary and secondary mean item scores were 3.3 and 3.0 respectively. The students who were generally negative on this scale were also positive but much less so (the primary and secondary means were 2.9 and 2.8 respectively. This activity is clearly similar to the preceding item about designing things and could reasonably be linked to it.

Like working as part of a team. Both the primary and secondary students responded favourably to this item, and this was true even of the generally-negative students at both levels (all group and sub-group item means were greater than 3.0). Working in groups (teams) is something that primary students normally experience regularly in class, perhaps less so for secondary students. Combining working in teams designing, creating and constructing things have the potential to facilitate learning and promote student interest.

Positive personal perceptions of engineering

The primary students had the lowest perceptions of engineering – although generally quite favourable. It can be assumed that most of these students knew little directly about engineering. The secondary students had slightly more favourable perceptions, which were significantly different from the primary, and the engineering students again had the most favourable perceptions, with the first year students marginally (but not significantly) higher than the fourth year students.

There were generally lower proportions of all samples who did not have positive personal perceptions of engineering (between 6 and 10% for the primary and secondary school samples were negative overall, see Table 8.2). It is again useful to consider some individual items concerned with school student perceptions of engineers and engineering.

Engineers make people's lives better. Both the overall groups of primary and secondary students agreed with this item (mean item scores were both 3.1). The generally negative sub-groups were neutral rather than negative towards this item at both school levels.

Engineers have interesting jobs. Again the overall groups at both school levels agreed with this item (mean item scores were 3.0 and 2.9). But in this case both the primary and secondary negative sub-groups responded negatively to the item (mean item scores were 2.1 and 2.2). It would seem that greater exposure to the range of engineering jobs and their relationships to socially-desirable tasks, would be useful simply by providing additional information, which would seem particularly necessary for the negative sub-groups of students, A complementary approach is to have engineers visit classrooms from time to time to talk about their work in a positive way.

Engineers spend a lot of time working with people. The overall student groups at both school levels responded close to the neutral position (the means were between 2.5 and 3.0). The generally-negative groups responded also slightly negatively to this item (both means were almost 2.3). Again an exposure to engineering jobs showing teams working on specific, interesting tasks would address the apparent misconception that engineering work generally is isolated from others.

Holding of engineering stereotypes

All student groups differed from each of the others with the direction of the difference as would be expected – engineering stereotypes being held less strongly with increasing age and experience. Of particular interest is the significant difference indicating a lessening of stereotyping between the first and fourth year engineering students.

Engineering stereotypes are particularly strong for both school samples. Given that the questionnaires were administered very early in the academic year before the year 1 university students had experienced any 'engineering', it is perhaps not surprising that stereotypes are also much more pervasive among the year 1 compared with the year 4 engineering students.

The following figure (Figure 22) shows the means of the last three scales for the four cohorts, including the professional engineers.

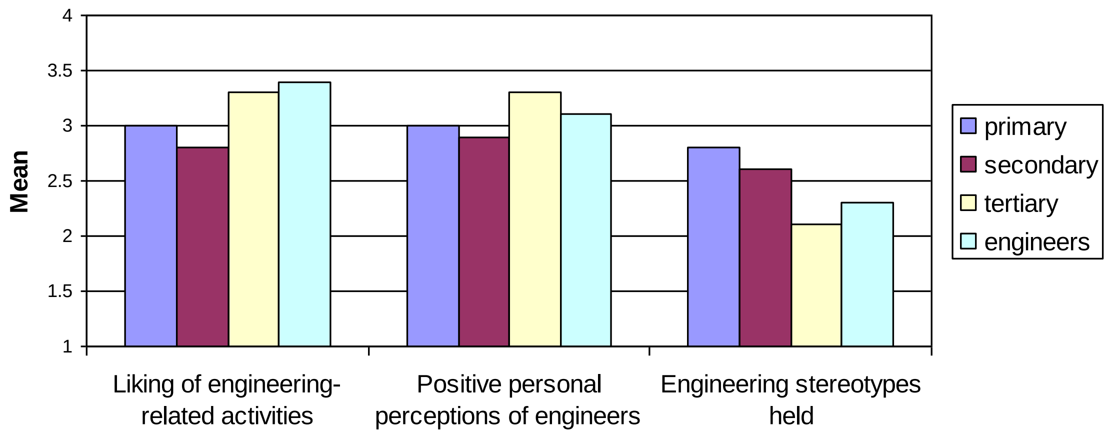


Figure 22: MEANS OF RESULTS IN ENGINEERING SCALES

Geekiness index

This index was formed as the mean of two questionnaire items, one about science (*'People who do science are geeks'*) and a similar item for engineering. The primary students had the lowest mean score for this item. The secondary and year 1 university students had mean scores that were significantly higher than the primary, and did not differ significantly from each other. The fourth year university student sample had (significantly) the highest mean score, although this score still indicated a tendency to disagree that those who do science and engineering were geeks.

It is perhaps of interest to note the proportions of students in each group who did agree that those who do science and engineering (including themselves) were geeks – the range rose progressively across the samples from about one tenth of Year 5 primary students, to a quarter of year 4 engineering students. Perhaps *geekiness* has become a badge of honour among the more mature and experienced engineering students.

Equality in gender
All groups saw gender equality as desirable, with the primary and secondary students supportive, and not significantly different from each other. The first year engineering students had a significantly higher agreement than the school students, and the fourth year students had a further significantly higher agreement than the first year students.

The proportions of students who did not support equality in gender were quite small, reducing to less than half a percent for the year 4 engineering sample. In this regard, it is of interest to note that both university student samples were predominantly male at approximately 80%.

The following figure (Figure 22) shows the means of the Equality in Gender Scale for the four questions in the scale for the four cohorts, including the professional engineers.

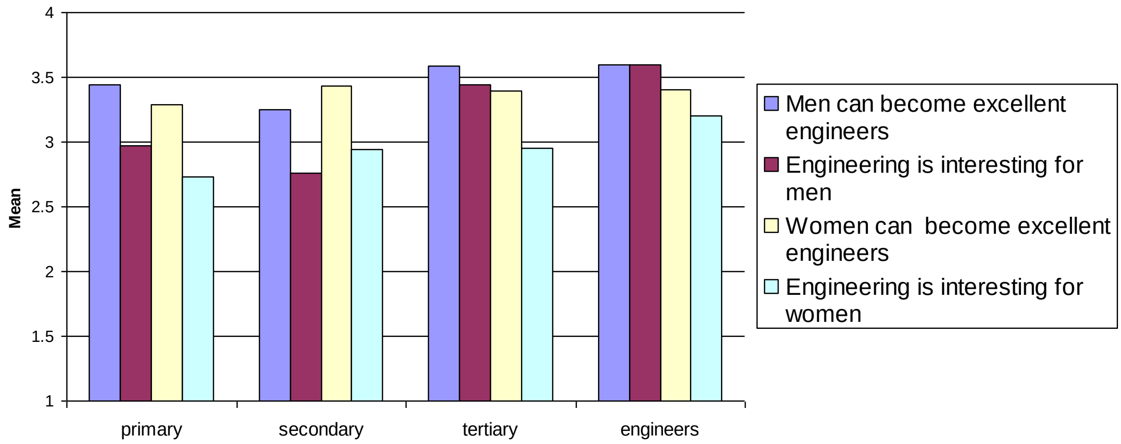


Figure 23: GENDER IN ENGINEERING

8.5 - Comparisons on scales by gender and location

When compared in terms of gender (using independent-sample t-tests, at the 5% significance level), the difference in attitudes towards science, mathematics and computing was statistically significant for primary students. Boys always showed more interest than girls in all three scales at this stage of schooling. Engineers and secondary students did not show difference according to gender in these scales and

Primary school male students' positive personal perceptions of engineers were higher than those of female students. It was also statistically significant that year 4 engineering female students had a better perception of the engineering profession than their male counterparts.

None of the cohorts showed any difference in their attitudes towards the sciences when compared by location.

8.6 - Students who were consistently negative

There were small proportions of students in each of the four samples who were quite consistently negative about science, mathematics, computing and engineering activities. These students were defined as those who had responded negatively (having mean scores less then 2.5) on at least three of the four scales. These negative students constituted small proportions of the year 1 (3%) and year 4 (2%) university samples, but higher proportions of the Year 5 primary (7%) and Year 11 secondary (11%) school samples.

The 11% of the Year 11 secondary sample who were negative is of particular interest for two reasons – this is a sample that has by far the highest proportion of consistently negative students in the subject areas of interest, and the sample consists of students who have chosen to do a science subject. Despite their enrolment in a science subject in the senior secondary school, it is likely that the possibility of interesting these students in an engineering career would be extremely low. Consequently it might be argued that these students should not be the major focus of attempts to improve interest levels and that greater attention should be afforded to those who have responded positively overall, but with some negative responses. The details of the negative components can be investigated with a view to specific remedial action. At the same time it should be ensured that those who have responded positively throughout, although perhaps requiring less attention, are not overlooked.

8.7 – Conclusions

The major findings from these cohort comparisons are summarised below.

- The importance of mathematics for an engineering career and the indication that primary students' interest in mathematics was generally quite high, jointly suggest that this is an interest that should be particularly fostered, when possible.
- There were significant components of all samples who did not have an interest in subjects, and this was greatest for secondary school sample. Interest in secondary mathematics was a particular concern, even when allowance is made for late-teenage angst.
- School location was not related to interest in school subjects or any of the other measures taken.
- For the two scales concerned with liking engineering activities and having positive personal perceptions of engineering, increasing school experiences involving designing and creating things through group (team) work was recommended to improve school students' knowledge and understanding of what engineering can involve.
- When attention was focussed on those school students who had responded negatively to some aspects of the survey, but not consistently so, a range of information about the nature of engineering work was suggested as important to be delivered to some groups of school students. It is with these negative groups that specific initiatives would be most likely to bear fruit.

PART 2 – DATA INTERPRETATION, CONCLUSIONS AND RECOMMENDATIONS

Part 2 of this report synthesises the findings of current academic literature and the surveys analysed in the previous chapters and makes specific recommendations for action.

The outcomes and recommendations of the study are presented under three themes to cover the full range of the student experience:

- ***Enriching*** the primary school experience (Chapter 9)
- ***Enthusing*** secondary school students (Chapter 10)
- ***Encouraging*** students into engineering degrees (Chapter 11)

Final recommendations and strategies are presented in Chapter 12.

CHAPTER 9– Enriching the primary school experience

As detailed in the introduction, there have been some very substantial investigations in the past into the decrease in the number of tertiary enrolments in engineering degrees in Australia and other first world countries. However, this work is rarely drawn together to investigate what potential contributions can be made to future research programs, and more specifically to find solutions. One of the most striking similarities found in most reports and articles reviewed in the first part of this report is that they focus on the symptoms of the underlying problem and they canvass but do not move to examine the causes. For example, when dealing with low enrolments in science and engineering, the reports typically focus on the fact that not enough students are taking science and mathematics in secondary school, but do not in general try to ascertain why. What all of the reports reveal is the multi-dimensionality of the problem and the need to consider the problem more holistically. The ongoing debate has reached the point where there is a need to establish with accuracy the degree to which the different factors influence decision making when it comes to enrolments in engineering tertiary studies and how they are linked. It is essential that all of the relevant factors be drawn together in order to fully understand the phenomenon and then to address it.

9.1 – Liking of school subjects

There is a range of reasons why young persons like or dislike school subjects, including mathematics. These feelings may be especially important for mathematics because students tend to have stronger views about this subject than they have for others. There may also be inherent predilections towards or against mathematics as expressed through student interests. Social expectations and emphases are also important since the key aspects are learnt from or, at the least, are influenced by others, Liking subjects also depends in part on teaching approaches and methods. As students generally do not seek to continue with something they do not like, it can be argued that the most basic requirement that students continue with mathematics to keep open the widest range of career options, including areas such as engineering. Therefore it is important that teachers attempt to ensure that students develop a liking of mathematics. Going further, liking of and interest in mathematics would be even more effective in encouraging young persons to expend time and effort on the subject in the primary school years and to continue the serious study of mathematics into secondary school and perhaps into the future.

Unfortunately, there is a significant drop in liking of mathematics between primary and secondary school. This, however, is not a new phenomenon. Research also indicates that students' liking of school science declines from their early school years onward (Ormerod & Duckworth, 1975; Piburn, 1993; Pell & Jarvis, 2001). The present study found that at primary school level, science ranked second (with 82% of student indicating that they like it) among favourite school subjects. Also, 71% of primary school children participating in the study declared they liked mathematics. At a secondary level, over 45% of students taking at least one science subject in Year 11 indicated that mathematics was their least preferred subject. This finding is also reinforced by other recent studies. In interviews conducted by Alloway et al. (2004), the early years of high school were identified by respondents as a critical phase.

The Trends in International Mathematics and Science Study (TIMSS), the world's longest running mathematics and science study, was designed to help all countries improve student learning. It collects educational achievement data periodically at Year 4 and Year 8 in over 60 countries to provide information about trends in performance over time. TIMSS 2006 reported that students in Australia at Year 4 of primary schooling have an interest in science that is well above the OECD average while the same index of "students valuing science" in Year 8 (early secondary) is well below the OECD average as is their "enjoyment of learning science". This information coincides with the findings of the present study. Students seem to lose their love for mathematics and science in the latter years of primary school, and/or about the time of transition between primary and secondary school, and/or in the junior secondary school. This loss could be linked with "primary teachers' relatively low levels of interest and academic attainment in science and mathematics" (DEST, 2003, p.18), but many other factors related to the transition itself or students' early secondary experiences could be contributing. In any case, students' inclination to continue with the enabling sciences and mathematics through secondary school is vital to their possible future pursuit of engineering tertiary studies. Because mathematics curricula in Australia and the USA often do not require thinking beyond simple analysis (Wood, Williams, & Mc Neal, 2006), the intellectual quality of mathematics learning may not be preparing students for developing interest in STEM at and beyond secondary stages of schooling. An initiative is required to enrich primary school mathematics if the aim is a **long-term solution** to the skill shortage currently being experienced in Australia.

One of the key findings from the study presented in this part of the report is the critical importance of raising the interest of primary students in mathematics, and relating that mathematics to the real world, particularly areas such as science and engineering. **Enriching the mathematics and enabling sciences experience for students at a primary school level may hold the key to increasing enrolments in engineering studies in the long term**. If the students are not stimulated at that stage, the chances of them pursuing an engineering related career are then significantly diminished. Unfortunately, it is also clear that this is currently not happening sufficiently in primary schools in Australia. However, the research presented in this report clearly indicates that inspiring students into the engineering field would best begin at an early age. It also suggests that this enrichment has to be contextualised within the school curriculum, stimulating interest in school mathematics and science ideally, in part, using engineering as the vehicle to naturally convey their usefulness and appeal.

There are strong grounds in this study supporting this conclusion. A very high proportion of engineers and engineering students participating in this study indicated a liking for mathematics from an early age as one of the key reasons for becoming an engineer later in life. Furthermore, most of the participants in this study selected mathematics as one of their two most preferred subjects at school, a very different view from that of the secondary school science students in the sample in which 45% of the students indicated that mathematics was their least preferred subject, closely followed by chemistry and physics, two other very important requirements for several branches of engineering.

University engineering students and professional engineers alike generally indicated that their reasons for becoming engineers were an almost innate liking of mathematics and science ('maths was a strong subject in my early life' or 'interest in science on a theoretical as well as on a practical level') or an intrinsic inclination towards the basic principles of engineering ('Since the age of 6 [years] I wanted to design and construct things'). **Tapping into the liking of mathematics and science and 'urge to invent' at primary school, when the interest is very high amongst most students, could potentially lead to greater interest in the engineering profession in later life.**

One initiative that could help contextualise mathematics in the classroom for both students and teachers would be to use volunteer professional engineering mentors who could come to the classroom on an occasional basis to provide some simple activities illustrating the application of mathematics to the "real world". Professional organisations such as *Engineers Australia*, with its extensive Australia-wide network and membership, would be an obvious source of mentors in most locations.

9.2 – The role of teachers

How teachers portray the enabling sciences and mathematics at primary level is very important. Ensuring that early primary school mathematics and science classes are taught by qualified and capable teachers should thus be a major aim of any intervention with the ultimate intention of increasing enrolments in STEM subjects at a senior secondary level. The training and retraining of primary teachers, although clearly long-term, should be pursued. But in the interim there are more immediate possibilities such as the provision of expanded, innovative curriculum materials and qualified, itinerant staff to work in classrooms with students and teachers on a regular, long-term basis, perhaps during one mathematics lesson per week. Moving in this way towards more interesting mathematics lesson experiences is not a new approach, but one worthy of re-invention.

The primary school student questionnaire used in this study indicated that the ways in which mathematics and the enabling sciences are portrayed and perceived in primary school strongly influences perceptions of engineering as a profession. There is a strong correlation between students liking for mathematics (and science, although to a lesser extent) and their positive responses to questions such us “engineers make people’s lives better”. Taking into account that “for the majority of students, their life aspirations are formed before the age of 14” (DEEWR, 2008, p. 9), it is crucial to tackle the issue of mathematics engagement to achieve increased engineering enrolments in tertiary studies as early as possible. Lord et al. (2006) identify primary school as a critical phase in developing attitudes towards careers and the responses of primary students in the present study certainly concur with those of this recent UK study.

Another interesting fact that arose from the study is that there was no correlation between students’ interest in mathematics and the enabling sciences and the perceived difficulty of these subjects. Students generally seemed to like these subjects regardless of how hard they thought they were. Thus, enthusing primary students over mathematics to make the subject more attractive does not necessarily mean decreasing the level of difficulty of the subject content. On the whole, students like or dislike the subject regardless of how difficult they think it is.

Also, it is important to note that, at primary school, students gave positive responses to the “liking of engineering-type activities” scale: most students liked the engineering-type activities (designing, experimenting, testing, etc.). Even more students had positive personal perceptions of engineers. This suggests that the natural enthusiasm of young students for novel experiences could be boosted by the introduction of programs and school experiences to tap into these favourable attitudes. Again the aim would be to motivate students towards engaging more fully with mathematics and science at school, thereby opening the possibility of an engineering career.

9.3 – Reflections on gender

Gender is another issue which appears to have a bearing on students’ attitudes towards the engineering profession. There exists a perception among the majority of primary school students in the sample that males are more likely to be knowledgeable about engineering than females. Also, recent studies by Helme and Lamb (2007), Watt (2005, p. 21) and Forgasz (2006) indicate that gender impacts significantly upon student career aspirations and subject selection. The research mentioned above finds that there are more female students choosing lower-level mathematics courses than males, and that this difference is not based upon mathematics achievement. It is also found that males are more likely to continue in STEM study than their female peers irrespective of past performance in mathematics.

These attitudes tend to reflect the broader community picture with regard to female engineers, where there is similar imbalance in general perceptions. Although the trend has improved slightly in recent years, *Engineers Australia* data indicate that the proportion of female engineers currently in the workforce is approximately 7%, with female enrolments in engineering programs being of the order of 15% nationally (Mills et al, 2008). The proportion of female engineers in some disciplines such as Environmental engineering is much higher than this average figure, but correspondingly it is much lower in some of the more traditional areas such as Civil or Mechanical Engineering.

Clearly the engineering profession has a major role to play at a broader community level to change the perception of engineering as a "male only" profession and to raise the awareness in the community of the satisfying and rewarding potential careers for females in engineering.

The present study found a correspondingly significant difference in both interest and perceptions of engineering by boys and girls in primary school, with boys higher on both measurements. This suggests that **greater effort needs to be made to address the perception that engineering is a male dominated profession**. Most students accepted as facts the engineering stereotype items offered. Mainly, two noticeable stereotypes that appeared repeatedly amongst children's impressions were the misconceptions that engineers must be physically strong and that car mechanics are engineers. Also, many of the primary students in this study had difficulty identifying simple engineering tasks. Less than one third of the students had a perfect score in identifying correctly as engineering related or non-engineering related the six activities given to them, and just over half (53%) correctly identified the three engineering tasks. This would imply that many primary students do not have a clear understanding of what being an engineer entails. Although they do have a liking for engineering-type activities, they may not link these activities to engineering as a profession.

The above perceptions highlight the current confusion in the general community about the term "engineer", which is used in a wide range of instances, many of which do not refer to professional engineers. In this regard, the engineering profession in general, and *Engineers Australia* in particular have a major role to play in clarifying this issue with the general community. With better informed parents, many of the above misconceptions in children could be dispelled at an early age.

9.4 – Conclusions

As stated in the previous discourse, according to both current literature and the research undertaken by this team, ***enriching*** the primary school experience of young Australians holds the key to a successful long-term solution to the engineering skill shortage currently experienced in Australia. A range of areas should be covered by any such enrichment initiative but there are three main points which would need to be addressed:

* Enriching the mathematics and enabling sciences experience for students by providing high-level thinking problems in a contextualised curriculum.
* Tapping into 'urge to invent' at an early age, by introducing engineers in the classroom who can ably explain the joys and intricacies of their profession, thus debunking existing stereotypes.
* Addressing the perception that engineering is a male dominated profession by providing young girls with role models they can be inspired by.

CHAPTER 10 – Enthusing secondary school students

Enthusing secondary students about the possibilities of careers in engineering is a mid-term solution to the engineering skills shortage. Stereotypes and misconceptions about careers in science and engineering tend to restrict students' understanding of their own career options. In order to make informed decisions, students need to access accurate information about pathways, careers and workforce demand. Students also need the capacity to imagine themselves as future scientists or engineers. School counsellors and careers advisors are two of the principal resources students use when trying to decide which career path they want to pursue (Patton, 2005). In the case of science and engineering degrees, science teachers are also a source of information which students reportedly use often (ETB, 2005). In fact, the two main sources of information that students gave in a recent UK study (Blenkinsop et al., 2006) were 'someone who works in that job or career' (72%) or 'a school careers teacher' (67%). Who better than their science teacher to inform them of careers in science? Students need to be made aware of careers in science and careers based on science, and of the flexibility offered by enabling sciences subjects they take at school (DEST, 2002).

10.1 – The role of science teachers and careers advisors

The quality of the educational experience provided by teachers, and most importantly science teachers, plays a critical role in students' success in the enabling sciences, mathematics and engineering. Recent studies highlight the fact that the quality of teaching is more important than any other factor when it comes to enthusing students with the possibility of a career in the STEM area (Darling-Hammond, 2007). Unfortunately, at secondary level, Australia has "insufficient numbers of highly trained teachers in science, technology and mathematics" and is encumbered with a style of "teaching which does too little to stimulate curiosity, problem solving, depth of understanding and continued interest in learning among students, or to thus encourage them to undertake advanced study in science and mathematics at school and beyond" (DEST, 2003, p. 18). In this chapter the potential roles of both careers advisors and science teachers in stimulating interest and inspiring students in mathematics and the enabling sciences are analysed.

The Longitudinal Studies of Australian Youth (LSAY) series, produced and analysed by the Australian Council for Educational Research, comprises three large cohorts of students in Year 9 (in years 1995, 1998 and 2003). The total number of students surveyed exceeds 40,000 making LSAY the most comprehensive study about school students and their career pathways after leaving school in Australia. In a recent report about careers advising (Rothman & Hillman, 2008), all students in the LSAY 2003 cohort reported to having participated in at least one type of career advice activity across Years 10, 11 and 12. Furthermore, most activity occurred in Year 10, when 99 per cent of students accessed at least one activity.

This widespread use of the counselling is unfortunately paired with a relative lack of empirical evidence available to guide school career counsellors. An international literature review on counselling outcomes indicated that school counselling (equivalent to Australia's careers advising) 'has the least amount of empirical evidence available to practitioners' (Sexton et al., 1997, p. 125). In Australia, a study focused on Year 10 and Year 12 student perceptions of school careers advising (Walker et al., 2006) reported that the type of services provided by school career advisors varied considerably between schools. The authors communicated that these variations ranged from student-centred approaches to information-centred approaches. Although both approaches are widely used, students in schools identified as having a student-centred approach to career advice expressed more confidence in accessing this advice than students in schools identified as having a more information-centred approach.

The present study found that careers advisors, TV/internet and science teachers were seen as sources of information by the majority of secondary student respondents, replacing dad/brother who were the major source for the primary students. Unfortunately it was found in the study that, on average, both science teachers and careers advisors acknowledged low levels of familiarity with different engineering areas of specialisation. In the case of environmental engineering (one of the most popular degrees amongst engineering students) the level of knowledge was even lower than the average, suggesting that definite efforts should be made to **better inform teachers and careers advisors of the range of opportunities arising from a career in engineering**. Once again the engineering profession in general, and *Engineers Australia* in particular, have the potential to make a significant contribution in this regard. With a local presence in each state through its Divisions, *Engineers Australia* is well placed to provide information sessions and site visits to careers advisors on an annual basis. A very successful pilot initiative of this type was carried out in 2008 in the Newcastle Division as part of Australian Engineering Week – this was enthusiastically received by the 40 careers advisors who participated.

While there is evidence that students' perceptions of potential careers are formulated in late primary and early secondary school, the most evident impact arises in their choice of elective subjects. This choice commences beyond year 7 and, in the best of circumstances, the student is able to choose subjects of direct relevance to their planned career path. Often, however, some choices are not available to students owing either to a lack of subjects offered or to timetable conflicts with other subjects running concurrently in the school program. These restrictions can impact significantly on the potential for students to follow particular career paths.

This effect is no more important than in years 9 and 10 when students are contemplating the courses they will chose to undertake in years 11 and 12. By not choosing core preparatory courses for engineering (i.e. chemistry, physics and mathematics at a sufficient high level) they significantly reduce their chances of following a scientific/technical career path. It is therefore imperative that in this most influential stage of their education, students have access to quality information about career potential in engineering and guidance on the choice of final year subjects which will allow them to keep as many career options open as possible.

In general, the careers advisors had more positive perceptions of their students' interests in school subjects than the science teachers. Given that the science teachers would be in more constant direct teaching contact with students, perhaps their perceptions were more realistic for most of the subjects of interest in this study. This was reinforced by the student responses, and could imply that careers advisors may have slightly inflated views of students' interests on mathematics and the enabling sciences. The study presented in this report showed that all university engineering students had a fairly positive perception of the importance of enabling sciences in their future career. Beginning engineering students' interest in science and mathematics was stronger at university than it had been at high school, suggesting that the importance of these subjects may not have been emphasised enough through their late schooling.

10.2 – Reflections on gender

In general this study found that teachers had quite positive perceptions of engineering, although they had less positive views of women in engineering. It is important to note that this view could be passed on to female students, potentially deterring them from undertaking science or engineering studies at a tertiary level.

In "*Engineering choices, engineering futures*" it was found that, although secondary science students generally agreed they were satisfied with school, the relatively high proportions of Year 11 secondary science students who did not find science, mathematics or computing interesting is a matter of concern (see Chapter 4, Section 2). The background experiences of students, through primary and secondary schooling, and the various aspects of science, mathematics and computing curricula and teaching seem to have contributed to this situation. Other international studies support this hypothesis. Jenkins and Nelson found that 61% of a sample of 1277 English students, aged 15, responded with at least some agreement with the statement "school science is interesting". They also found that only 21% of their sample had a similar level of agreement with the statement "I would like to become a scientist". As a further comparison, with the study presented in this report, the Programme for International Student Assessment (PISA)[5] 2006 survey of school performance revealed a similar result, but slightly less negative attitudes in Australian youth (PISA, 2006).

10.3 – Outreach

One distinct, diverse and rapidly growing approach to enthusing students in STEM is the utilisation of outreach in its many forms. STEM outreach programs exist around the world, although the majority of the limited literature that exists on them emanates from the United States (deGrazia, Sullivan, Carlson. & Carlson, 2000; Farmer-Cox, 2005; Gascoigne, 2001; Hwang, 2006; Rushton, 2002; Ybarra, 2006).

The following numbers are not exhaustive, however, Jeffers et al (2004) identified 59 outreach initiatives across the United States. Furthermore, Garnett (2003) identified 63 face-to-face outreach programs taken to K-12 schools across Australia. Although actual numbers of outreach programs in Australia are not precisely known, it was estimated that in excess of 400 programs were currently in operation (Garnett, 2003; ASTA, 2004).

As mentioned above, outreach programs take many diverse forms; spanning from the simple development of classroom or web-based materials, through to complex, teacher development sessions or mobile, face-to-face, resource intensive, student activities (Jeffers, 2004). Such programs may be implemented by older school students, teachers, independent educators, university students and staff, or staff from other STEM education institutions such as science centres, museums or zoological parks.

Despite the different motivations, themes, approaches and target audiences of various outreach programs, the most common goal is to engage students and encourage participation in STEM fields. Often the strategy used to achieve this goal is to focus on informing students and dispelling negative perceptions of STEM subjects and careers (Pickering, 2004).

STEM outreach programs, as an approach, have many potential benefits. The first of which is the potential to alter negative perceptions of STEM courses and careers. In an Australian study (Raison, 2006), 44% of undergraduate engineering students surveyed reported that participating in an outreach activity greatly influenced their attitudes to STEM careers and their decision to enrol in tertiary courses in these fields. Also in Australia, Fletcher (2003) reported that 35% of participants in the *Questacon Smart Moves* program indicated a higher level of interest in STEM school courses, and 6.2% changed their career plans as a result.

[5] PISA is a triennial international study conducted by the Organisation for Economic Co-operation and Development (OECD). The 2006 survey included 57 countries.

In the NACME (2001) study in the United States, it was found that students who were aware of the 'Maths is Power' outreach program were significantly more likely to report that mathematics is 'easy' and 'fun'.

However, the potential benefits of STEM outreach programs extend beyond changing perceptions. The programs bring new enthusiasm, approaches, content, teaching techniques and resources into the classroom. Furthermore, as Canavan et al state,

> "Many STEM initiatives provide valuable platforms for meaningful experiential learning to take place, in a manner and setting which is unavailable particularly in the primary education sector. As well as promoting STEM awareness, they engender social interaction and can facilitate the raising of young people's self-esteem. To this end the value of STEM outreach initiatives moves beyond the scope of changing perceptions." (2002, p.6)

In light of the potential benefits of these programs and the recent concern over student engagement and enrolments in STEM, many institutions have reacted with a proliferation of outreach programs (Rockland, Gibbons, Bloom & Kimmel, 2002). In Garnett's (2003) Australian study, 30% of the surveyed outreach programs had been created in the previous five years.

The two cohorts of teachers in the present study focussed on exposure to engineering and to engineers as the most likely to be productive in interesting their students in engineering and encouraging them towards that possible career choice. A significant minority of students included in the present study (29%) were in schools that had participated in one of the science and engineering outreach programs, although they personally may not have been involved. Perhaps **an increase in students' exposure to science/engineering outreach programs, including visits to schools from engineers would positively contribute to increasing students' appreciation and understanding of engineering**.

10.4 – Promotion of Engineering

Promoting engineering to students who have already chosen a science path in high school could encourage some of them towards completing engineering degrees. The study presented in this report found that, at 16-17 years of age, most Australian students were quite interested in engineering activities and did not seem to hold negative stereotypes about the engineering profession. In fact, they thought that engineers were to be admired and respected. Why are then are too few choosing to undertake engineering studies at a tertiary level? This study suggests that students do not seem to see a link between the science they study and the engineering profession and also that, amongst students with high Universities Admission Index scores (UAI), there is a perception of better remuneration by becoming a medical doctor or a lawyer.

The Year 11 science students in the sample liked the engineering-related activities presented (designing, experimenting, testing, etc.) and their personal perceptions of engineering were generally quite positive. In particular, surveyed students thought engineers made people's lives better, that their jobs were interesting and that their work was well remunerated. In fact, health care, office work and engineering were all selected as preferred occupations by more than one-third of respondents, engineering accounting for over 35% of students' occupational preferences.

There was less agreement with the engineering stereotypes offered. The comparison with the primary students' perceptions suggests that the secondary students had more knowledge about engineering and therefore were less likely to hold a stereotypical view. For example, the perception of scientists and engineers as 'geeks' was, on average, not agreed with. Also, by and large, a majority of the secondary students had a reasonably good grasp of what types of careers and tasks are related to the engineering profession.

Most teachers, professional engineers and engineering students considered that **school promotion plays an essential role in influencing students' career decisions**. However, the two most popular suggestions for promoting engineering related to **promoting community perceptions through the media, particularly TV and the internet**, together accounting for over 60% of responses. A typical example of this type of response is 'CSI has done wonders for Forensics - maybe an action show with the protagonist as an engineer...'..

Two of the most prominent barriers to becoming an engineer stated by the professional cohort relate to status/rewards of engineering, together accounting for 57% of the barriers cited. Examples of this type of response range from 'lack of profile and recognition' to 'inequality in the pay between Engineers and tradespeople'. The two most popular suggestions for promoting engineering related to community perceptions through modern media, accounting for over 50% of responses. **The use of internet-based promotion could lead to better engagement with tertiary students**.

There is an interesting complexity in reporting engineering salaries in that, within a few years of commencement as a professional engineer, a significant proportion of the total cohort move into more senior management positions and see themselves more as managers than as engineers. The remaining engineers are not (generally) as well paid as management staff, leading to a bias in the reporting of salary potential. Students are not aware of this feature of career progression and remuneration so may have a distorted view of salary opportunities in embarking on an engineering career compared to other well-paid professional paths. To address this issue, more work needs to be undertaken on properly researching engineering graduate careers and salaries some years out from graduation including engineers who move into other professions or management.

Once available, such information needs to be communicated directly to careers advisors for transmission to secondary students. An additional path to these students is having professional engineers visit schools to explain more about what an engineer does, engineering careers and remuneration, and by promoting this issue on popular websites more frequently visited by teenagers.

As discussed in the previous section, *Engineers Australia* has a crucial role to play in raising the profile of engineering and clarifying the role of the various engineering disciplines in helping society function. This goal should be pursued at all levels – in the general community and at primary and secondary school levels. At secondary level in particular, the profession is well positioned to provide role models and mentors, to facilitate motivational site visits for students, to offer appropriate scholarships and traineeships to students about to enter the tertiary system and to participate in school visits and briefings on an *ad hoc* basis.

10.5 – Conclusions

Enthusing secondary school students already taking high-level science and mathematics subjects into considering the engineering field is a task that could be accomplished in a time frame which could help ease the skill shortage in the medium term. The results of this research indicate that the following four points should be taken into consideration in any action aimed at increasing enrolments in the medium term:

* informing teachers and careers advisors of the range of opportunities arising from a career in engineering.
* Promoting community perceptions through the media, particularly using internet-based promotion could lead to better engagement with secondary students.

* Increasing students' exposure to this science outreach programs, including visits to schools
* Clarify the nature of engineering and its crucial role in society through proactive initiatives.

CHAPTER 11 – Encouraging students into engineering degrees

There is considerable evidence to show that, despite strong career prospects, there has been a decline in the study of science and engineering in universities in Australia. Young Australians must be encouraged to undertake careers in these areas if the technical skills shortage currently experienced in our country is to be addressed.

The recent PISA report gives some data on the human resource problem of recruiting and filling science posts (PISA, 2006). Their data would suggest that the supply in Australia of suitably qualified science teachers is worse than the OECD average. In 2006, individuals who held their highest qualifications in the fields of Health and Natural and Physical sciences had the lowest rates of unemployment (1.5% and 1.9% respectively). This indicates a high demand for these skills within the workforce (Australian Bureau of Statistics, 2007). The future presents itself in even brighter light when talking about career prospects: in an audit conducted in 2006 by the Australian Department of Education, Science and Training, it was projected that the demand for science professionals would increase by around 55,000 by 2012, and demand for engineering professionals would rise by over 46,640 in the same period. However, over the six-year period from 2001 to 2006 there were enrolment declines in the natural and physical sciences as well as environmental studies. Overall, during this six-year span there was a small decline in the numbers of domestic undergraduate commencements in science-related fields of education. In 2006, fewer than 10 per cent of commencing enrolments were in the natural and physical sciences, six per cent were in engineering and related fields, just over three per cent were in information technology, just fewer than three per cent were in architecture and building, and less than two percent were in environmental studies (Ainley et al., 2008).

In the case of engineering graduates, the prospects into the future are alarming for industry. The Chief Executive of *Engineers Australia*, Peter Taylor, projected the following: “During the five years to the 2011 Census, we estimate that 70,000 engineering professionals will have retired. At current rates, the expected 45,000 graduates will not even cover the losses over the same period. It is possible that current professional engineering skills shortages will double by 2011: the numbers are unnerving for Australia’s future.” (*Engineers Australia*, 2008).

This study identified a range of issues concerning student enrolment in engineering tertiary studies which poses a range of challenges difficult to address. The previous two chapters of this report attempted to give long and mid-term solutions to the problem. This chapter proposes strategies to deal with the issue in a short term basis. The conclusions here are based upon the present study’s findings reinforced by recently published literature.

11.1– Prerequisites

The evidence from the surveys undertaken in this study indicates that most professional engineers and university engineering students link their career choice, at an early stage, to an interest in mathematics and in an interest in understanding how things work. It is important to capture that interest early in a student’s education and to direct it into the foundation areas of study in secondary school. The natural extension of this interest is in the subjects of physics, chemistry and mathematics. These three subjects form the foundation, and usually clearly stated prerequisites, for most, if not all, of the university-level courses.

As an example of how prerequisites can affect student uptake of certain degrees, in New South Wales, the Higher School Certificate (HSC) is the credential awarded to secondary school students who successfully complete senior secondary school level studies (years 11 and 12 or equivalent). HSC results are also used to calculate the Universities Admission

Index (UAI) score, considered the primary criterion for entry into most undergraduate-entry university programs

In recent years there has been a trend away from undertaking extension mathematics courses (the highest level mathematics courses offered in New South Wales' schools) for the HSC. This has led to many students choosing either a lower level of mathematics or no mathematics at all in the final two years of their secondary schooling making it difficult for them if they subsequently wish to choose a university degree which relies on such a background. **It is essential that students are not discouraged from studying high level mathematics, physics and chemistry by misinformation about prerequisite options as this could effectively hinder their future pursuit of engineering studies.**

11.2 – HECS, scholarships and transitions

The Higher Education Contributions Scheme (HECS) was introduced in 1989 as a means of financing the expansion of the higher education system. At the time, the introduction of the scheme was perceived as a more appropriate means of seeking a greater contribution from individuals towards the cost of their education, while minimising potential adverse impacts on participation. In 1996 a further increase in fees was introduced and students were also required to repay their loan at a faster rate. In the case of science and engineering degrees this increase amounted to an additional 90% (Aungles et al., 2002, p. 7). Aungles et al. argue that “approximately 9,000 fewer school leavers a year applied for university from 1997 onwards.” (Aungles et al., 2002, p. 16), which may be a factor contributing to the decline in science and engineering enrolments.

Recent Australian studies (e.g., Ainley et al., 2008) point out that schemes to off-set HECS charges may provide an incentive to attract science graduates to teaching even if that is not always for a life-time career. This study found that many university students and professional engineers agreed with this view by suggesting that scholarships and/or subsidisation of HECS fees at university level hold a key to increasing engineering enrolments in the short term. It is important to note here that a proportion (8.5%) of current professional engineers indicated that one of the reasons they became an engineer was the availability of scholarships. This reason was cited by less than 1% of current engineering students suggesting a shortage of scholarships could prove detrimental in the uptake of engineering studies at a tertiary level. For a short-term strategy to increase enrolments to be implemented, both **the creation of scholarships and the subsidisation of HECS fees for engineering studies could play a crucial role**.

The research presented in this report also found that professional engineers agreed that facilitating the upskilling of engineering sub-professionals by appropriate articulation arrangements between TAFE and Universities could be an effective measure to increase enrolments in engineering degrees in Australia. Assisting the transition from engineering trades into the engineering profession can in the short term encourage students who have already shown a predisposition towards engineering to undertake engineering tertiary studies.

11.3– Reflections on gender

Rates of participation across disciplines vary significantly between subjects according to gender. In Australia there are more females choosing biological sciences, while males make up a greater proportion of the enrolments in the physical sciences (Ainley & Elsworth, 2003; Fullarton et al., 2003). Even though women represent the majority of Australian university enrolments (54%), they make up less than a third of tertiary STEM enrolments. Females are especially under-represented in tertiary engineering (16%), computing (24%) and Physics (27%) (Dobson, 2007). The number of women entering the engineering profession in Australia and other western countries remains low, and recent figures indicate that both the number and percentage of women entering university to study engineering have decreased in Australia in recent years and that this trend is also being mirrored in the UK, USA and Canada (Mills at al., 2008). In a time of severe skills shortage in the engineering profession women still make up less than 10% of professional engineers in Australia and current membership of *Engineers Australia* was still only 6.4% female in 2007 (*Engineers Australia*, 2007). **Encouraging more women to undertake engineering studies could drastically increase the number of young engineers entering the profession,**

There are a number of barriers operating against an engineering career choice for females (Darby et al., 2003). In Darby's study, young women at 14-15 years of age were not able to create links between their own interests and what engineers do because of lack of knowledge of what engineering involves – a problem which is common to males at this age, too. Thus, they resort to stereotypes of a male dominated industry. At a university level, a study of the language of an engineering classroom environment (Burrowes, 2003) identified a gender-biased classroom environment in engineering faculties. She identified persistent comments with sexual connotations and examples of sexist language that treated women in a way that excluded them from any scientific or technical accomplishments. With this is mind, it is not surprising that the rates of participation in engineering tertiary studies, and certain science degrees are low.

This study found that almost half of the respondents in the professional engineering cohort recognised the need to address gender imbalance in the engineering profession, while a smaller but substantial group (one third) thought that further effort was either not warranted or would be wasted. However, gender equity in the engineering profession was strongly supported by engineering students in both year levels, with those in the final year having a significantly more positive view than those in first year. Perhaps some misconceptions of engineering being a male-dominated profession are still engrained in the professional cohort, but this seems to be changing rapidly and is hardly noticeable at all in the responses of younger engineers or engineering students.

11.4 – Conclusions

Encouraging students into accessing university engineering degrees, and retaining those who have already started these studies is an approach to tackling the skill shortage in the shorter term. A number of actions could be taken to accomplish this:

* Ensuring that students are not discouraged from studying high level mathematics, physics and chemistry by misinformation about prerequisite options as this effectively hinders their possible future pursuit of engineering studies.
* Creating of scholarships, in particular industry-sponsored scholarships and the subsidising HECS fees for engineering studies.
* Encouraging more women to undertake engineering studies.
* Facilitating the upskilling of engineering sub-professionals by appropriate articulation arrangements between TAFE and Universities to assist transition from engineering trades into the engineering profession.

CHAPTER 12 – Recommendations and Strategies

The themes of the previous three chapters were *enriching, enthusing* and *encouraging*. Each of them addressed issues arising from primary, secondary and tertiary stages of education. In this last chapter the recommendations will be grouped into two sets: general recommendations arising from the research and specific recommendations to *Engineers Australia*, one of the industry partners of this project.

The conclusions drawn from all previous analysis in this report, indicate that solving the problem of skill shortages in engineering requires a holistic approach to addressing all issues raised in the previous discussion. A solution must be viewed as a whole, starting with children at a very young age, including their parents, their teachers and the schools they attend. In fact, a long term solution can only occur if the society as a whole changes the way it perceives mathematics, science and the importance of the work of our engineers.

12.1 – The short term approach

If the situation continues to develop without intervention of any kind, things are likely to deteriorate. As new technologies emerge, the need for skilled scientists and engineers will increase and thus the shortage currently experienced in the field will only worsen.

Following the conclusions from Chapter 11 we recommend that the following actions be taken in the short term as a means to, if not reverse, at least decrease the skills shortage in the short term.

Recommendation 1:

Creation of Industry-University partnerships to provide scholarships to students entering engineering degrees.

These scholarships should have a strong work experience component, provided by the companies sponsoring the students.

A main focus of the scholarships should be encouraging women to become engineers.

Recommendation 2:

HECS subsidisation in order to attract more students to engineering degrees.

This should be done in conjunction with better information for students of the essential and desired prerequisites to enter engineering studies

engineering choices
engineering futures

Recommendation 3:

Facilitation the upskilling of engineering sub-professionals by appropriate articulation arrangements between TAFE and Universities

This should be done by providing clear pathways from the engineering trades to technologists to professional engineers.

engineering choices
engineering futures

12.2 – The medium term approach

There are a number of measures that could be undertaken to reverse the skill shortage in the medium term. The reasons for these measures are detailed in Chapter 10. A set of recommendations for both government agencies and Engineers Australia follows:

Recommendation 1:

We recommend improving students' understanding of engineering as a profession by the involvement of the engineering profession in general, and Engineers Australia in particular in:

5. Organising visits to Year 12 students from professional engineers
6. Organising a media campaign to promote engineering as a profession debunking current myths and misconceptions
7. Creating a more modern web-based approach to engineering promotion highlighting the status and rewards of the profession
8. Providing mentoring and role models to schools as required.

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Recommendation 2:

Investment should be placed on Science and engineering Outreach Programs which:

3. Improve students' awareness of engineering and engineers' work
4. Improve students' understanding of the enabling sciences leading to engineering careers

These Outreach Programs should be co-ordinated at a national level and organised to reach all Australians

engineering choices
engineering futures

Recommendation 3:

Careers advisors play a very important role in shaping young people's occupational choices. It would be advisable to improve their awareness of engineering choices and rewards. This can be achieved by:

Mobilising the resources of Engineers Australia to provide regular information and site visits for Careers Advisors in all of its Divisions throughout Australia

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12.3 – The long term approach

The previous three chapters provide information about issues concerning the shortage of engineering skills currently experienced in Australia and other western nations. Several recommendations to deal with these issues are outlined in the previous two sections. However, a strategy to permanently solve the engineering skills shortage can only be developed by addressing all issues. It is a long term approach: no quick fix can really deal with the underlying causes of the problem.

One of the most striking results arising from the data collected in this study was the fact that 13% of primary school participants indicated that they would like to become engineers when they grow up. Extrapolating this fact to the total number of Year 5 students in Australia, 269,300, there is a potential pool of 35,009 students who would consider engineering as a possible career option each year. This alone, especially if sustained throughout the secondary years of schooling would possibly meet the engineering shortage. To achieve this goal, however, measures to keep students interested in the enabling sciences and mathematics is paramount.

The researchers in charge of this study believe that solving the skill shortages in engineering requires a holistic approach to addressing all the issues highlighted in this study, starting with children at a very young age, including their parents, teachers and the schools they go to.

Recommendation 1:

We recommend the development of an intervention strategy suitable for wide-scale implementation to enrich mathematics skills at primary school in order to increase the possibility of choice of a career in engineering. The goals of the intervention would be to:

4. Improve awareness of engineering and engineers' work within the school community
5. Increase children's interest in taking engineering in the future through an enriched maths experience
6. Enhance teachers ability to teach mathematics at a level that enables transition to secondary school maths

engineering choices
engineering futures

Recommendation 2:

The resources of *Engineers Australia* be mobilised to:

In conjunction with a Primary School Mathematics Intervention Strategy, develop a voluntary mentorship scheme for appropriately motivated and skilled engineers to assist in the classroom in relating mathematics to the real world in general and engineering in particular.

Develop strategies to more clearly clarify and define the term “engineer” in the eyes of the general community

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The design and implementation of this strategy is a complicated task. Fortunately, many recent reports provide information which provides a basis for creating a long term approach to prevent decreasing enrolments in the fields of secondary mathematics and the enabling sciences. Increasing student numbers in those subjects is paramount to the success of increasing enrolments in engineering studies at a tertiary level and thus eliminating the skills shortage in the long run.

Because of these intrinsic links between engineering and school mathematics/science to create a strategy that effectively combats the skills shortage, there is a question that should be answered first. How can the predisposition to continue with mathematics and the enabling sciences leading to enrolments in engineering degrees be improved? To do so two aims should be addressed in conjunction:

* How can we improve the interest of young children in mathematics and science?
* How can we improve children’s understanding of engineering?

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APPENDIX 1: GRID OF EVALUATED REPORTS

The following table summarises the most significant recent reports specifying their scope and the approach used.

Report Title	Origin	Scope	Findings	Approach
Ainley, J. and S. T. Khoo *Attitudes, Intentions and Participation*	AUS 2005	Examine effects of attitudes to school on school completion and participation in tertiary education	Students' attitudes to school and learning influence both educational intentions and continuation in formal learning through school and beyond.	Longitudinal survey of students (13,600 returned).
Ainley, J., Kos, J, and Nicholas M. *Participation in Science, Mathematics and Technology in Australian Education*	AUS 2008	This report presents comprehensive information about science and mathematics education in Australia, including student achievement, participation, and teacher qualifications.	Australian students perform comparatively well in mathematics and science. There has been a steady decline in the percentage of Year 12 students participating in biology, chemistry and physics over the years 1976 to 2007. The overall pattern of enrolments in tertiary studies is of decline in information technology and a rise in health with a steady state in the physical and natural sciences, and in engineering.	Review of international studies (PISA and TIMSS) and patterns of participation and enrolments of the Department of Education, Employment and Workplace Relations.
American Society for Engineering Education *Survey Results of Teacher's Attitudes Towards Engineering*	USA 2006	Teachers' attitudes, knowledge and interest on engineering as an academic discipline and profession	Official conclusions are yet to be released, but statistics are available on-line at: http://www.engineeringk12.org/educators/taking_a_closer_look/survey.htm	On-line survey to school teachers (1012 completed).

Report Title	Origin	Scope	Findings	Approach
Australian Council of Deans of Science *Science at the Crossroads?*	AUS 2003	Examination of enrolment trends in Science and Information Technology. It looks at the number of and growth in student enrolments, and the subjects students are studying as components of their university degrees.	The report shows that the decline in Science between 1989 and 1997 has continued into the new century. The downward trend in the teaching of many areas of traditional Science has now been with us for over a decade. In terms of the years selected for this study, 1993 was the zenith for Chemistry, Earth Sciences, Mathematics and Physics. Behavioural and Biological Sciences have grown considerably, but both at rates below the system-wide pattern of growth.	This study is based on analyses of higher education statistics databases. Data were drawn primarily from the Commonwealth Department of Education, Science & Training of Australia.
Batterham, R. *The Chance to Change*	AUS 2000	Improve Australia's Science, Engineering and Technology (SET) capabilities	Simply increasing funding will not ensure innovation process. This report provides recommendations for enhancement of SET base in the areas of People and Culture, Ideas and Commercialisation.	Consultation with strategic advisers, professional consultants, and general public.
Blenkinsop, S., McCrone, T., Wade, P. and Morris, M. *How do young people make choices at age 14 and age 16?*	UK 2006	Explore how young people make the educational choices at ages 14 and 16 by looking into the ways in which structural contexts and individual attributes interact both before and during the decision-making process.	Schools can make a difference to how young people make decisions. When students felt supported in decision-making by the school they were more influenced by school factors (such as individual talks with teachers and the careers education and guidance provision) and less reliant on external factors such as friends and family. Young people brought different mindsets to the decision-making process, and made decisions differently across and within schools. Their decisions had also often fluctuated over time.	Two waves of in-depth interviews were held with 165 young people across 14 schools between February 2005 and February 2006.

Report Title	Origin	Scope	Findings	Approach
COAG *National Numeracy Review Report*	AUS 2008	Stocktake of research-based evidence about good practice in numeracy and the learning of mathematics in Australia	Students need to learn mathematics in ways that enable them to recognise when mathematics might help to interpret information or solve practical problems, apply their knowledge appropriately in contexts where they will have to use mathematical reasoning processes, choose mathematics that makes sense in the circumstances, make assumptions, resolve ambiguity and judge what is reasonable.	Consultation with strategic advisers, a reference group and a panel of experts.
DEST *Audit of science, engineering and technology skills*.	AUS 2006	Investigate the adequacy of supply of SET skills by examining trends, both in demands from industry and the scientific research community, and in supply from all education and training sectors.	There are sectoral SET supply issues. There is a declining participation in SET study which relates to an inadequate supply of suitably qualified teachers, The ability to attract high quality candidates into SET will impact Australia's ability to build its future SET capacity. Skill shortages will remain in several SET skills set, particularly engineering and earth scientists, chemists and special information scientists.	Draws data from Australian Bureau of Statistics and other national and international sources.
DEEWR *Opening up pathways: Engagement in STEM across the Primary-Secondary school transition*	AUS 2008	Review of the literature on the barriers and supports that young people encounter in pursuing studies in STEM disciplines in Australia.	For the majority of students, their life aspirations are formed before the age of 14. Student aspirations are significantly mediated through the secondary school years and transformed into career choices later by a range of factors including interest and self-efficacy in relation to mathematics and science, parental expectations and encouragement, teacher support and inspiration, career expectations and exposure to career guidance, exposure to role models and successful adults, and perceptions of the usefulness of the subject.	Online keyword search strategy included searching library databases for journal articles, books and reports.

Report Title	Origin	Scope	Findings	Approach

Douglas, J., Iversen, E. *Engineering in the K-12 Classroom*	USA 2004	Examine why there is cause for concern for the US to maintain global leadership in technological innovation. Study teachers' attitudes on engineering education	School science curriculum is too theory-based and should be more context-based. A technological component to all subjects is necessary in order to improve SET education. More school teachers should engage in outreach efforts and curriculum writing, and teacher salaries should be increased to attract the best technological minds to teaching. Outreach to urban schools and females should be more aggressive. More mentors and role models to attract these constituencies are needed along with partnerships with industry.	Statistics demonstrating that the US must improve the technical literacy of its population. Statistics from the ASEE 2006 survey mentioned above.
Engineers Australia. *Technically Speaking: Confronting the challenges facing science, engineering technology and mathematics education and promotion*	AUS 2006	This report summarizes the views of Engineers Australia drawing on preexisting literature which documents the problems currently faced by the Australian education system in providing SETM education to Australian youth.	1. A strategic vision is needed for SETM education. 2. Planning requires data. A long-term projection of future needs for SETM professionals needs to be undertaken. 3. More teachers comfortable with and capable of teaching SETM need to be trained and supported for both the primary and secondary education systems. 4. Government, industry, professional associations and educators, including schools and universities, need better connections and linkages to support the professional development of teachers, SETM programs in schools.	Review of government and non-government reports to date
Engineering and Technology Board. *Factors Influencing Year 9 Career Choices*	UK 2005	Determine how Year 9 students could be better supported with advice and background information (role models etc.) relating to career opportunities in the SET sector	Perceptions of the effects that their subject choice could have on future career flexibility Whether students actively seek career information or access it indirectly and their sources of such information What type of medium students best respond to, or engage with What are the most visited SET-related websites for this age group	Questionnaires (1,011 returned) sent out to a representative sample of schools

Report Title	Origin	Scope	Findings	Approach
Fullarton, S., Walker, M. *Patterns of Participation in Year 12*	AUS 2005	Study the participation in the final year of school in Australia. It is not specifically focused in participation in engineering tertiary education, although provides very relevant data related to the topic of Science, Technology and Mathematics participation	Differences in Year 12 participation rates between males and females (the gap is about ten percentage points in favour of females), socioeconomic background (the gap between the highest and the lowest of six socioeconomic groups in 2001 is 15 points), cultural background (the participation rate for those of a non-English speaking background is about eight percentage points higher than other students) and earlier school achievement (the gap between the highest and lowest of four achievement groups is 31 percentage points). There are also differences associated with school sector (the gap between independent and government schools is 14 percentage points) and location (the gap between metropolitan and non-metropolitan home locations is eight percentage points).	Longitudinal survey. Includes all cohorts which were doing Year 9 from 1995 to 1998. The total number of students surveyed exceeds 30,000.
Gallup, A. M, Rose, L. C., et al *The Second Instalment of the ITEA/Gallup Poll*	USA 2004	Public's concept of technology. Importance assigned to technology knowledge. Impact of technology on our daily lives and the world around us.	The public understands the importance of technology and understands and supports the need for maximizing technological literacy. Public thinks first of computers when technology is mentioned, while experts in the field assign the word a meaning that encompasses a wider area. The public wants development of technological literacy to be a priority for schools. Men and women are in agreement on the importance of this last point.	Phone interviews (800 completed). Random sample.

Report Title	Origin	Scope	Findings	Approach
Garnett, R. *Reaching All Australians*	AUS 2003	Study most SMET outreach programs reaching students in regional, rural and remote Australia.	Visiting SMET programs increase student interest and skills levels. The number of available SMET outreach programs, the frequency of their visits and the range of experiences they provide are insufficient to meet the needs. Schools and communities in rural and remote areas, with their lower population base, are not in a position to afford the higher costs and therefore are not adequately serviced by most SMET programs. It is more cost and time efficient for schools if outreach programs visit schools rather than have students travel to the nearest city or regional centre to experience SMET programs. The greater the distance from the capital cities, the greater the 'educational divide' becomes.	Consult with Outreach Providers and teachers in rural and remote areas
Helme, S., Polesel, J. *Young Visions 2003*	AUS 2003	Examine the post-school transitions of school leavers and the experiences of continuing students	School completers from high occupational status backgrounds were almost twice as likely as those from low occupational status backgrounds to be studying at university. Part-time work and work experience placements were found to have a significant impact on the career decision-making of school leavers who migrated to post-school VET and training positions. VET in Schools programs were generally well regarded by those who participated, and valued for the experiential learning, workplace training and industry-recognised qualifications they offer.	Questionnaires of Year 10, 11 and 12 students in all states and territories of Australia (2,271 returned)

Report Title	Origin	Scope	Findings	Approach
Kuenzi, J., Matthews, C. *Science, Technology, Engineering and Mathematics (STEM) Education Issues and Legislative Options*	USA 2006	Provide a useful context for legislative proposals to address economic competitiveness that support STEM education.	This report first presents data on the state of STEM education and then examines the federal role in promoting STEM education. The report concludes with a discussion of selected legislative options currently being considered to improve STEM education. It was designed by the Congressional Research Service (CRS) for the USA Congress.	Draws data from 6 reports released in 2005-06 in the United States. These reports are not reviewed in this article, since this CRS report covers them.
National Science Board *Science and Engineering Indicators*	USA 2008	Provide indicators that might reasonably be thought to provide summary information bearing on the scope, quality, and vitality of the science and engineering enterprise in the US and overseas.	Although Americans express strong support for science and technology (S&T), most are not very well informed about these subjects. The public's lack of knowledge about basic scientific facts and the scientific process can have far-reaching implications.	Statistical data derived from a variety of national, international, and private sources.
Osborne, J. and Dillon, J *Science Education in Europe: Critical Reflections*	EU 2008	Investigate the extent to which issues in science education are common across Europe, the similarities and differences between countries, and some attempted solutions and remedies.	There are shortcomings in curriculum, pedagogy and assessment, but the deeper problem is one of fundamental purpose. School science education has never provided a satisfactory education for the majority. Now the evidence is that it is failing in its original purpose, to provide a route into science for future scientists.	Based on two seminars held in London in 2006 at the Nuffield Foundation with contributions from academics in the field of education

Report Title	Origin	Scope	Findings	Approach
PISA *Science Competencies for Tomorrow's World*	INTER 2006	Explore students' performance, their interests in science and the awareness of the opportunities that scientific competencies bring as well as the environment that schools offer for science learning.	Finland was the highest-performing country on the PISA 2006 science scale. Followed by Canada, Japan and New Zealand and the partner countries/economies Hong Kong-China, Chinese Taipei and Estonia. Australia, the Netherlands, Korea, Germany, the United Kingdom, the Czech Republic, Switzerland, Austria, Belgium and Ireland, and the partner countries/economies Liechtenstein, Slovenia and Macao-China above the OECD average.	PISA is a triennial survey of the knowledge and skills of 15-year-olds. More than 400 000 students from 57 countries participate in the survey.
Raison, M. *Macquarie University Science, Engineering and Technology Study*	AUS 2006	Address the observed decline in enrolments in the science, engineering and technology areas over time and particularly in recent years.	The majority of survey participants believe SET areas are exciting and relevant to themselves and the wider community. More effort is required for promotion and support of SET, to which universities are thought to play a key role in addition to high school science teachers. High school science teachers hold a strong influence over the attitudes of their students, with general enthusiasm cited as the most important factor in maintaining student interest.	On-line surveys of high students (1,316 returned) and science professionals (74 returned). Focus groups (215 students).
Reid, A., Denley, P. et al *Tomorrow's World, Today's Reality*	UK 2003	Document teachers' awareness of engineering, including how STEM contributes to the promotion of careers in engineering.	Primary and secondary school teachers believed that Design and Technology played most important role to develop skills in engineering. STEM teachers were unclear about how pupils could become engineers and what qualifications were best suited to this. There is a need to update perceptions among teachers, parents and students.	Qualitative and quantitative: focus groups (5), individual interviews (27) and a survey (134 returned).

Report Title	Origin	Scope	Findings	Approach
Roberts, G. *Roberts' Review*	UK 2002	Review into the supply of science and engineering skills in the UK.	(Only some, relevant to this study) The experiences of pupils in school are crucial to their education, training and careers. There are a number of issues particular to these subjects that need to be addressed in order to improve the UK's supply of science and engineering skills. • shortages n the supply of physical science and mathematics teachers /lecturers; • poor environments in which science, and design and technology practicals are taught; and • the ability of these subjects 'courses to inspire and interest pupils, particularly girls.	Not specified
Rothman, S., & Hillman, K. *Career Advice in Australian Secondary Schools: Use and usefulness*	AUS 2008	Examine young people's participation in career advice activities while at school and their perceptions of the usefulness of the advice they receive.	All students in the cohort participated in at least one type of career advice activity. Most activity occurred in Year 10. The most common type of career advice activity was the distribution of written material and handouts. Career advice is delivered to students equitably across schools and within schools.	A group of more than 5000 young people were surveyed. Part of the LSAY 2003-2005 cohort.
TIMSS *International Mathematics Report.*	INTER 2007	Internationally comparative assessments dedicated to improving teaching and learning in mathematics and science for students around the world.	A full overview of findings can be found at http://timss.bc.edu/TIMSS2007/PDF/T07_TR_Chapter10.pdf	Evaluation of results of surveys of fourth and eighth grades of schooling in 59 countries.

Report Title	Origin	Scope	Findings	Approach
Thomson, S *Pathways from School to Further Education and Work*	AUS 2005	Examine the subjects that students choose in their last year of high school and their influence on the educational and career options after finishing school.	Level of achievement was one of the dominating characteristics in determining course participation. Students from high achievement levels dominated the areas of advanced mathematics–physical sciences, and the mixed area that included mathematics-physical sciences. Socio-economic status had little effect once other confounding factors were removed. Students in government schools were more likely than those in other sectors to be undertaking courses in service–clerical and technical vocational studies, and other sciences. Language background had some effect on course choice, with students with a language background other than English more likely to study in the mathematics-physical sciences and business studies areas.	Longitudinal survey. Includes all cohorts which were doing Year 9 from 1995 to 1998. The total number of students surveyed exceeds 30,000.
West Midlands Education and Training Department *A Survey into the Perceptions and Attitudes of Year 7, 8 and 9 Students Towards Engineering*	UK 2004	Address issues concerning the poor image of engineering and the difficulty of attracting sufficient talented young people to the engineering and manufacturing sector	Perceptions of engineering are generally quite good. Engineering/manufacturing is the second most preferred career choice for males. Pupils are 4 times more likely to be influenced by their parents for career choice. There is a correlation between visiting a factory and developing an interest in engineering as a career.	Questionnaires (2,500 returned) sent out to secondary schools to pupils from years 7, 8 and 9.

APPENDIX 2: GRID OF EVALUATED JOURNAL/CONFERENCE PAPERS

The following table summarises the most significant peer reviewed journal and conference articles specifying their scope and the approach used.

Article Title	Origin	Scope	Findings	Approach
Brown, M., Brown, P., and Bibby, T. *"I would rather die": reasons given by 16-year-olds for not continuing their study of mathematics.*	UK 2008	Explore reasons for non-participation in mathematics at age 16	Perceived difficulty and lack of confidence are important reasons for students not continuing with mathematics, and that perceived dislike and boredom, and lack of relevance, are also factors. There is a close relationship between reasons for non-participation and predicted grade, and a weaker relation to gender. An analysis of the effects of schools, demonstrates that enjoyment is the main factor differentiating schools with high and low participation indices.	Free response and closed items in a questionnaire with a sample of over 1500 students in 17 schools
Cunningham, C., Lachapelle, C. *Assessing elementary school students' conceptions of engineering and technology*	USA 2005	Probe students' conceptions of what engineers do and what technology is.	The top student choices are rooted in activities that focus on construction, building, machinery and vehicles. Fewer than third of the students recognized design as a feature of engineering. There is a wide spread lack of understanding about the breath of the fields of engineering: children identify engineering exclusively with civil engineering.	"Draw an Engineer", "What is an Engineer?" and "What is Technology?" tests in Years 1-5 (504 returned)
Darling-Hammond, L. *The flat earth and education: How America's commitment to equity will determine our future*	USA 2007	Outline disparities in educational access; illustrate relationships between race, resources, and achievement.	Progress in equalizing resources will require attention to inequalities at all levels—between states, among schools, and among students differentially placed in classrooms. State funding should be allocated to students adjusted for specific student needs, such as poverty, limited English proficiency, or special education status.	Analysis of current statistics and US government policies

Article Title	Origin	Scope	Findings	Approach
Davies, R., I. Ginns, McRobbie, C. *Elementary school students' understandings of technology concepts.*	USA 2002	Identification of students' understanding of technology concepts, across a range of age levels in elementary school.	Groupings of students' explanations at the different age levels are most frequent for the concept of material strength and the concept of stability. There appears to be a progression toward more abstract common explanations with increasing age for the concept of material strength.	92 interviews-about instances: presenting a student with artefacts or pictures to explore concepts that he/she associates with a particular label.
Georg, D. *Engineers in high demand*	AUS 2005	Factors influencing enrolments in engineering degrees in Australia.	There is a shortage of professional engineers. Attracting engineers from overseas is only a short team options for addressing demand in engineering. Increasing enrolments in engineering degrees should be a government priority.	Statistics and interviews with key players in Australia.
Finson, K. *Draw a Scientist: What we do and we do not know after fifty years of drawings*	USA 2002	Overview of research about children's perceptions of science and scientists.	Stereotypical perceptions are persistent. There has been a subtle shift in one of the classic stereotypical elements in students' drawings in the past 5 years. The combination of drawings with interviews appears to be the most useful strategy to test knowledge about scientists.	Review of existing literature on this topic
French, B., Immekus, J., and Oakes, W. *An examination of indicators of engineering students' success and persistence*	USA 2005	Examine student success and persistence within the major subject and university	For students to persist in their tertiary education, particularly as an engineering major, a strong academic background, achievement of good grades, and academic motivation are needed.	Hierarchical linear and logistic regression analyses for two cohorts of engineering students
Heywood, J. *Pupil's Attitudes To Technology: A review of studies which have a bearing on the attitudes which freshmen bring with them to engineering*	IRE 1998	Review of different studies on attitudes towards technology.	Engineering and school technology educators engaged in attitudinal and personality research would benefit from collaborative investigations. There is a need for synthesis of existing studies so that engineering educators can make the curriculum and teaching more effective.	Literature review with special emphasis on the Pupil's Attitudes Towards Technology (PATT) project

Article Title	Origin	Scope	Findings	Approach
Holbrook, A. Panoza, L. and Prieto, E. *Engineering in Children's fiction - not a good story?*	AUS 2007	Identify how science and engineering is portrayed in contemporary junior fiction (ages 8–12) and to what extent.	As few as 71 titles that addressed themes related to engineering and the sciences. Fictional characters were split between the nerdy, eccentric, and the more serious and professional types who were depicted as more popular. The emphasis was on male characters, but not exclusively so.	Examination of 4,800 junior fiction titles in one region in New South Wales, Australia
Jacobs, B., Scanlon, C. *Perceptions of 'engineering' – too little too late*	AUS 2002	Outlines research into the level of understanding of 'engineering' by school students.	Unless students with ability are familiar with engineering before high school they may stream themselves out of engineering as a career choice. The invisibility and misrepresentations of engineering are important issues that must be addressed if marketing is to be effective in encouraging diversity in the engineering profession.	Survey of undergraduate engineering students in 1999 (295 returned) and in 2000 (228 returned)
Johnson, W. C., Jones, R. C. *Declining interest in engineering studies at a time of increased business need*	USA 2006	Identify reasons of low enrolments in engineering tertiary education	Factors contributing to the decline in number of engineering students include the difficulty of the curriculum, the attractiveness of alternate paths to good technical jobs, and the lack of attractiveness of projected employment paths due to off-shoring for engineering graduates.	General conclusions on NSF reports' and statistics.
Knight, M., Cunningham, C. *Draw an engineer test – Draw an Engineer Test: Development of a tool to investigate students' ideas about engineers and engineering*	USA 2004	Understanding students perceptions of engineers and engineering	The results of this pilot study indicate that the students in this study have preconceived ideas about engineers and engineering. Many students, especially younger ones, think that engineers use tools to build buildings and fix car engines. This paper elaborates the survey method later used in Cunningham and Lachapelle (see previous page).	Surveys with the "Draw an engineer test" (253 returned)

Article Title	Origin	Scope	Findings	Approach

Kukreti, A., Islam, S. *Investigating student interest in post-secondary STEM education*	USA 2005	Analyse student's perceptions of engineering both as a discipline and as future career.	In the K-12 survey, 28% students were interested in engineering but only 5% apply for engineering admission. Students confuse engineers with technicians. They feel science lessons are too demanding. The college survey indicates because it is a stable living and they are interested in it.	K-12 and college student surveys (4,263 returned), focus groups (attendees from 14 school districts in Cincinnati)
Langen, A., Dekkers, H. *Cross-national differences in participating in tertiary science, technology, engineering and mathematics education*	NL 2005	Factors influencing enrolments. Comparison of different countries.	Despite similarities concerning policy attitudes and identified problems, western countries differ considerably from each other concerning the percentages of students that choose STEM education and the proportion of female students included here.	Comparison of OECD statistics from different western countries.
Mau, W. *Factors that influence persistence in science and engineering career aspirations*	USA 2003	Investigate student's persistence regarding career aspirations in science and engineering as a function of race and sex.	Persistent racial minority and female students are compared with non-persistent and male regarding their self-concept, parental involvement, socioeconomic status and academic achievement. Concludes academic proficiency and math self-efficacy are two main factors. Men are more likely to continue than women. None of the family variables had a significant impact on persistence in SE career aspirations.	Data was obtained from a three year longitudinal survey. The survey comprised sample of over 20,000 students selected from 1,052 middle schools in the United States.
Palmer, S. Bray, S. *Reasons stated by commencing students for studying engineering and technology*	AUS 2006	Identify reasons to enrol in engineering tertiary education	Engineering students are strongly career oriented and believe engineering is a rewarding career which offers both enjoyment and remuneration.	On-line surveys to first year engineering students (377 returned in a 3 year period)

Article Title	Origin	Scope	Findings	Approach
Poole, S., and DeGrazia, J. *Assessing K-12 pre-engineering outreach programs*	USA 2001	Assessment of outreach programs	Assessment strategies should consist of three key components: 1) assessment of workshop participant feedback (teachers and students), 2) assessment of long-term outcomes (teachers), and 3) assessment tools developed for the teachers' classroom use (i.e., embedded assessment).	Assesses as a case study of an outreach program by the University of Boulder, Colorado.
Oberst, B. S., Jones, R.C. *Offshore outsourcing and the dawn of the post-colonial era of Western engineering education*	USA 2006	Summarise the phenomenon of offshore outsourcing related to current state of engineering education and the engineering profession in Europe and the USA.	Despite anxiety about the out-migration of engineering and technical jobs to places such as India and China, there is reason to see offshoring as the result of Western investment in capacity building in developing countries and to believe that the creation of new jobs will outpace the rate of job loss in Europe and the USA.	In order to assess the climate affecting employment decisions by and about engineers the authors use as sources serious press, with an emphasis on material dating from 2004 forward.
Reed, P., Sontos, D. *A United States perspective:112 years of graduate research in technology education*	USA 2006	Analyses general trends of graduate research in technology education from 1892 to 2005.	Topics such as Women in Science and Technology have been discussed for over a century. A more comprehensive analysis of the TEGRD database would likely yield significant data on these and other pressing issues.	Analysis of review papers of graduate research on technology education and the TEGRD database.
Walker, K., Alloway, N., Dalley-Trim, L and Patterson, A. *Perceptions of career counselling in Australian secondary schools*	AUS 2006	Efficacy of school-based career counselling services as viewed by students	Students valued a proactive service with staff who were perceived to be responsive to their individual needs. Counselling services located on the student-centred end of a continuum (ranging from student-centred services to information-centred services) were viewed more positively by students.	Researchers interviewed 340 students in Years 10 and 12 in three Australian states to determine student perceptions of career counselling services.

Article Title	Origin	Scope	Findings	Approach
Watt, H. *Exploring adolescent motivations for pursuing maths-related careers*	USA/ AUS 2005	Explore adolescents' motivations and perceived influences on their plans to either pursue, or not pursue, maths-related careers	The most common reason for planning not to pursue a maths-related career was that students were interested in areas other than maths. Self- and values perceptions are posited to be the most immediate influences on students' plans for mathematics coursework participation. The analysis has also extended this proposition to maths-related career participation, which has clear social relevance.	Interviews with adolescents from grade 9 in Sydney Australia (N=60)
Wolters. F. *A PATT study among 10 to 12-year-old students in The Netherlands*	NL 1989	First of a series of studies on attitudes towards technology. Gender comparison.	Most students agreed that inventing, doing things with your hands and repairing are part of technology, but are unable to mention school subjects it is related to. Boys have a more positive attitude towards technology than girls. The variable Home Environment has a moderately positive influence on attitude towards technology.	Surveys (2,050 returned).
Wood, T., Williams, G., and Mc Neal, B. *Children's mathematical thinking in different classroom cultures*	USA 2006	The relationship between normative patterns of social interaction and children's mathematical thinking was investigated in 5 classes (4 reform and 1 conventional) of 7- to 8-year-olds.	The results suggest that increased complexity in children's expressed mathematical thinking was closely related to the types of interaction patterns that differentiated class discussions among the 4 classroom cultures (conventional textbook, conventional problem solving, strategy reporting, and inquiry/argument).	Analysis of 42 lessons for children's mathematical thinking as verbalized in class discussions

APPENDIX 3: SCALES

PRIMARY

Scale name	Questions
- Attitudinal Scales	
+ Satisfaction with school	I feel happy at school
	I like learning
	I really like to go to school each day
	I find that learning is a lot of fun
	I feel safe and secure at school
	I like to do extra work
+ Interest in enabling sciences	I would like to spend more school time doing science
	The science I learn at school is hard
	Learning science is important for my future
	I think science is exciting
	The science I learn at school makes me think
	Science is useful in every day life
	The science I learn at school is confusing
+ Interest in mathematics	Maths is useful in every day life
	Learning maths is important for my future
	The maths I learn at school is confusing
	The maths I learn at school makes me think
	The maths I learn at school is hard
	I think mathematics is exciting
+ Interest in other school subjects	I would like to spend more school time using computers
	I think computing is exciting
	Learning English is important for my future
+ Interest in engineering	I like designing things
	I like testing my ideas
	I could be a scientist
	I like working as part of a team
	I like creating and constructing things
	I could be an engineer
	I like solving problems and experimenting
- Information Scales	
+ Understanding of engineering	Building a raft
	Catching fish to eat
	Testing a radio transmitter
	Helping sick people
	Designing a catapult
	Making fire
+ Perception of engineering	Engineering is interesting for boys
	I admire people who do science or engineering
	People who do science are geeks
	Girls can become excellent engineers
	Engineers have interesting jobs

	Engineering is interesting for girls
	People who do engineering are geeks
	You must go to university to become an engineer
	You must know a lot about computing to be an engineer
	You need to know maths and science to become an engineer
	You must be physically strong to be an engineer
	Engineers spend a lot of time working with machines
	Engineers work mostly outdoors
	Boys can become excellent engineers
	Engineers make a lot of money
	A car mechanic is an engineer
	Engineers build things
	Engineers spend a lot of time working with people
	Engineers make people's lives better
	Engineers do dangerous things in their work
+ Sources of information	My dad or brother
	My mum or sister
	Any other relative
	My friends
	My science teacher
	TV or the internet
	Science museums or shows

SECONDARY

Scale name	**Questions**
- *Attitudinal Scales*	
+ Satisfaction with school	I feel happy at school
	I like learning
	I really like to go to school each day
	I find that learning is a lot of fun
	I like to do extra work
+ Interest in enabling sciences	I would like to spend more school time doing science
	The science I learn at school is hard
	Learning science is important for my future career prospects
	I think science is exciting
	The science I learn at school makes me think
	Science is useful in every day life
	The science I learn at school is confusing
	The science I have learnt so far at school will be useful in my future career
+ Interest in mathematics	Maths is useful in every day life
	Learning maths is important for my future career prospects
	The maths I learn at school is confusing
	The maths I learn at school makes me think
	The maths I learn at school is hard
	I think mathematics is exciting

	The maths I have learnt so far at school will be useful in my future career
+ Interest in other school subjects	I would like to spend more school time using computers
	I think computing is exciting
	The computing I have learnt so far at school will be useful in my future career
	The English I have learnt so far at school will be useful in my future career
+ Interest in engineering	I like designing things
	I like testing my ideas
	I could be a scientist
	I like working as part of a team
	I like creating and constructing things
	I could be an engineer
	I like solving problems and experimenting
- *Information Scales*	
+ Understanding of engineering	Building a raft
	Catching fish to eat
	Testing a radio transmitter
	Helping sick people
	Designing a catapult
	Making fire
	Changing raw chemicals into products
	Managing a restaurant
	Developing equipment to monitor and control pollution
	Driving a train
	Maintaining children's playground equipment
	Constructing and testing aircraft and their components
	Modelling and overseeing the building of structures such as bridges, dams and towers
	Working in the stock market
	Assembling cars in a factory
	Designing electrical systems for electric generators
	Producing music CDs
	Devising and testing new medical equipment for hospitals
+ Perception of engineering	Engineering is interesting for men
	I admire people who do science or engineering
	Engineers are high achievers
	People who do science are geeks
	Women can become excellent engineers
	Engineers have interesting jobs
	Engineering is interesting for women
	People who do engineering are geeks
	You must go to university to become an engineer
	You must know a lot about computing to be an

	engineer
	You need to know maths and science to become an engineer
	It costs a lot to become an engineer
	You must be physically strong to be an engineer
	Engineers spend a lot of time working with machines
	Engineers work mostly outdoors
	Men can become excellent engineers
	Engineers make a lot of money
	A car mechanic is an engineer
	Engineers build things
	Engineers spend a lot of time working with people
	Engineers need to be good at thinking creatively
	Engineers make people's lives better
	Engineers do dangerous things in their work
+ Sources of information	My dad or brother
	My mum or sister
	Any other relative
	My friends
	My science teacher
	TV or the internet
	Science museums or shows
+ Effectiveness of outreach	Questacon
	Smart
	CSIRO
	Zoomobile
	Science and Engineering Challenge
	Re-engineering Australia
	Programs for gifted and talented students

TERTIARY AND PROFESSIONAL ENGINEERS

Scale name	**Questions**
- *Attitudinal Scales*	
+ Interest in enabling sciences/ mathematics/computing (past)	Science was an exciting field
	Mathematics was an exciting field
	Computing was an exciting field
	Science was useful in every day life
	Maths was useful in every day life
	Understanding science would be important for my future career prospects
	Understanding maths would be important for my future career prospects
	The science I learnt would be useful in my future career
	The maths I learnt would be useful in my future career
	The computing I learnt would be useful in my future career
	The English I learnt would be useful in my future career
+ Interest in enabling sciences/	Science is an exciting field

mathematics/computing (present)	Mathematics is an exciting field
	Computing is an exciting field
	Science is useful in everyday life
	Maths is useful in everyday life
	Understanding science will be important to my career prospects
	Understanding maths will be important to my career prospects
	The science I learnt in high school will be useful in my future career
	The maths I learnt in high school will be useful in my future career
	The computing I learnt would be useful in my future career
	The English I learnt in high school will be useful in my future career
+ Interest in engineering	I like designing things
	I like testing my ideas
	I could be a scientist
	I like working as part of a team
	I like creating and constructing things
	I could be an engineer
	I like solving problems and experimenting
- *Information Scales*	
+ Perception of engineering	Engineers have job security
	I admire people who do science or engineering
	Engineers are high achievers
	People who do science are geeks
	Engineers need to have good management skills
	Engineers have interesting jobs
	You must be academically gifted to become an engineer
	People who do engineering are geeks
	You must go to university to become an engineer
	You must know a lot about computing to be an engineer
	You need to know maths and science to become an engineer
	It costs a lot to become an engineer
	You must be physically strong to be an engineer
	Engineers spend a lot of time working with machines
	Engineers work mostly outdoors
	Remuneration makes it worthwhile to become an engineer
	Engineering is a ‘family friendly’ profession
	Only the top students in my Year 12 went on to study science and engineering

	People from higher income backgrounds are more likely to become engineers
	Engineers spend a lot of time working with people
	Engineers need to be good at thinking creatively
	Engineers make people's lives better
	Engineers do dangerous things in their work
+ Sources of information	Most of the things I know about engineering is provided by my lecturers
	Most of the things I know about engineering I read in textbooks and professional journals
	Most of the things I know about science and engineering I find out on TV or the internet
	Most of the things I know about engineering I read in newspapers
	Most of the things I know about engineering is provided by my family/friends
	I don't think it is easy to find out about engineering
+ Perception of gender imbalance	Engineering is interesting for men
	Women can become excellent engineers
	Engineering is interesting for women
	Men can become excellent engineers
- Communication and national investment	Any shortfall of engineers in Australia should be made up by skilled migration
	Any shortfall of engineers could be made up by assisting transition from engineering trades to the engineering profession
	If more students did maths and science there would be more students undertaking engineering degrees
	Other countries have greater success in encouraging more students into engineering degrees
	More effort should be taken to address gender imbalance in the engineering profession

TEACHERS AND CAREERS ADVISORS

Scale name	Questions
- Attitudinal Scales	
+ Students interest in enabling sciences/mathematics/computing	would like to spend more of their school time on science?
	admire people who do science or engineering?
	think that maths is important for their future career prospects?
	find science exciting?
	think that engineers are high achievers?
	find computing exciting?
	think that science is useful in everyday life?
	think that people who do science are geeks?

	think that science is important for their future career prospects?
	would like to spend more of their school time on computing?
	think that the science they have learnt so far will be useful in their future career?
	think that engineering is a highly respected profession?
	would like to spend more of their school time on mathematics?
	think that the english they have learnt so far will be useful for their future career?
	think that maths is useful in everyday life?
	think that people who do engineering are geeks?
	find mathematics exciting?
	think that the maths they have learnt so far will be useful in their future career?
- Information Scales	
+ Perception of engineering	You must go to university to become an engineer
	You must know a lot about computing to be an engineer
	You need to know maths and science to become an engineer
	You need to be physically strong to become an engineer
	It costs a lot to become an engineer
	Engineers spend a lot of time working with machines
	Engineers work mostly outdoors
	Engineers have interesting jobs
	Engineers make a lot of money
	A car mechanic is an engineer
	Engineers build things
	Engineers spend a lot of time working with people
	Engineers need to be good at thinking creatively
	Engineers make people's lives better
	Engineers do dangerous things
	Only very good students have a chance of becoming engineers
	Students from higher income backgrounds are more likely to become engineers
	Any shortfall of engineers in Australia should be made up by skilled migration
	If more students did maths and science there would be more students undertaking

	engineering degrees
	More effort should be taken to address the gender imbalance in the engineering profession
	Other countries have greater success in encouraging more students into engineering degrees
+ Sources of information	I find information about engineering through professional journals
	I find information about engineering through TV or the internet
	I find information about engineering through newspapers
	I find information about engineering through a professional association
+ Perception of gender imbalance	Engineering is interesting for men
	Women can become excellent engineers
	Engineering is interesting for women
	Men can become excellent engineers
- *Community, outreach and promotion*	Outreach programs are effective in influencing career decisions
	I have available adequate information about engineering for my students
	I have been adequately prepared to advise in engineering related areas
	Governments
	Universities
	Engineers Australia
	Industry
	Schools
	Parents
	Others, please specify

APPENDIX 4: DESCRIPTION OF OUTREACH PROGRAMS USED IN SURVEYS.

1. SCIENCE SHOWS

QUESTACON

The Australian National Science Centre, Questacon, has six outreach programs that regularly tour to schools. The longest running of these is *The Shell Questacon Science Circus*. This program tours around regional Australia for 18—20 weeks each year reaching approx 83,000 people. The program involves young science communicators presenting interactive school shows and setting up a public, hands-on exhibition in a community space. Professional development programs are also available for teachers. Among the aims of the program is 'to promote positive and relevant images of science and technology, scientists, and career opportunities' and 'provide resources and ideas for teachers in support of classroom curriculum'.

http://sciencecircus.questacon.edu.au/

SMART

The *SMART* program is an initiative of the University of Newcastle, and aims to bring science into the wider regional community. The target group is school-aged children but shows can be modified to suit audiences of any age. The program reaches approximately 20,000 annually and aims to 'Inspire, inform & involve people of all ages in science, mathematics, engineering & technology' and to 'encourage widespread ongoing participation and dialogue - public discussion, and personal interest, relating to S&T'

http://www.newcastle.edu.au/faculty-old/science-it/news/smart/

2. SCIENCE WORKSHOPS:

CSIRO

Australia's Commonwealth Scientific and Industrial Research Organisation (*CSIRO*) offers a number of school outreach programs including the Double *Helix Science Club* and the *Lab on Legs* program. The Double Helix Science Club is a within-school, extra-curricula program that can include experiments, visits from scientists or discussions about thought-provoking topics. The program is run by a teacher within the school using online and mailed resources from the CSIRO. The Lab on Legs program is a suite of touring interactive science presentations that reach approximately 100,000 students across Australia annually.

http://www.csiro.au/resources/ScienceClubs.html

ZOOMOBILE

Sponsored by the NSW Department of Education and Training, the Taronga *Zoomobile* has been specifically designed for schools that have difficulty coming to the Zoo. During a visit, the student audience will be able to meet, learn about and interact with native animals, encouraging them to take positive action in the conservation of our native wildlife. The Zoomobile is available to schools in and around the Sydney Region.

http://www.taronga.org.au/taronga-zoo/education/zoomobile/taronga-zoomobile.aspx

3. COMPETITIONS:

SCIENCE AND ENGINEERING CHALLENGE

The Science and Engineering challenge is a national outreach initiative of the University of Newcastle. The program reaches approximately 16,000 students annually and involves students competing against other school teams in a number of fun and exciting activities related to science, technology and engineering. The main aims of the Challenge are to 'engage and inspire year 9 and 10 students to study the enabling sciences in their senior secondary studies' and also to 'provide an insight into the teamwork aspects of solving STEM type problems'.

http://www.newcastle.edu.au/group/challenge/

RE-ENGINEERING AUSTRALIA

The ReEngineering Australia program offers outreach initiatives including the *F1 in Schools Challenge*. This initiative is a competition; open to all Australian secondary schools to design and manufacture CO2 powered model Formula One cars. Student teams compete against each other in a Regional, State and a National championship to determine the fastest and best engineered car for a chance to represent Australia at the annual F1inSchools World Championships. The program focuses on developing creativity and innovation through a structured engineering Design and Technology project and aims to raise the awareness of modern engineering design and manufacturing careers.

http://www.rea.org.au/pages/sch_summ.htm

4. PROGRAMS FOR GIFTED AND TALENTED STUDENTS

The purpose of these programs is to improve the outcomes of schooling for gifted and talented students, and thus they target a smaller group of the student population.

These programs incorporate a combination of grouping strategies, enrichment, counselling interventions and acceleration which are interdependent and strongly supported by research as central to maximising learning outcomes for gifted students.

http://www.curriculumsupport.education.nsw.gov.au/policies/gats/index.htm