SOUTH AUSTRALIA
Confronting the challenges facing science, technology, engineering and mathematics education and promotion
Technically Speaking
South Australia

Confronting the challenges facing science, technology, engineering and mathematics (STEM) education and promotion
Technically Speaking – South Australia
Confronting the challenges facing science, technology, engineering and mathematics education and promotion

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Acknowledgments
The South Australia Division Committee of Engineers Australia recognises the efforts of volunteer members and staff in developing this report. In particular it expresses its gratitude to two members, Hugh Orr FIEAust CPEng and John Agnew FIEAust CPEng, for their advice, guidance and support.
Our members have an ongoing and vital interest in promoting the science, technology, engineering and mathematics (STEM) education of South Australian students. The quality of the education students receive today will be reflected in the speed of economic and social progress of South Australia tomorrow.

South Australia’s economic future will be balanced by our ability to invest and reap rewards from a strong skills base and skilled workforce. The current shortage of members of the engineering team has the very real potential of hindering the economic and social progress of South Australia.

The relative decline in the STEM capability and literacy of South Australian school students sounds warning bells that we will simply not have enough STEM professionals to meet our future needs.

It is no exaggeration to say this is a very serious situation that requires decisive remedial action by the government.

Central to the creation of a strong skills base is our education system. Opportunities allowing children to excel in STEM subjects at school and to then choose further study in engineering are an investment in our future. There is no doubt that attracting more students to study and choose careers in STEM is vital for South Australia’s future and essential if the State is to achieve the targets of the South Australia Strategic Plan.

While South Australia has a comprehensive and inclusive education system that performs well under international comparisons, there is a need to mobilise schools to improve the STEM capability and literacy of students. Currently there is very little in the primary school curriculum to allow children to enhance their capability and literacy in STEM. In secondary school, many students lose interest in STEM subjects and despite showing potential, turn away from these courses. There is an urgent need for reprioritisation in schools, staffing and curricula to overcome this problem.

The following report examines the challenges facing STEM education and promotion in South Australia. It identifies areas where South Australia is already doing well and opportunities for improvement in the future.

Engineers Australia, the peak professional body for engineering practitioners, presents this report to provide input into future discussion and activities to enhance the technological capacity of the South Australian education system.

Bill Filmer AM FIEAust CPEng EngExec FRAeS
Division President, South Australia
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Executive Summary

This report is concerned with the declining participation in science and mathematics subjects in schools and the consequent reduction in the numbers of scientists, technologists, engineers and mathematicians available for employment in an expanding South Australian economy. Engineers Australia is particularly concerned with the shortage of engineers.

In order to meet the goals of the South Australian Strategic Plan significant improvements will need to be made to the resourcing of, and emphasis on, science, technology, engineering and mathematics (STEM) education in primary and secondary schools.

Improving the STEM capability and literacy of students is a prime purpose of school STEM education. People with these skills form a key component of the knowledge economy.

Omission of “Technology” from the list of key learning areas in the recent Draft National Declaration on Educational Goals for Young Australians is strongly opposed, as this removes the balancing focus on synthesis, design, and invention. Whilst science seeks answers to the question “why is it so?”, technology and engineering provide answers to the question “how can it best be done?”.

This report makes recommendations, primarily to the South Australian government, which will strengthen the STEM capability and literacy of students and encourage more students to enter related professions. This will enable the State to be more competitive in the knowledge-based economy.

To achieve the required outcomes the South Australian government will need the input and support of professional bodies, industry, and the education sector. Engineers Australia commits to working with government to enhance STEM education throughout the State. Our members are eager to offer their skills to address this vital issue and we encourage the government to take advantage of this resource.

It is no exaggeration to say that this is a very serious situation and that a much greater emphasis on STEM is required within the education system if the problem is to be overcome. This report identifies five major issues:-

- The shortage of skilled engineers is impacting on the ability of organisations to undertake and complete projects;
- The use of “science” as an umbrella term for STEM including engineering, which masks the function of engineering and the career opportunities available;
- The lack of training in, and commitment to, STEM among primary school teachers;
- The need for substantially increased STEM teaching resources and hands-on practical experience in secondary schools; and
- The lack of coordination of the many STEM resources available to ensure that comprehensive, relevant, and hands-on STEM education is delivered in South Australia.
Recommendations that address these issues are set out below.

**Primary School Education**

South Australia needs:

1. A much higher emphasis on STEM education at the primary level, with subjects taught systematically in all primary schools across the State;

2. To ensure that all primary school teachers have a trained capacity to teach STEM components of the primary school curriculum and to ensure there is a sufficient number of teachers with adequate knowledge to provide leadership within schools in these areas;

3. To increase resources (student time and teaching) to give a greater emphasis on STEM education at the primary level;

4. A fully supported professional development program for primary teachers in STEM methods and content sponsored and managed by the South Australian Government;

5. Primary school STEM programs that are taught in a manner that demystifies STEM and presents lessons in an engaging, hands-on manner and increases the use of excursions, visiting speakers and industry mentoring programs. Programs should demonstrate the social and environmental advantages provided by engineering;

6. To support the use of the term “engineering” as distinct from science to help students understand the relationship between science, engineering, technology and mathematics; and

7. STEM coordinators for clusters of primary schools.

**Secondary School Education**

South Australia needs:

8. An increase in Year 12 students, with equal gender representation, studying STEM subjects to effectively compete in the knowledge economy;

9. To increase the teaching resources in secondary schools with more teachers well trained in STEM;

10. To support the use of the term “engineering” as distinct from science so that students have a better understanding of the career choices open to them;

11. The provision of effective and ongoing professional development for teachers with a focus in STEM teaching;

12. To develop flexible pathways into the teaching profession to meet the needs of a diverse group of prospective candidates; and

13. To ensure that STEM curricula are developed in a creative and imaginative way (around core subjects) so that the full potential and excitement of STEM careers can be seen by students.
Connecting Stakeholders

South Australia needs:

14. The government to take on an effective coordination and facilitation role that aims to build existing programs facilitated by community and professional associations into a comprehensive STEM education program for all South Australian students;

15. Government, industry, community, professional associations and educators, including schools, vocational education providers and universities, to be better connected to support the professional development of teachers, STEM programs in schools and the delivery of both classroom and off-site STEM education; and

16. Research into what influences students to undertake further study in STEM subjects after secondary school. The results should give guidance on how to best design and deliver programs promoting STEM.
Introduction

Education in science, technology, engineering and mathematics (STEM) has been pivotal in the development of economically successful communities for at least two centuries and particularly since the 1950s. The continued wealth of our economy is supported by professionals who are trained and knowledgeable in the STEM domains. However, with the ever increasing range of subjects taught and the resulting reduction of school resources, the attention able to be given to STEM subjects has reduced significantly in the last 30 years.

Of Organisation for Economic Cooperation and Development (OECD) countries, Australia rates in the lower order of engineers per head of population. The root cause is too few students studying science, mathematics and technology subjects and/or pursuing these subjects at the vocational or tertiary level. The proportion of students able to pursue studies and careers in both engineering and science needs to be increased.

It is of considerable concern that in Australia and in South Australia, student enrolments in STEM subjects are falling. The average science teacher age profile is rising, science teacher numbers are falling and levels of funding for research and development, both government and privately funded, are below many other countries. These trends are well documented.

In primary school, STEM subjects are often taught on an ad hoc basis and, in some schools not adequately taught at all. Coherent STEM programs at the primary school level tend to be the exception rather than the rule. At the secondary level many students lose interest in STEM subjects and, despite showing potential, turn away from enabling science courses. This is inconsistent with the knowledge needs of an advanced technological society, and the issue will need to be addressed as a priority.

To emphasise STEM subjects within the education system is to recognise their fundamental roles in the processes of innovation and economic growth, and to recognise the transformations they are effecting in social and cultural life. All Australian citizens need to gain sufficient STEM knowledge to enable them to make informed decisions about their lives and to engage intelligently in the knowledge economy.

This report summarises the views and opinions of the Engineers Australia South Australia Division and draws from member interaction with the STEM teaching profession and with those involved in the promotion of STEM generally. Existing literature (both government and non-government) that documents the problems currently faced by the South Australian education system in providing STEM education to Australian youth has also been used.

Although Engineers Australia is aware of many additional issues at play in the primary and secondary education sector including those related to female participation in STEM, teacher training and registration, the age profile of classroom teachers, teachers teaching out of field and moves towards a national curriculum, these are beyond the scope of this report.

The aim of this report is to make specific recommendations, primarily to government, which have the potential to improve the STEM capability and literacy of South Australian students. The aim of the recommendations is to encourage more students to take up the professions within STEM fields and to enable the State to be more competitive in the knowledge-based economy.
Shortage of Engineers

Recent analysis of the Australian Census by Engineers Australia has shown that in the five years between 2001 and 2006, the number of engineers in the profession has decreased by around 6500 individuals, with more engineers having left the engineering workforce than having joined it.

By the 2011 Census, a conservative estimate of up to 70,000 retirements may have occurred from the engineering profession. Over the same time period, only 45,000 Australian graduates will have completed study in engineering.

Engineers Australia believes that the future Australian skills base will not cover retirements, let alone increased demand for engineering expertise driven by growth in the Australian economy and our transition to a climate friendly, knowledge based economy. Government focus on infrastructure renewal, the engineering inputs needed to support the resources boom and to tackle climate change all mean that demand for engineering expertise will only continue to increase.

2.1 Engineering skill shortages

The engineering profession is experiencing a significant skills shortage. The flow-on effects of low participation in STEM subjects at primary and secondary schools into the tertiary level have been inevitable. The annual output of Australian domestic students in engineering has remained almost static for more than 10 years.

Although there have been some increases in the number of undergraduate places in engineering, many more are needed. Additional university places are only part of the problem. We also need students willing to fill them and currently there is not a large enough pool of students interested in studying engineering and other STEM subjects.

Defining the size of the engineering skills shortage is difficult due to scarcity of relevant data. Some documented examples of the size of the skills shortage include:

- Australia faces a 20,000 shortfall of scientists and engineers by 2011.
- An additional 70,000 more workers required in the minerals industry by 2015.
- By 2017 the urban water industry will face a professional engineering skills gap of more than 80 percent, and engineering paraprofessional shortage of around 50 percent.
- In the electronics industry in South Australia, graduate rates from university and TAFE SA will fill less than one third of the vacancies available. (refer Appendix A)

In addition to the above, Engineers Australia undertakes a regular survey of engineering companies and has included questions on engineering skill shortages in the last two surveys. Anecdotal information that engineering skills shortages were harming the Australian economy was confirmed by both surveys, with 82 percent of businesses reporting that there were moderate to severe consequences.
Moderate problems with some monetary consequences were experienced by about half of this group (39 percent in 2006 and 40 percent in 2008) and major problems including project delays and major cost consequences by the other half (43 percent in 2006 and 42 percent in 2008). The share of businesses which reported that projects did not proceed because of engineering skills shortages was 6 percent in 2006 and 7 percent in 2008.6

What is particularly concerning in terms of the long term skills need of Australian industry is that graduation and migration rates are not meeting the current skills shortage, let alone compensating for retirements from the profession.

Currently migrants account for more than half of growth of new entrants to the Australian engineering profession each year. Since 2003-04, the number of engineers working in Australia on 457 temporary visas has more than doubled, increasing from 810 to 1,9707.

The significance of these changes can be put into perspective by comparing migration to the output of Australian universities. In 2006, there were 5044 new four year Bachelor of Engineering graduates. The supply of new engineers to the Australian workforce is the sum of university output and immigration. Thus in 2006, the supply of new professional engineers was 11,134 (5044 new domestic bachelor of engineering graduates and 6090 new migrant engineers) with migration accounting for more than half of new supply.

Engineers Australia recognises the significant contribution made by migrant engineers to Australia’s competitiveness and economic growth. Migrant engineers are a vital element in generating new ideas and approaches to engineering, and for providing skills where there are shortages.

However, there is an acute need for the Australian education system to produce more engineering graduates. Countries experiencing labour shortages and population pressures are directing the focus toward skilled migration. Australia’s reliance on migrant engineers to meet skills shortages leaves industry and our innovation system vulnerable.

The engineering shortage is an issue across all disciplines of engineering. The key message being communicated by Australian industry is that we need more engineers. Engineers Australia believes that school-room solutions to the engineering shortage need to be developed and that the numbers of students studying STEM subjects at secondary school and into university need to be increased.

There is no doubt that the employment of well-qualified STEM practitioners pays off in terms of a State’s competitiveness. This is especially so in relation to high quality, high technology industries. The use of highly skilled engineers increases a company’s profitability and through it, the State’s productivity.

Higher productivity can lead to higher economic growth. Conversely, fewer and less-skilled engineers and scientists and the associated diminished innovative activity adversely affects domestic market share for local goods and services, decreases international trade share, and erodes product quality and variety.

The skills shortage in engineering expertise needs to be counteracted as a priority and rebuilding the South Australian STEM skills base from primary school up should be the key pillar of any skills shortage mitigation program. Appendix B demonstrates how the goals of the South Australian Strategic Plan are highly dependent on STEM.
2.2 Engineering education

There is a broad range of skills and services that fall within the ambit of engineering and not all of these are provided by “professional” (four year university trained) engineers. Most professions, including engineers, acknowledge the broad scope of possible practice within them, and allow for differences in qualifications and for specialisation in areas of work.

For instance, engineers can be divided into three main occupational categories: professional engineer, engineering technologist and engineering officer/associate. The occupational categories can be differentiated by the length of education and training undertaken by the engineer (See Appendix C for a full description of the occupational categories).

Professional engineers, technologists and officers/associates come together in different combinations to undertake projects and programs. Their activities and competencies are often closely inter-related and it is difficult and sometimes artificial to say where the responsibilities of one category end and those of the next category begin.

There are activities that could be undertaken, in different circumstances, by members of any of the three categories. Other activities are clearly the province of one category but not of another – for example, the province of a professional engineer but not an engineering associate, or vice versa.

The higher education sector currently has the sole responsibility for educating Professional Engineers (four year awards leading to a Bachelor of Engineering) and Engineering Technologists (three year awards leading to a Bachelor of Technology). The higher education sector also shares responsibility with the VET sector in providing award programs for Engineering Officers/Associates through two year Associate Degrees and Advanced Diplomas.

Table 1: Domestic engineering graduates, Australia, 1994-2006

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Note: The protocols followed by the provider of TAFE data means that TAFE totals will not sum.
Source: Data supplied by DEEWR and the National VET Provider Collection NCVER

Generally, enrolments in engineering are low across all education levels. More graduates are needed and mechanisms to encourage school leavers to choose engineering education options must focus on promoting all the available education and career pathways within the engineering profession.
2.2.1 Professional Engineers

Engineering university graduates are the main domestic supply from which new demand for engineers and the replacement of engineers retiring from the workforce, must be met. Although there have been some increases in the number of university places in engineering, many more are needed.

Table 2 shows the number of engineering graduates per year from Bachelor of Engineering (four year) courses across Australia.

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Source: Data supplied by DEEWR and excludes surveying/geomatic engineering

Nationally, graduations are not meeting industry skills needs. In South Australia, the number of professional engineers graduating each year has been declining (from already low levels) despite ongoing calls from industry that engineering skills shortages are negatively impacting on business operations.

As shown in Table 3, in 2006 only 223 people graduated from Bachelor of Engineering courses in South Australia.

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<td>2006</td>
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Source: Data supplied by DEEWR and excludes surveying/geomatic engineering

2.2.2 Engineering Technologists

While the graduation of engineering technologists has increased across the nation over the past decade, South Australia has experienced a steady decline over the past five years.

Due to the relatively low number of engineering technologists graduating from three year Bachelor of Technology courses, many universities across Australia have ceased enrolling new students in three-year courses.

The number of enrolments in engineering education is dependent on two factors: the number of qualified applicants and the proportion of these who are motivated towards engineering. University engineering schools have seen very low demand for three-year courses from potential students and have responded by reducing course offerings.

Engineering Schools are now primarily focused on providing four-year professional engineering courses. As Tables 2 and 4 illustrate, while 5044 professional engineers graduated in 2006, only 809 engineering technologists graduated Australia wide.
In an environment where unit offerings within engineering schools are driven by student demand, there is a growing concern from engineering employers that the three-year Bachelor of Technology degree is in danger of disappearing because of small student numbers. In South Australia, graduation levels are low, with only 16 engineering technologists graduating in 2006.

### Table 5: Bachelor of Technology graduates, three year degrees, South Australia

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<td>23</td>
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<td>21</td>
<td>16</td>
</tr>
<tr>
<td>Total Australia</td>
<td>576</td>
<td>550</td>
<td>523</td>
<td>517</td>
<td>716</td>
<td>809</td>
</tr>
</tbody>
</table>

Source: Data supplied by DEEWR and excludes surveying/geomatic engineering

### 2.2.3 Engineering Officers/Associates

There has been a blurring of the boundary between the delivery of vocational (VET/TAFE) and university education with engineering associates now being able to undertake study at both VET and University institutions.

While Associate Degree offerings at the university level declined in the mid 1990s, graduation numbers have increased again since 1999. Vocational data, which is only available from the National Centre for Vocational Education and Research (NCVR) from 2002, shows that graduations from the VET system have been reasonably stable with around 3000 students graduating nationally from Associate Degrees each year, as shown in Table 6.

### Table 6: Engineering Officer/Associate graduates, University and VET/TAFE, Australia wide

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Uni Men</td>
<td>315</td>
<td>313</td>
<td>186</td>
<td>65</td>
<td>62</td>
<td>129</td>
<td>106</td>
<td>162</td>
<td>176</td>
<td>141</td>
<td>115</td>
<td>134</td>
<td>106</td>
</tr>
<tr>
<td>Uni Women</td>
<td>23</td>
<td>17</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>16</td>
<td>6</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>9</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>VET Men</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>2810</td>
<td>2850</td>
<td>2905</td>
<td>2898</td>
</tr>
<tr>
<td>VET Women</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>405</td>
<td>390</td>
<td>420</td>
<td>550</td>
</tr>
<tr>
<td>Total</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>3401</td>
<td>3396</td>
<td>3449</td>
<td>3339</td>
</tr>
</tbody>
</table>

Source: Data supplied by DEEWR and the National VET Provider Collection NCVER

Associate degree offerings at South Australian universities are extremely small, with only 2 engineering associates/officers graduating in 2006.

Additionally, associate degree offerings within the VET system in South Australia suffer from fluctuations in student graduations with a high of 345 graduates in 2002, to a low of 15 graduates in 2006 as shown in Table 7.
Table 7: Engineering Associate/Officer graduates, University and VET/TAFE, South Australia

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>University</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>na</td>
</tr>
<tr>
<td>VET/TAFE</td>
<td>345</td>
<td>195</td>
<td>175</td>
<td>215</td>
<td>na</td>
</tr>
<tr>
<td>South Australia</td>
<td>348</td>
<td>196</td>
<td>175</td>
<td>215</td>
<td>na</td>
</tr>
<tr>
<td>Australia</td>
<td>3401</td>
<td>3396</td>
<td>3449</td>
<td>3586</td>
<td>3169</td>
</tr>
</tbody>
</table>

Source: TAFE data not yet available at State level for 2006
Source: Data supplied by DEEWR and the National VET Provider Collection NCVER

It is clear that both the university and vocational education systems need to increase engineering graduation numbers in order to meet industry needs. The problems of attracting students to study engineering are equally valid for both the university and VET/TAFE system

South Australia needs capable students who are willing to fill engineering education and training places. With an ageing population and growing economy it is no surprise that both graduating and experienced engineers are in high demand.

For the long-term success of the South Australian economy and to meet the challenges of the future, the supply of “home grown” engineers must be increased.
3 Perceptions of engineering

Engineers Australia is concerned that insufficient numbers of students are continuing with STEM subjects in secondary school and taking pathways to STEM related careers in science and engineering.

With regard to engineering, Engineers Australia believes that two key problems are affecting this situation:

- The use of science as an umbrella terms for engineering; and
- Perceptions of engineering as a career.

Engineers Australia believes that fewer students consider a career in engineering because most students – and their parents and teachers – do not understand the function of engineering and the career opportunities available. The experiences of young engineers reproduced at Appendix D are revealing. In addition, a brief outline of “What is Engineering?” is provided at Appendix E.

Engineering, science, technology and innovation are very closely linked and interrelated but they do not have the same meaning. Engineering is a creative activity based on science, mathematics and technical knowledge applied with art, skill and the management of both risk and stakeholder expectations in a way that is sustainable for the benefit of future generations. Engineers marshal science and technology to create new artefacts and services. To engineer literally means “to make it happen”.

As long as science remains the umbrella term used to describe engineering or technology, engineering remains hidden and therefore less attractive as a profession. Engineering is distinct from science, yet they are natural partners.

The concern therefore, is that anyone using the term science interchangeably with engineering is clearly not differentiating the contribution each has to the other. Unless the distinct differences and synergies are recognised, neither is well served and students will be unable to identify engineering as a valued and rewarding career option.

The importance of making this distinction among students has been overlooked in the Draft National Declaration of Education Goals for Young Australians. This document, developed by Australian Education Ministers in collaboration with the Catholic and Independent school sectors, aims to set the direction for Australian schooling for the next ten years. While “Science” is retained as a key learning area, “Technology” has been dropped.

This proposal, if implemented, would set STEM education back, not forward, as it would remove the distinction between the discovery philosophy of “Science” and the complementary design and build philosophy of “Technology”, which closely relates to engineering.

Whilst science seeks answers to the question: “why is it so?”, technology and engineering provide answers to the question ‘how can it best be done?’. Removal of “Technology” would have the counter-productive effect of de-emphasising creativity, design, innovative capability and wealth creation at a critical time for the Australia economy.
The engineering profession, peak professional bodies, tertiary engineering educators and governments all need to take some responsibility in providing teachers with the necessary tools to better inform students of the opportunities provided within an engineering career.

Engineers Australia has been encouraged, however, by the inclusion of engineering in the “Prime Minister’s Science, Engineering & Innovation Council (PMSEIC)” and the following statement by the Hon. Peter McGauran, former Federal Science Minister, in 2002:

“Science plus engineering is the foundation of innovation, which is the key to Australia’s future prosperity.”

Also during 2002, Victorian engineers, Dr Brian Lloyd and Mr Michael Rice successfully proceeded against the ABC Television program, Catalyst.

Lloyd and Rice alleged that Catalyst attributed the project profiled by the program to scientists without mentioning the fact that the great bulk of the work had been done by engineers, with some input from scientists. In this way, an authoritative television program that sought to inform its viewers about developments in various disciplines had inadvertently diminished the profession of engineering.

The ABC defended the use of the umbrella term scientists on the grounds it included a number of professions without the need to itemise them. “Scientist”, the ABC said, was a term easily understood by a diverse audience and was short and succinct. However, the independent complaints review panel found the complainants justified in their objections to engineers and scientists being lumped together, and the work of engineers being incorrectly attributed to science.

It is in the nation’s interest that young Australians perceive engineering to be a desirable career choice. As outlined by Dr Robin Batterham, then Chief Scientist of Australia in the report *The Chance to Change*:

“*Australia’s success as a knowledge economy is dependent on a highly skilled, informed and scientifically literate workforce that receives a strong foundation of science, engineering, technology and mathematics knowledge throughout their primary and secondary education.*”

This view also finds an ally in the House of Representatives Standing Committee on Science and Innovation report, *Riding the Innovation Wave*. Recommendation 6 stated the Commonwealth Government, in conjunction with the States should:

- assess the efficacy of current efforts to improve students’ knowledge of, and interest in, technology-oriented careers, with a view to introducing specific schemes to encourage young people to undertake the study of engineering and technology; and
- promote the interest of school students in such careers by publicising the achievements of successful engineers and technologies.

Beyond concerns about the status and perception of engineering as a career outlined above, Engineers Australia believes that there are a number of other contributing factors related specifically to primary and secondary education, the school environment, the teaching profession and government, industry and professional linkages. These issues are discussed in detail throughout the following sections.
Primary school education

While there is debate on how STEM can be best handled by primary level teachers, including the type of specialist support that is needed, the importance of students developing an interest in STEM subjects from an early age cannot be overstated. This first interest is developed in primary schools. It is very positive that two of the eight key learning areas in the South Australian primary school curriculum cover “science” and “design and technology”.

While this would appear to ensure that these subjects are taught systematically and comprehensively there is a heavy onus in the school system for teachers to develop their own course design, construct learning tasks and to map the curriculum to fit into daily classroom events. This gives teachers considerable freedom in designing syllabuses, adapting curricula and selecting learning resources.

This system functions effectively when teachers have an interest and suitable training in STEM subjects. Unfortunately it also provides teachers with the autonomy to simply leave some STEM subjects, like science, out of the classroom if the teacher is not comfortable teaching the subject matter. This results in instances where some subjects, especially science, are being taught poorly, or not being taught at all. Coherent science programs at the primary level still tend to be the exception to the rule.

This situation occurs, despite there being a wide range of support resources already available to teachers and schools to strengthen their own knowledge, capability and capacity to deliver first class STEM education to students in South Australia (see Section 6 on connecting stakeholders).

In STEM areas, teachers have access to effective teaching and learning strategies through the established curriculum resources of education departments and the broader resources made available, for example, by professional associations often via the Internet. These resource banks make it possible for teachers to draw on a vast array of resources, both national and international.

A good example of a resource available to support the teaching of STEM is the ‘Primary Connections’ program delivered by the Australian Academy of Science and the Australian Government Department of Education, Employment and Workplace Relations.

Ensuring that STEM subjects are being taught in all primary schools across South Australia is essential if the government is serious about being a world leader in the knowledge economy and achieving the goals of the South Australia Strategic Plan.

4.1 Class time devoted to STEM

Within the primary curriculum there is a strong focus on the key learning areas of English and Mathematics. The report, *The Status and Quality of Teaching and Learning of Science in Australian Schools* prepared by the Department of Education Training and Youth Affairs (DETYA) in 2000, outlined that of the primary teachers surveyed:
Science, Technology, Engineering and Mathematics: Education and Promotion

- Science subjects were taught for an average of 59 minutes per week;
- 29 percent of teachers rated the level of equipment available in their schools for teaching science as "poor";
- Only 1 percent of teachers had a visiting STEM speaker in their classroom over the 12 month period; and
- Only 4 percent of teachers had taken their students on an excursion to a museum, zoo or science centre.

In light of these results, it is not surprising that many students are unable to make connections between school science education and the world outside of the classroom.

When asked "What factors limited the quality of science teaching in their schools?", 39 percent of teachers listed resources, 22 percent highlighted inadequate time for the preparation needed for teaching science and 17 percent outlined that they had an inadequate background to teach science.

A lack of adequate professional development was also indicated by 33 percent of teachers as a reason why they lacked the confidence and competence to teach STEM subjects to their students. The responses from teachers indicate that there is limited knowledge of the resources and support available for the teaching of STEM subjects.

Despite these problems, students indicated that on the whole they enjoyed science subjects and over a third indicated that their teacher “always makes science fun”. A third of students reported that they are “never bored” during science lessons but a quarter reported that they are “never excited” about what they do.

### 4.2 Primary teacher qualifications

There are pathways to encourage the teaching of STEM at primary school within the existing undergraduate Bachelor of Education degree. A double degree in science and education along with a diploma following a science or engineering degree are also pre-existing options for primary and secondary teachers intending to develop a speciality in STEM education.

It appears that while there is no shortage of opportunities for prospective primary teachers to study STEM as part of their education degree, few are doing so, with the majority of students choosing non-scientific discipline areas.

A review of undergraduate primary education by Lawrence and Palmer\(^\text{14}\) found that only a quarter of university programs had compulsory science foundation subjects especially designed for primary students, and no technology subject options existed. Some university courses gave students the option to study STEM subjects, but these were offered by science, mathematics and engineering faculties and were not tailored for education students.

Primary teacher education programs need to offer students clear opportunities to specialise in STEM teaching, and teaching students should be encouraged by universities and education authorities to pursue those opportunities.
To support those teachers already teaching within the primary system without appropriate qualifications in STEM, specialist STEM teachers are needed to act as leaders within schools. The appointment of STEM coordinators for clusters of primary schools should also be considered. Coordinators could work across schools stimulating STEM teaching and learning while ensuring that STEM teaching is articulated well by teachers and adequately supported.

Undergraduate STEM students and STEM researchers could also be engaged to assist school students and teachers, through individual tutoring with students, by assisting with lessons alongside teachers, organising excursions to STEM facilities and giving presentations to students about their work and interest in STEM.

Scholarships and other incentives will also need to be considered for primary school teachers without a STEM background, to undertake further study and professional development to advance their knowledge and skills in STEM teaching.

4.3 Opportunities for improvement

Engineers Australia believes that STEM education in primary school should ensure that children are:

- Encouraged in imaginative ways to explore how science and engineering impact society and underpin a sustainable lifestyle;
- Taught STEM concepts in a manner that demystifies them and presents lessons in an engaging, hands-on manner;
- Able to see engineering as a rewarding and challenging career that is made possible by success in science, mathematics and technology subjects at school; and
- Taught by teachers with the confidence and capacity to teach STEM without feeling they are out of their depth.

In primary school, STEM courses should aim to motivate students to continue to study STEM subjects in high school. Greater use should be made of the support offered by professional associations, for example Engineers Australia’s EngQuest program. More school excursions to STEM projects should be supported and guest speakers should be regularly invited into classrooms.

A fully supported professional development program for primary teachers in science methods and content should be sponsored and managed by the South Australian Government and delivered collaboratively through the university sector supported by community and professional organisations, such as the Science Teachers Associations of Australia.

Members of the Engineers Australia Special Interest Group, Young Engineers, have provided an outline of what encouraged them to study engineering at university.

Katherine Ward, a first year engineering student, states that her decision to study environmental engineering in 2004 was influenced by a school visit by an environmental engineer to her year seven class. Further comments provided by the Young Engineers group are provided at Appendix D.
Box 1: Recommendations - Primary school education

South Australia needs:

- A much higher emphasis on STEM education at the primary level, with subjects being taught systematically in all primary schools across the State;

- To ensure that all primary school teachers have a trained capacity to teach STEM components of the primary school curriculum and to ensure there is a sufficient number of teachers with adequate knowledge to provide leadership within schools in these areas;

- To increase resources (student time and teaching) to give a greater emphasis on STEM education at the primary level;

- A fully supported professional development program for primary teachers in STEM methods and content sponsored and managed by the South Australian Government;

- Primary school STEM programs that are taught in a manner that demystifies STEM and presents lessons in an engaging, hands-on manner and increases the use of excursions, visiting speakers and industry mentoring programs. Programs should demonstrate the social and environmental advantages provided by engineering;

- To support the use of the term “engineering” as distinct from science to help students understand the relationship between science, engineering, technology and mathematics; and

- STEM coordinators for clusters of primary schools.
Year 12 student numbers across Australia grew from 177 681 students in 1995 to 199 611 students in 2004. In this same period the percentage of Year 12 students studying science subjects have steadily declined, as shown in Figure 1.

![Figure 1: The proportion of Year 12 students studying engineering enabling subjects](chart)

There has also been a national decline in the percentages of students studying various combinations of science subjects. Of particular concern is the decline in students studying both chemistry and physics, given that these subjects are the foundation for further STEM studies.

Fewer than 10 percent of the 2001 Year 12 cohort undertook a course of study that included both chemistry and physics. This is compared with 11 percent in 1998, 13 percent in 1993 and 15 percent in 1990. In 2001, only 10 percent of Year 12 students had completed the prerequisites required to study engineering at university.¹⁵

For mathematics a decline is also evident. As represented in Figure 2, in South Australia from 1995-2004 the percentage of Year 12 students taking advanced mathematics showed a small rise from 11.8 percent to 13.4 percent in 1997 but then fell to 9.1 percent in 2004.
The average across all Australian States and Territories showed a downward trend, with a small improvement in 2003-04, reducing from 14.1 percent to 11.7 percent over the same period.

During the period 1997 to 2000, South Australia matched the Australian average of the proportion of Year 12 students studying advanced mathematics. It is alarming that in four short years South Australia has moved from the national average, to being 22 percent below the national average.

5.1 The link between Year 12 subject choice and university enrolments

Unlike many other fields of study at the tertiary level, senior school study of science and mathematics is a prerequisite for study in many post-school STEM fields, and essential for further study in engineering.

There is a strong connection between specialising in science in the final year of secondary school and continuing study in a STEM-related field at university. In 1998, 86 percent of students studying both chemistry and physics continued on to university, as did 77 percent of those students studying any two science subjects. Both groups were much more likely to continue to study at university than those who did not study science subjects at all.16
The participation rates of schools students in the enabling sciences have a broad and far reaching effect. While participation rates are a key indicator of the potential number of students entering STEM courses in vocational education and at university, ultimately it is a representation of how well prepared Australia and South Australia is to meet the needs of the knowledge economy.

Each Australian State and Territory, including South Australia, should be aiming to significantly increase the number of students studying STEM subjects in Year 12. A step in the right direction can be found in the 2007 update of the South Australia Strategic Plan. A target has been set to increase by 15 percent, the number of Year 11 and 12 students studying at least one of mathematics, physics or chemistry subjects by 2010.

The 2008 update of the South Australian Strategic Plan reports that the number of students successfully completing Year 12 mathematics, physics or chemistry subjects has further decreased and it is unlikely that the 2010 target will be met. This disappointing result highlights that changes are required in the education system to address this critical problem.

5.2 Student expectations

The Status and Quality of Teaching and Learning of Science in Australian Schools report identified that generally, students entering high school have a high level of enthusiasm for STEM subjects.

Unfortunately, this excitement is rarely maintained beyond their second year in high school. Expectations of an interesting and challenging science curriculum are not met and students are faced with a “chalk and talk” style of teaching that does not meet their needs of a hands-on practical experience. By their second year in high school, positive experiences students may have been exposed to in primary school have evaporated and many students begin to feel that STEM subjects are too hard or are irrelevant to their everyday lives.

Australian results from the Trends in International Mathematics and Science Study (TIMSS) which reports on the learning outcomes of students at ages nine, thirteen and in their final year of secondary school revealed that Australian students’ attitudes towards science deteriorate considerably between primary and secondary school. When answering the question “I enjoy learning science”, the numbers of students responding “disagree” and “strongly disagree” increased from 19 to 22 percent in primary school and from 32 to 37 percent for lower secondary students. Almost 40 percent of secondary students also indicated that they “never got excited about what they do in science”.

Results from the TIMSS Video Study gave the following overall picture of the teaching of mathematics in the typical Year 8 classroom:

"The teacher talks a lot, the students mainly reply with very few words, most of the time students work, using only paper and pencil, on a repetitive set of low level problems, mostly presented via a board or textbooks or worksheets; discussion of solutions is mainly limited to giving the right answer or going through the one procedure taught. There is little or no opportunity for students to explain their thinking, to have a choice of solution methods or to realise that alternative solution methods are possible and very few connections are drawn between mathematical ideas, facts and procedures."

"
The TIMSS results suggest that improvements can be made in the teaching of mathematics subjects in Australian schools. In particular, South Australian students would benefit from more class discussion of alternative solutions and more opportunity to explain their thinking. Opportunities for students to appreciate the connections between mathematical ideas and to understand the “real world” applications behind the problems they are working on are also needed. Similar problems exist in the teaching of other STEM subjects.

The Status and Quality of Teaching and Learning of Science in Australian Schools (DETYA) \(^{19}\) report highlighted that the most significant factors limiting the quality of secondary STEM teaching were inadequate resources, and a lack of time for teachers to prepare, reflect and collaborate on curriculum and class size.

These factors were also identified as key problems faced by primary teachers attempting to teach STEM subjects. The data in Table 4 reproduced from the study also highlights that the use of excursions, visiting speakers and practical experiments is limited in secondary education to similar levels found in primary classrooms:

<table>
<thead>
<tr>
<th>Item</th>
<th>Never</th>
<th>Once a term or less</th>
<th>Once a month</th>
<th>Once a Week</th>
<th>Nearly every lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>In my science class:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We learn about scientists and what they do</td>
<td>35</td>
<td>28</td>
<td>24</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Do practical work outside in the schoolyard, the beach or in the bush</td>
<td>43</td>
<td>37</td>
<td>17</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Have excursions to the zoo, museum, science centre or places like that</td>
<td>76</td>
<td>21</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>We have visiting speakers who talk to us about science</td>
<td>84</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**5.3 Secondary teacher qualifications**

Many issues are at play within the teaching profession that are beyond the scope of this report. However, like teachers in the primary education sector, teachers at the secondary level need support to upgrade their skills where they are working without appropriate qualifications in STEM. Scholarships and other incentives will need to be considered.

Flexible pathways into the teaching profession will also need to be fostered. Bringing workers from other professions into teaching will require new training structures and the skills of teachers will need to be maintained through a fully supported professional development system.

As for primary school, undergraduate STEM students and STEM researchers could also be engaged to assist schools, students and teachers. Engineers Australia's South Australia Division and other STEM professional groups, including the Science Teachers Association, already have a number of programs to support STEM education in South Australia which could be looked to as a template.
5.4 Opportunities for improvement

Creating flexible pathways into the teaching profession, ensuring that teachers are not teaching out of field and working towards a compulsory professional development program, are all key opportunities to improve the secondary education system in South Australia.

Additionally, the DETYA report identified that the key approaches to improving secondary STEM teaching (in order of relevance) were: more time for planning, reflection, collaboration with colleagues, younger and more skilful teachers, more professional development, smaller classes for practical work and improved budgets and resources.

Discussions on the development of a national curriculum, particularly in STEM areas, must look to existing programs for inspiration. For example, the Australian Academy of Technological Sciences and Engineering (ATSE) has developed a curriculum-based secondary school science and technology program known as STELR, an acronym for Science and Technology Education Leveraging Relevance. The Department of Education and Children’s Services will be supporting two South Australian secondary schools to receive equipment and curriculum materials and to trial the project in 2009. Engineers Australia strongly supports this development.

New curriculum initiatives, such as STELR, will need to be made available in all secondary schools if the declining national STEM participation rates are to be reversed.

Box 2: Recommendations - Secondary school education

South Australia needs:

- An increase in Year 12 students, with equal gender representation, studying STEM subjects to effectively compete in the knowledge economy;

- To increase the teaching resources in secondary schools with more teachers well trained in STEM;

- To support the use of the term “engineering” as distinct from science so that students have a better understanding of the career options open to them;

- The provision of effective and ongoing professional development for teachers with a focus in STEM teaching;

- To develop flexible pathways into the teaching profession to meet the needs of a diverse group of prospective candidates; and

- To ensure that STEM curricula are developed in a creative and imaginative way (around core subjects) so that the full potential and excitement of STEM careers can be seen by students.
Connecting stakeholders

Without an effective ongoing dialogue between the STEM community including professional associations, the teaching profession, curriculum developers and education facilities, the right mix between content and up-to-date knowledge needed by teachers will be compromised. The importance of this dialogue is heightened by the rapid advances in STEM, which cause the foundation skills of STEM teachers to lose currency quickly.

Government, industry, professional associations and educators including both schools, vocational education providers and universities need better linkages facilitated to support the professional development of teachers, STEM programs in schools and the delivery of both classroom and off-site STEM education.

Many government, community and professional organisations including Engineers Australia are involved in providing STEM education to students in South Australia but there is little or no coordination and an effective overall framework is lacking.

These resources within the community could be more effectively called on to assist with some of the problems identified by this report. There is a vital role for the South Australian government as a coordinator and facilitator.

Options include using retired STEM teachers, engineers and other technical professionals to assist practising teachers with advice, counselling, training and lightening the workload. Many programs along these lines are already being run in South Australia.

However, there is a lack of coordination and the same level of assistance or exposure to STEM programs is not provided to all schools or students within the State. The South Australian government has an opportunity to build on the work of community organisations and professional associations like Engineers Australia to better support STEM education in South Australia.

Some examples of the many excellent programs promoting STEM currently in operation in South Australia include:

- **National Science Week and National Engineering Week** have both grown into large programs, with events and strong public exposure in the media. This has undoubtedly raised the public awareness of STEM and reached students;

- **Government funded groups and projects** aimed at the promotion of STEM include the Australian School of Mathematics and Science and the Technology School of the Future. The South Australian Government has provided resources for these projects. At the Federal level CSIROSEC (including Double Helix) provides hands on experimental science in the laboratory as an adjunct to schools education.

- **Competitions** including Robo Cup, the Oliphant Science Awards, Tournament of Minds, the Science and Engineering Challenge and Engineers Australia’s EngQuest are all effective in raising community awareness of STEM.
The Robot Peer Mentoring Program conducted by Associate Professor Brenton Dansie of the University of South Australia involves undergraduate engineering students from the three universities delivering 20 hours of curriculum to Year 10 students. It includes the important element of mentoring and role models as well as hands-on experience in electronics and participation by students in industry projects. The program is supported financially by industry the Premier’s Science and Research Council and the University of South Australia.

Australian Science and Mathematics School (ASMS) is based on the Flinders University campus and is providing opportunities for Year 10-12 students to undertake studies with a special emphasis on mathematics and science, particularly the new sciences such as Information Technology, Biotechnology and Nanotechnology. Students have access to university facilities and laboratories, and university staff contribute to the teaching programs. ASMS also provides an important service in the professional development of secondary school science teachers, and in curriculum development.

The Bragg Initiative is a government initiative aimed at raising the profile of science and includes a number of different programs two of which are aimed at supporting science in the schools environment. The “Twinning Program” is an online mentoring program that enables scientists from universities and research organisations to be linked or ‘twinned” with teachers of science for all student groups including both primary and secondary. The second program, “Neuroscientists, Educators and Learning” is a series of projects developed between the Department of Education and Children’s Services and the South Australian Neuroscience Institute (SANI) to establish professional development environments and working links between scientists and teachers.

It is important in teaching and promoting STEM to demonstrate its relevance to students’ lives. STEM has to compete with many other subjects that may appear more relevant to students and therefore “relevance” should be a part of all programs whether inside or outside the classroom. Mentoring and role model exposure would be very effective in breaking down the barriers to STEM and showing how it can open career pathways. These initiatives, particularly the competition-based programs, are well received by both teachers and students.

Many of the above programs have developed in the vacuum created by having no State-wide coordinated programs which are classroom based within the education system. In many respects they are “stop-gap” measures for an inadequate approach to STEM education within the current education system.

While Engineers Australia will continue to work to bring EngQuest and the Science and Engineering Challenge to a greater number of students in South Australia, what is needed is greater coordination of the activities which are already occurring, to ensure all students are exposed to hands-on STEM education opportunities.

There is also a need to ensure that effective programs are given ongoing support. For example the Science @ Work initiative delivered by the Investigator Science and Technology Centre where students were invited to industry facilities to see the processes carried out on site has been discontinued.
The closure of the Investigator Science and Technology Centre was a great disappointment, especially considering that no centralised and coordinated program has been established in its place. This is a major shortcoming of STEM education within South Australia that needs to be rectified as a matter of urgency.

Additionally, while all these programs are effective in promoting STEM at some level, there is no adequate research into what influences students to continue into vocational education or university in STEM subjects. Research into student motivators should be done as a matter of urgency to give guidance to government, industry, community and professional organisations on how best to design and deliver programs promoting STEM.

Much is being done to provide STEM education to students in the State and opportunities to build on current programs are significant. Unfortunately, many of these programs will continue to operate in isolation, reaching only small numbers of students at South Australia schools.

The opportunity exists for the South Australian government to take the lead to oversee and help coordinate the fragmented approach of STEM education programs in South Australia. Unless this opportunity is taken, South Australia will remain without a comprehensive STEM education program for all students in South Australia.

A positive example of the approach that can be taken is the SA Great Speakers in Schools program. This program offers a centralised and coordinated approach to provide students with access to hear first hand from practising professionals from a range of occupations.

It is recognised that the South Australian government provides a significant level of funding to support numerous STEM education programs, including those offered by Engineers Australia. However, the urgent issue that needs to be addressed is the lack of coordination and facilitation to ensure all South Australian students have the opportunity to participate in STEM programs.

As the government takes on a facilitation role and support for STEM education is refocused, additional financial support or a rationalisation of existing expenditure may need to be undertaken by the Government.

Funding a partnership between industry, community, professional associations and educators, including schools, vocational education providers and universities to deliver a comprehensive STEM education for all South Australian students should not be seen by the government as a cost. Instead it should be considered an investment in South Australia’s future which will have long term benefits for the South Australia community and economy.
Box 3: Recommendations - Connecting stakeholders

South Australia needs:

- The government to take on an effective coordination and facilitation role that aims to build existing programs facilitated by community and professional associations into a comprehensive STEM education program for all South Australian students.

- Government, industry, community, professional associations and educators, including schools, vocational education providers and universities, to be better connected to support the professional development of teachers, STEM programs in schools and the delivery of both classroom and off-site STEM education; and

- Research into what influences students to undertake further study in STEM subjects after secondary school. The results should give guidance on how to best design and deliver programs promoting STEM.
Conclusion

If we are to achieve the goals of the South Australia Strategic Plan, it is essential that there are adequate numbers of well trained scientists, technologists, engineers and mathematicians available to fulfil the essential roles that will be required. At this time there is real concern by Engineers Australia – and many other organisations and individuals – that this will not be the case.

Improving the STEM capability and literacy of students, and thus opening up career opportunities in these fields, is a prime purpose of school STEM education. Individuals literate in STEM are interested in and understand the world around them. They are sceptical and questioning of claims made by others about STEM matters, participate in the discourses of and about science, engineering, technology and mathematics, draw evidence-based conclusions and make informed decisions about the environment and their own health and well being. People with these skills form a key component of the knowledge economy.

Although there have been some good initiatives by the government in this area, for lasting and effective results to be achieved strategies need to be adopted to make structural improvements to the way STEM is taught, promoted and delivered to young people within the school system. In addition, the government needs to form effective partnerships to support and facilitate the work done by community and professional groups to enhance STEM education in South Australia.
Case Study by the Electronics Industry Association

Many industries are finding it increasingly difficult to recruit employees with suitable qualifications in STEM. This is a national problem, so serious in fact that it is influencing immigration policy.

This brief case study by the Electronics Industry Association (EIA) is provided to illustrate the problem.

The EIA represents an industry that has:

- annual revenue of $4.2 billion;
- revenue growth of 17 percent;
- employment growth of 9 percent;
- growth that is highly reliant on obtaining people with relevant skills, and underpinned by studies in science and mathematics.

Potential employment in the electronics industry has increased by 800 to reach 14,500 people in 2008 with almost 1000 more required by the end of 2009.

Approximately 350 (this includes postgraduate and masters) students were enrolled in 2008 in electronics-related undergraduate courses (single and double degree) at the three local universities. Although the figures for TAFE SA are yet to be confirmed, indications are that approximately 70 students are currently enrolled.

The number of students enrolling to study electronic-related courses (University and TAFE SA) is well short of the more than 1000 vacancies that will exist in the Electronics Industry at the time of their graduation. To compound this, the attrition rate may result in only about 350 graduates entering the marketplace; less than one third of the number actually required by the South Australian Electronics Industry at that time.

Adelaide electronics companies, while being highly supportive of the post-secondary education system, have nevertheless had to turn to the international marketplace to secure their staffing and their future growth. An increasing reliance on the ready availability of skilled personnel from the international marketplace may put South Australia’s thriving electronic industry in a vulnerable position. It may also influence future investment and threaten to curb the impressive performance of the industry over the past decade.

This case study illustrates the dilemma faced by many companies that depend on STEM workers for their viability.
## Appendix B

### Links between STEM Initiatives and the South Australian Strategic Plan

Links to STEM Initiatives Key:  ★ Low, ★★ Moderate, ★★★ High

<table>
<thead>
<tr>
<th>GROWING PROSPERITY</th>
<th>Connections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jobs</strong></td>
<td>★★★ Employment prospects are greatly improved by a high level of technological expertise</td>
</tr>
<tr>
<td><strong>Unemployment</strong></td>
<td>★★★ As above</td>
</tr>
<tr>
<td><strong>Competitive business climate</strong></td>
<td>★★★ Low costs derive in part from efficiency of services which are highly STEM dependant</td>
</tr>
<tr>
<td><strong>Economic growth</strong></td>
<td>★★★ Workforce must be highly capable in STEM if economic growth in the global environment is to be achieved</td>
</tr>
<tr>
<td><strong>Investment</strong></td>
<td>★★★ Will be attracted to successful enterprises which in turn depend on STEM</td>
</tr>
<tr>
<td><strong>Total population</strong></td>
<td>★★★ Will be attracted to jobs and opportunities</td>
</tr>
<tr>
<td><strong>Interstate migration</strong></td>
<td>★★★ As above</td>
</tr>
<tr>
<td><strong>Overseas migration</strong></td>
<td>★★★ As above</td>
</tr>
<tr>
<td><strong>Productivity</strong></td>
<td>★★★ Depends on high level STEM capability</td>
</tr>
<tr>
<td><strong>Industrial relations</strong></td>
<td>★★ Success reduces working days lost</td>
</tr>
<tr>
<td><strong>Exports</strong></td>
<td>★★★ Cost of production / quality can only be achieved via high level STEM</td>
</tr>
<tr>
<td><strong>Tourism industry</strong></td>
<td>★★★ Tourists are attracted to lively, creative, successful places --these are fostered by STEM</td>
</tr>
<tr>
<td><strong>Share of overseas students</strong></td>
<td>★★★ Will be attracted to lively, creative successful places that have high level STEM reputation</td>
</tr>
<tr>
<td><strong>Minerals and exploration</strong></td>
<td>★★★ Depend absolutely on STEM (critical shortage of mining engineers)</td>
</tr>
<tr>
<td><strong>Strategic Infrastructure</strong></td>
<td>★★★ Depends absolutely on STEM</td>
</tr>
<tr>
<td><strong>Credit rating</strong></td>
<td>★★★ Depends on achievement --see above</td>
</tr>
<tr>
<td><strong>Public sector productivity</strong></td>
<td>★★ Depends on information, education and vision</td>
</tr>
</tbody>
</table>
### IMPROVING WELL BEING

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Quality of Life</td>
<td>Will be improved by low unemployment, low pollution levels, good public transport etc – all STEM dependant.</td>
</tr>
<tr>
<td>Healthy South Australians</td>
<td>Depends on medical services, good diet, healthy environment etc</td>
</tr>
<tr>
<td>Infant mortality</td>
<td>Health care and education</td>
</tr>
<tr>
<td>Psychological distress</td>
<td>Will be reduced by the promotion of a good quality of life – see above</td>
</tr>
<tr>
<td>Smoking</td>
<td>Education</td>
</tr>
<tr>
<td>Overweight</td>
<td>Education, improved diet, better life styles</td>
</tr>
<tr>
<td>Sport and Recreation</td>
<td>Education, better facilities</td>
</tr>
<tr>
<td>Crime Rates</td>
<td>Can be reduced by improving detection and prevention</td>
</tr>
<tr>
<td>Road Safety</td>
<td>Depends on better road design, education, car design etc</td>
</tr>
<tr>
<td>Greater Safety at Work</td>
<td>Can be improved by education, work practices, equipment design</td>
</tr>
</tbody>
</table>

### ATTAINING SUSTAINABILITY

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>River Murray</td>
<td>Increasing environmental flows and effectively managing water issues generally requires a high degree of STEM expertise in many disciplines</td>
</tr>
<tr>
<td>Energy Consumption-Government</td>
<td>Reducing energy consumption by 25% and providing renewable alternatives requires cutting edge STEM</td>
</tr>
<tr>
<td>Land biodiversity</td>
<td>Biodiversity corridors – selection and management will require must be based on STEM knowledge</td>
</tr>
<tr>
<td>Marine biodiversity</td>
<td>Marine protected areas require knowledge to scope the areas and future management - STEM based</td>
</tr>
<tr>
<td>Native vegetation</td>
<td>Biodiversity offsets require STEM based knowledge</td>
</tr>
<tr>
<td>Use of Public transport</td>
<td>To double the rate of public transport use will require STEM based skills in many areas</td>
</tr>
<tr>
<td>Ecological footprint</td>
<td>Reduction will require the comprehensive use of STEM</td>
</tr>
<tr>
<td>Zero waste</td>
<td>Will require extensive waste reduction and recycling – both STEM dependant.</td>
</tr>
</tbody>
</table>

### FOSTERING CREATIVITY

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creativity</td>
<td>The Creativity Index (Richard Florida) is highly dependant on STEM capability</td>
</tr>
<tr>
<td><strong>Science, Technology, Engineering and Mathematics: Education and Promotion</strong></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
<tr>
<td><strong>Commercialisation of research</strong></td>
<td>★ ★ ★</td>
</tr>
<tr>
<td><strong>Film, TV</strong></td>
<td>★ ★</td>
</tr>
<tr>
<td><strong>Investment in science, research and innovation</strong></td>
<td>★ ★ ★</td>
</tr>
<tr>
<td><strong>Internet usage</strong></td>
<td>★</td>
</tr>
<tr>
<td><strong>CRC’s, Centres of Excellence etc</strong></td>
<td>★ ★ ★</td>
</tr>
<tr>
<td><strong>Creative education</strong></td>
<td>★ ★ ★</td>
</tr>
</tbody>
</table>

**BUILDING COMMUNITIES**

| **Women in Leadership** | ★ ★ ★ | Increasing numbers of women achieving in STEM will open leadership opportunities to them |
| **Political participation** | ★ |  |
| **Volunteering** | ★ ★ | There is a large number of retirees experienced in STEM who are not being utilised as volunteers |
| **State and local government strategic plan alignment** | ★ |  |
| **Regional population levels** | ★ ★ | Population levels will be maintained by provision of jobs which depends on STEM capability in the regions |
| **Regional unemployment** | ★ ★ | As above |
| **Regional crime rates** | ★ ★ | As above |
| **Regional infrastructure** | ★ ★ ★ | Infrastructure is STEM dependent |

**EXPANDING OPPORTUNITY**

<p>| <strong>Aboriginal wellbeing</strong> | ★ ★ ★ | Achievements in STEM education can greatly increase employment opportunities and hence wellbeing |
| <strong>Income inequality</strong> | ★ ★ ★ | Similarly, income increases can result from improved achievements in STEM education |
| <strong>Homelessness</strong> | ★ |  |
| <strong>Disability</strong> | ★ ★ | The disabled can be greatly helped by innovations in STEM |
| <strong>Housing</strong> | ★ ★ | Improved employment prospects and innovative house design – both STEM related - can improve housing prospects |</p>
<table>
<thead>
<tr>
<th>Education Type</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junior primary class sizes</td>
<td>★</td>
</tr>
<tr>
<td>Reading challenge</td>
<td>★</td>
</tr>
<tr>
<td>Primary education</td>
<td>★★★</td>
</tr>
<tr>
<td>Middle schooling</td>
<td>★★★</td>
</tr>
<tr>
<td>Senior secondary schooling</td>
<td>★★★</td>
</tr>
<tr>
<td>Regional education</td>
<td>★</td>
</tr>
<tr>
<td>Non school qualifications</td>
<td>★★★</td>
</tr>
<tr>
<td>University participation</td>
<td>★★★</td>
</tr>
<tr>
<td>TAFE participation</td>
<td>★★★</td>
</tr>
</tbody>
</table>
Appendix C

The Engineering Team

Engineering work is undertaken by individuals trained at both university and through the vocational educational system. As a group these engineers form the “Engineering Team”. Engineers, technologists and officer/associates come together in different combinations to undertake projects and programs. Their activities and competencies are often closely inter-related with some features of engineering being common to all three categories. All members of the “engineering team” work together and provide services to each other in order to complete engineering tasks.

**Professional Engineers**: The benchmark qualification for professional engineers is the four-year Bachelor of Engineering university degree. Professional engineers are required to take responsibility for engineering projects and programs in the most far reaching sense. This includes the reliable functioning of all materials and technologies used; their integration to form a complete and self-consistent system; and all interactions between the technical system and the environment in which it functions. Professional engineers have a particular responsibility for ensuring that all aspects of a project are soundly based in theory and fundamental principles, and for understanding clearly how new developments relate to established practice and experience and to other disciplines with which they may interact.

**Engineering Technologists**: The benchmark qualification for engineering technologists is the three-year Bachelor of Engineering Technology university degree. Engineering technologists normally operate within a relatively well-defined technical environment, and undertake a wide range of functions and responsibilities. They are typically specialists in a particular field of engineering technology and their expertise lies in familiarity with its current state of development and its most recent applications.

Within their specialist field, their expertise may be at a high level, and fully equivalent to that of a professional engineer; but they are not expected to carry the same wide-ranging responsibilities for stakeholder interactions, for system integration, and for synthesising overall approaches to complex situations and complex engineering problems. The competencies of engineering technologists equip them to approve and certify many technical operations such as calibration and testing regimes, compliance with performance-based criteria for fire safety, and design of components and sub-systems and of installations such as building services in circumstances that do not call for significant new development.

**Engineering Officer/Associates**: The benchmark qualification for engineering associates is the two-year Advanced Diploma of Engineering under the Australian Qualifications Framework or the Associate Degree in Engineering. Engineering Officers/Associates focus mainly on practical applications. They may be expert in installing, testing and monitoring equipment and systems, in the operation and maintenance of advanced plant, and in managing or supervising tradespeople in these activities. They may be expert in selecting equipment and components to meet given specifications, and in assembling these to form systems customised to particular projects. Engineering associates are often required to be closely familiar with Standards and Codes of Practice, and to become expert in their interpretation and application to a wide variety of situations.
Appendix D

Young Engineers – Why study engineering?

Nationally, almost 50 percent of the membership of Engineers Australia can be identified as “Young Engineers”. That is, engineers under the age of 35. Obviously this group makes an important contribution to our 86 000 strong membership.

Recently, the interest group “Young Engineers Australia” were asked what were the factors which led to them to study engineering at university:

David Hobbs, Young Engineer, South Australia

My name is David Hobbs and I am a biomedical engineer. I work at Novita Children's Services (formerly the Crippled Children’s Association of South Australia) in Adelaide as a Rehabilitation Engineer. Our core business is conducting research and providing services and equipment for people with a disability to improve their quality of life. I’m currently 30 years old.

I have always had an inquiring mind and a love for science and maths. I used to feel odd at school because I was not only good at maths, but I really enjoyed it. Later in life I became a maths teacher at an Adelaide TAFE and thoroughly enjoyed inspiring adult students to study maths and have fun at the same time. Yes, this is possible. Teaching maths was a buzz.

My earliest memories of science can be traced back to seeing me race home from school to be glued to the TV to watch Rob and Deane on “The Curiosity Show”. I was always sad when this program was not on as it was my favourite. ‘Beyond 2000’ was another program I avidly watched. Programs like these were fuel for my ever-thinking mind.

I became a Biomedical Engineer because I wanted to combine my love and enthusiasm for science and engineering with my passion for helping people. I cannot think of a better combination. As a physicist first (I graduated from my BSc in 1995), I specifically chose engineering because it allowed me to apply my knowledge in a hands on and tangible way in a team environment.

Given the range of science and engineering activities today, such as Questacon, EngQuest and the Science and Engineering Challenge, I wish that I was a young student now so I could participate in these fantastic opportunities. They didn’t exist when I was at primary and high school.

I believe these programs should continue to be promoted as they are on the right track in that they make science and engineering fun and interactive. They break the perception that scientists and engineers are geeky, quirky, loners who wear white lab coats and talk using calculators. At the end of the day, an engineer’s output is for the benefit (and usually the ‘betterment”) of the community. What a great profession.
Brandon Lee, Young Engineer, Western Australia

My name is Brandon Lee and I work as an Electrical Engineer with the Water Corporation in Perth, West Australia. I am 24 years old and have been working for 2.5 years after graduating from a 5-year combined course in Commerce and Engineering.

What drew me to take up Engineering was the fact that I enjoyed maths, science, electronics and technical design subjects at school. At school, one of the major reasons that made me choose subjects like maths, physics and chemistry (other than the fact that I enjoyed them) was a desire to keep my options open for university course entry.

I was still undecided as to the career path that I wanted to take. Back then, my impression was that medicine and law were the prestigious courses to study, engineering was what I enjoyed, yet studying commerce (especially accounting and finance) would provide me with stability of employment - by taking up maths, physics and chemistry, I would be able to gain entry into all these options. This made studying them quite attractive.

In the end, I made a compromise between all my options by taking up a double degree. I must admit that there was also a lot of financial consideration into choice of university course as well, where engineering was known to pay well upon graduation but the opportunity for astronomical increases were not as apparent as in medicine or law.

Similarly, science courses, were viewed poorly because of the lack of career opportunities. It cannot be forgotten that for most, studying at university is looked upon as a means by which to aspire to a generous lifestyle, if there was no reward in the end, then there was no defined purpose.

I believe that a major factor inhibiting student participation in the enabling sciences when I was at school was the 'geeky' label that was attached to these subjects, something that has been around for a while. This stereotype disappeared once students entered university; however, choices had to be made in secondary school, where I suppose there were more pressures to conform.

Another factor was the perception that studying the 'enabling sciences' was inherently difficult and somehow I would agree with that there is some truth in that. It is a common thing to see students steering themselves away from anything difficult to avoid the potential for failure.

With that said, in trying to encourage more students to study 'enabling sciences', the targeting should only be aimed at those who have a curiosity for it or enjoy it naturally - without that inner drive from experience with peers and friends, they tend to either fail or altogether move into a another direction of study which does no good to anyone, especially the student as time has been wasted in career development.

The strength of any campaign will require the re-promotion of 'enabling sciences' to be fun and rewarding, through how society has benefited from advances in technology for lifestyle and health. As there is also greater social conscience over the topic of the environment, re-promotion can include that studying 'enabling sciences' does indeed provide someone with the tools to make a direct impact in that area. I believe science and engineering (which includes medicine) are the only areas of study that can make a direct impact to the world we live in, and that is definitely a point that seems to not be exploited.
Karyne Wong Young Engineer, Western Australia

I am currently an electrical engineer at South Power nearing the end of my three year graduate program. During my graduate program I have rotated every six months getting a variety experience from distribution to transmission to generation, design to commissioning to business development!

I became interested in engineering because I enjoyed the logic and problem solving involved with maths and science in school. I also wanted a challenging profession where I could get involved in different projects, work with a variety of people and have a mix of practical / field work as well as technical office based work. This all led me to choose Engineering!!

Hannah Clement, Young Civil Engineer, Northern Territory

At school I studied maths and science, but particularly enjoyed the practical application of scientific knowledge in problem solving plus I played with a lot of Lego as a kid! Plus my crayon pictures of houses always included plans, elevations and sections!

I've always viewed engineering as a practical and constructive profession (no pun intended) and I wanted a job where at the end of a day I could say I've achieved something tangible. It is a fantastic feeling seeing the bridge you've designed being built and used. When I started university I also chose to study science, however I stuck with engineering because I felt that engineers were definitely more employable than science graduates.

Katherine Ward, Engineering Student, Queensland

I am someone that likes challenges, that enjoyed maths and science for most of my school years and that liked to design things. At first I thought of studying architecture at university, thinking that this would enable me to design and use maths but upon talking to people in the field, I found that it was very competitive.

I decided that I wanted to get a degree in something that would still be challenging and would utilise my strengths but had better employment opportunities than those offered by architecture. I also wanted a career that was flexible, that allowed me the opportunity to change the direction I was travelling and what I was doing without having to start from scratch and do another degree.

My dad suggested engineering as an option, something that I was surprised he supported given my fairly traditional family background. My dad encouraged me to keep my options open when I was going through school pointing out that so long as I had a broad base to start with I could specialise and do anything I wanted when I got to university. This helped me to keep an eye on my long term goal while remaining realistic that my ideas could change and meant that I had provided myself a ‘safety net’ of options if they did.

I was shown how engineers did a lot of design and also worked on many varied projects. This attracted me to the profession as I have a natural aversion to excessive repetition. Apart from this I was shown that engineering was a career in demand and that I would have no trouble getting a job once I graduated.
I am a results based person so being able to be almost guaranteed employment if I worked hard enough was very encouraging. I decided to take on a combined environmental engineering and civil engineering degree to ensure that I stayed employable. What allowed me to have even a vague idea of what environmental engineers do was a visit from one of the major mining companies to my primary school when I was in Year 7.

The representative of this company, whose name I have long since forgotten, told us how they were rehabilitating mining sites after they had been exhausted. I was interested in this and so when I saw the degree ‘environmental engineering’ in the QTAC booklet I imagined rehabilitating mine sites and pollution control and thought that this would be interesting. I have since found that idea to be very close to reality and am very grateful to that company for opening my horizons by taking the time to visit my little school.

In summary, my interest in engineering was spawned by the power of suggestion which allowed me to see a career that would not only open doors but would be enjoyable as it will use my strengths to their full potential.

**Nicholas Dwyer, Young Engineer, Tasmania**

My name is Nicholas Dwyer, I am studying a Bachelor of Engineering (Civil) at the University of Tasmania. I have been interested in engineering since I was very young. I spent a lot of my time in my father’s workshop taking my toys apart to see how they worked. I was not only finding out what made these toys work, but I was trying to make them better.

Apart from “modifying” my toys I was also building new things, this began with an extensive collection of Lego and progressed to Meccano. When I wasn’t “hotting” up my remote controlled car or building new creations I was watching Beyond 2000 on television or any other science/technology show I could find.

These interests led me in secondary school to follow a maths and science stream combined with some humanities. Apart from the usual course work at school I was involved in many of the competitions held by Universities across Tasmania and Australia.

This gave me the opportunity when it came time to fill in my University application to enrol in just about any course. Naturally I chose engineering as my first choice and I haven’t looked back since.

**Rebecca Barker, Young Engineer, Victoria**

When I reflect on why I chose to study Engineering, a couple of catalysts come to mind. When I was growing up I had an inquisitive mind, and wanted to know why and how things happened the way they did. In primary school it led to involvement in biological and environmental clubs like the Gould League, where I was able to gain an appreciation for ecosystems and environmental issues.

This hunger for learning and wanting to understand the world we live in was not restricted to science and maths subjects, I had a similar passion for History and language, which gave me an understanding of how civilisation, and the world, had evolved to its current state.
I found science and maths subjects to be perhaps the most exciting part of learning as they required an understanding of science and scientific processes as they exist at the time, but provided such an extensive scope for innovation, creation, and research into new areas of science.

When I was at high school my hunger for understanding and learning continued, and I was fortunate to have an inspirational teacher, who recognised my skills and my thirst for knowledge. My teacher identified a number of events or forums which would expose me to a wider scope of science than is taught within the curriculum, and an opportunity to meet with similarly enthusiastic students. I attended the Siemens Science School in year 9, the Melbourne University Engineering Summer School in year 10, and the National Youth Science Forum in year 11. The exposure to such a wide range of applications for Physics, Chemistry, Biology and Geology, motivated me to continue to learn, and to explore the potential courses and careers within the field of science.

In year 12 when I was required to make the decision of what I wanted to study at University, although I was passionate about science and at this stage engineering or innovation, I had continued to study languages, history and literature to keep my options open. In the end for me, I turned down offers for law and business university courses, because I could see the potential that science and engineering had to change the world that we live in, whether it was through research into new fields of science, or applying science in a creative and innovative way to provide engineering solutions for society.

When I consider why students don't study enabling subjects such as maths and science, a number of issues come to mind. The negative image of maths and science as particularly dorky subjects, due to the manner in which these fields are marketed to both students and the general public. The manner in which these subjects are taught, luckily when I was studying I was able to grasp concepts as soon as they were taught, where as research has found that the majority of people will learn more efficiently and effectively if taught by example, or by the problem based learning method.

Students who do not initially understand a concept within subjects like maths and science in the past fell behind, and felt that they were stupid or just did not have the skills for maths and science. However it is extremely important to note, that every individual learns in a different way, and the use of problem based learning methods within schools is an excellent way for students to learn and understand the application of the concept at the same time.

The other key issue is the availability of skilled and enthusiastic teachers, a lack of teachers with the appropriate mathematical training, or scientific education, has started to limit the scope of subjects available at schools within Australia. It is important also to consider that a teacher of maths and science, needs to be passionate and enthusiastic about their subject, and skilled in educating the topic.

David Clyde, Young Engineer, Canberra

My name is David Clyde and I am an Engineering Officer in the Royal Australian Air Force. During my time in the Air Force I have completed a Bachelor of Engineering (Electrical) degree at ADFA, worked in major capital equipment projects in the surveillance and communications domains, and provided engineering advice on ICT in a Headquarters role. I am also currently undertaking a Master of Science (Information Technology) and moving towards airfield communications type roles.
Growing up I had a general curiosity regarding how things worked, an interest that was sharpened and developed by access to children's books exploring how things work technically and toys such as electronic and science kits. At High School a natural aptitude for the sciences over the arts led me to focus my studies on the mathematical and physical sciences.

Combining my early interests and High School studies, I considered undertaking a Bachelor of Science at the completion of year 12 but did not perceive many career opportunities at the completion of such a degree. It was at this point in time that I first considered engineering. I was attracted by the concept of engineering as applied science which not only catered to my personal interests but also led to career opportunities.

**Kym Wilkinson, Young Engineer, Queensland**

My name is Kym Wilkinson. I'm a 25 year old Civil/Structural engineer who works with my husband in our own consulting firm. I was a rather bright student at school and was attracted to the maths and sciences but engineering wasn't in my sights - I thought I'd be a Doctor or a Vet. This all changed during Engineering Week when I was in year 11.

I was invited to join a group of students on a tour of different Engineering Wonders. This included the operation and maintenance section at the Brisbane International Airport and the Shell Oil refinery. However it was the walk inside the Gateway Bridge that caught my attention. The sheer size of the anchorage cables and the distance from the bridge to the water was inspiring.

I then studied Civil Engineering at QUT and the rest is history.
Appendix E

What is Engineering?

Engineering in its many roles forms the backbone of our efficient, safe and convenient way of life. Modern communications, computers, transport, food processing, manufacturing buildings and many more all depend on the vital input of engineers. Engineering is about applying science and technology to develop and implement new technologies, placing engineers in a central role in improving the security and living standards of the community, improving the standards of environmental care and generating wealth for Australia.

There is a strong social and humanitarian dimension to engineering and virtually all engineering solutions are a response to a human need. Engineers solve problems. For example the most significant advances in medicine were not based on improved surgical or medical techniques, but almost entirely on engineering breakthroughs: from replacement joints to whole-body scanners; heart pacemakers; dialysis machines to artificial limbs - they are all designed, developed and built by engineers working closely with medical professionals and their patients.

The traditional focus of engineering activities has been in infrastructure – the fundamental facilities and systems that allow a modern society to function effectively. These include transportation, communication systems, energy and water supply, and waste removal. However, engineering impacts on many aspects of community life.

For instance, the following lists only some of the areas in which professional engineers commonly practice: Acoustics, Aeronautics, Agriculture, Automation and control, Biomedical, Bridges, Building services, Civil, Chemical, Coastal and oceans, Communications, Computing, Construction management, Dams, Electric power, Electronics, Education, Environment, Fire safety, Food technology, Fuels and energy, Geotechnics, Government, Maintenance, Manufacturing, Materials, Mechanical, Metallurgy, Military, Mining and tunnelling, Naval architecture, Nuclear, Petroleum and gas, Pipelines, Process control, Railways, Risk, Roads, Space, Structural, Telecommunications, Transportation and Water resources.

Engineers work independently, in teams with other engineers, or as part of larger multi-disciplinary groups alongside other professionals, like scientists, researchers, architects, lawyers, human resource managers and accountants.

The engineering sector is a diverse and large profession that includes a range of practitioners, such as professional engineers, engineering technologists, engineering associates, and tradespeople.
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