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# Engineers
# Make Things Happen

## The need for an engineering pipeline strategy

Engineers Make Things Happen

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## The need for an engineering pipeline strategy

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*Engineers Australia is the trusted voice of the engineering profession.*

*We are the global home for engineering professionals renowned as leaders in shaping a sustainable world.*

# Contents

# Executive Summary

In a modern society, practically every good and service consumed or used in production embodies engineering.

“No profession unleashes the spirit of innovation like engineering. From research to real world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward thinking ways. Few professions turn so many ideas into so many realities. Few have such a direct and positive effect on people’s everyday lives. We are counting on engineers and their imaginations to help us meet the needs of the 21st century.”[1] In short, engineers make things happen.

Australia’s ambition is to become an innovative, technically progressive and globally competitive nation. Innovation and technical progress do not just happen; realising this ambition depends on human capital in numerous fields, often working in inter-disciplinary arrangements. International studies point out that success is critically linked to increasing the scientific, mathematical and technical competence of the future national work force. This is the context for our contention that success for Australia depends on its future engineering profession.

Australia sources its engineers from graduates of Australian educational institutions and from skilled migration. Over the past 15 years skilled migration has become the dominant source. But relying on skilled migration for most of our new engineers comes with serious risks. We are not the only country with developmental and technical ambitions; first, success in countries we source our migrants from means more of them will prefer to stay at home limiting the pool we recruit from, and second, our skilled migration policies are more successful in raising the average skill level of the Australian labour force than in contributing to our engineering capability. This is because migrant selection is primarily geared to entry level qualifications rather than to attributes that define competent practicing engineers.

The engineering profession has experienced boom and bust since 2000. The end of the resources boom, neglect and decline of manufacturing and a widespread reluctance of governments to invest in essential public infrastructure have meant that high demand conditions common a few years ago have collapsed. Adjustment has been facilitated by the retirement of many engineers and the flexibility and adaptability of others who have changed direction, moving into jobs unrelated to engineering. Short term unemployment of engineers has also increased. These conditions will continue to play out for another year or so. When adjustment is complete, Australia will have sufficient engineers to meet the needs of our current slow growth economy.

We need more than this to meet our national ambition. We need a larger engineering capability and the expansion must include new areas of practice dealing with robotics, digital technology, artificial intelligence, and advanced materials, in addition to advances in familiar areas of engineering practice. We cannot achieve this objective by relying on skilled migration and Australia must produce more of its own engineers.

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[1] Changing the Conversation: Messages for Improving Public Understanding of Engineering, National Academy of Engineering, 2008, www.nap.edu/catalog/12187.html

*The Institution of Engineers Australia (Engineers Australia) is the peak body of the engineering profession. We are a member-based professional association with over 100,000 individual members. Established in 1919, Engineers Australia is a not-for-profit organisation, constituted by Royal Charter to advance the science and practice of engineering for the benefit of the community.*

This report evaluates Australia's prospects in meeting this challenge. The importance of science, mathematics and technology for our future development has received substantial and widespread attention, but high school participation in these subjects continues to fall. These trends constitute a serious obstacle for Australia's national ambitions. Firm grounding in science and mathematics is important in a number of fields, but particularly so for engineering because science and mathematics are the tools used by engineers to solve real work problems.

The report examines the latest statistics for participation in year 12 advanced mathematics, intermediate mathematics, chemistry and physics and updates them to 2015. There are two key differences to other studies; first, trends are examined separately for young men and young women, and second, participation in these subjects is quantitatively linked to statistics on acceptances of places in university engineering courses.

Separate analysis by gender conveys an important message obscured by cohort analyses. Participation in science and mathematics is typically far lower among young women than young men. In two year 12 subjects, advanced mathematics and physics, participation by young women is alarmingly low, an outcome that is not receiving the attention it deserves.

Our study emphasises numbers of students in the subjects examined, but although examining participation rates is important, it is just part of the story. A key issue is that in the face of falling participation in science and mathematics subjects, increasing high school retention further can stabilise the number of students in these subjects and create a window of opportunity that policy makers can take advantage of to implement new policies to reverse falling STEM participation. An important factor here is eliminating excessive differences in retention between states and territories.

High school numbers in science and mathematics are linked to acceptances of places in university engineering courses using the concept of the 'degree of difficulty' in securing sufficient numbers from a subject to match the number of students accepting places in engineering. The results are summarised in Table 1.

The results suggest that Australia's capacity to develop more of its own future engineers is limited by falling participation in year 12 science and mathematics and, in the case of women, is impeded by alarmingly low participation. There is an urgent need to reverse these trends to overcome these limitations and impediments.

Engineering has been a male dominated profession with the proportion of women engineers at 13 percent. While recognising that there are numerous workplace and cultural problems that need to be resolved here, our results suggest a more intractable problem. Participation by young women in critical foundation subjects for engineering is alarmingly low and is in stark contrast to their participation in higher education which is 30 percent higher than young men. In effect, this low participation has created an environment in which engineering recruits most engineers from half of the population, a situation that is unsustainable given our national ambitions.

**TABLE 1:**
DEGREE OF DIFFICULTY ASSOCIATED WITH YEAR 12 STEM SUBJECTS AND ENGINEERING COURSE ACCEPTANCES IN 2015

| Subject | Young men | Young women | Cohort |
|---|---|---|---|
| Advanced mathematics | moderate | severe | high |
| Intermediate mathematics | low | moderate | low |
| Physics | low | severe | moderate |
| Chemistry | moderate | moderate | moderate |

# 1.

# The challenges facing Australia

## 1.1

## The challenges ahead

The medium to long term challenges facing Australia in coming decades have been outlined in the Commonwealth Treasury's Intergenerational Reports[2] . These reports have been prepared by successive governments as responses to the charter of budget honesty established by the Howard Government in order to assess the long term sustainability of current government policies over the next 40 years, including the financial implications of demographic change.

There have now been four intergenerational reports (2002, 2007, 2010 and 2015) and although each, to some extent, has reflected the particular views of the government of the day, some issues have been raised by all four reports. These include:

- The main driver of improved standards of living has been productivity growth which in recent years has fallen below historical trends.
- Large demographic changes will occur in coming decades; in particular, population aging will reduce the relative size of the labour force of conventional ages accentuating the nation's productivity problem.
- Population aging will increase the size of post retirement cohorts and increase health costs and other age related budget expenditures.
- By 2030 Australia will need to cater for and create social and employment opportunities for an additional 6 million people, 70 per cent of whom are likely to be located in capital cities.
- Australia will need to deliver its commitment to reduce greenhouse gas emissions as agreed in the Paris conference to avoid some or all of the costs associated with climate change and to ensure Australians can adapt to climate change effects that are already unavoidable.

The medium term challenges start with transition to an innovative, technologically based economy while solving community and economic problems associated with an aging population and transitioning to a low carbon economy.

At present, government policy has the shorter term objective of facilitating Australia's transition from a resources and commodities based economy into a technologically and innovation based services oriented economy. Productivity growth is at the core of both short term and longer term challenges. Without productivity growth our standard of living will not improve and could fall. Productivity growth must improve to compensate for the relative decline in the working age labour force as the population grows older. Productivity growth is essential to absorb a growing population while maintaining or increasing our standard of living.

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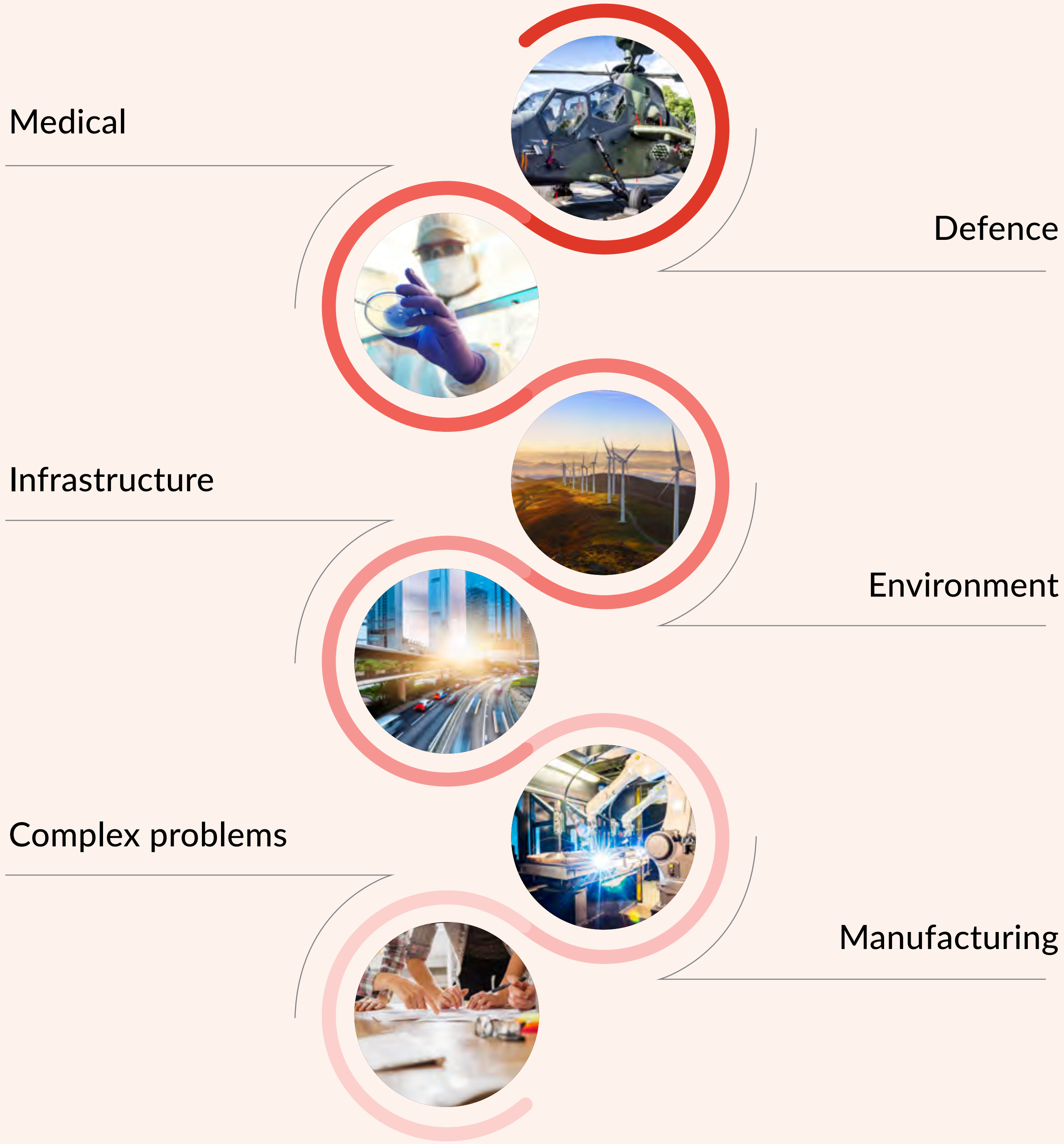
2: See archive.treasury.gov.au/igr/

## Engineers are vital for



# Australia's ranking on the World Economic Forum innovation index

| | |
|---|---|
| 23rd | Overall |
| 25th | Capacity for innovation |
| 8th | Quality of scientific research institutions |
| 27th | Spending on R&D |
| 21st | Uni-industry collaboration |
| 70th | Government procurement of advanced technological products |
| 17th | Availability of scientists and engineers |

*Practically every good and service embodies engineering. Innovative ideas are the beginning of technological advance, but it is engineers who translate new ideas into practical products and services.*

## 1.2

## Why Australia should value its engineers

Throughout the world, analysts have argued that the way to achieving a technologically based economy is to develop the mathematical, technological and scientific skills of the future workforce. Indeed, it is already apparent that the number of jobs being created utilising these skills is substantially greater than in areas of traditional skills and unskilled jobs. These views and trends have been supported in Australia by the work of the Chief Scientist and have given rise to a broad wave of support for more attention to STEM (science, technology, engineering and mathematics) skills in the development of Australia's future workforce[34].

Developing STEM skills per se will not be sufficient. The STEM skills of the future work force will need to be aligned with national economic development policies, the products and services produced in the Australian economy and how these products and services are produced. A recent report by the Grattan Institute observed that in the midst of present wide advocacy for the development of STEM skills, half of recent science graduates and one third of recent information technology (IT) graduates had not found full time work four months after graduation[5]. This unfortunate state of affairs shows that this alignment has not yet occurred in Australia and improved policies and hard work is needed to derive value from investment in STEM skills.

***The difficulties experienced by some STEM graduates in finding full time employment demonstrates that Australia's economic development policies still have a long way to go to meet our aspirations.***

Engineers, on the other hand, are far more adaptable than STEM graduates in other fields. This view has been apparent to Engineers Australia for some time and has now been substantiated by the Grattan report which found that this attribute applied both to the areas of their training and in the wider economy[6]. This is because, in a modern society, practically every good and service consumed or used in production embodies engineering to some extent.In launching the National Innovation and Science Agenda, the Prime Minister said he was ushering in "the ideas boom"[7]. New and innovative ideas are the beginning of technological advance, but it is engineers that translate new ideas into new products and services that are commercially attractive in domestic and overseas markets. Engineering and its continuous development over recent decades effectively uses knowledge of mathematics and science to solve real world problems. Australia's "ideas boom" depends on the skills of engineers to bridge the gap between idea and practical products and services that will drive productivity and economic growth.

Australians have a positive impression of engineers,[8] but few in the community and few political decision makers understand what engineers do, how this contributes to community well-being and prosperity and the critical role played by engineers in achieving technological progress. The result is that the contribution of engineers and engineering to Australian society and the economy are under-valued, a situation not unique to Australia.

3: Chief Scientist, Science, Technology, Engineering and Mathematics; Australia's Future, 2 September 2014, www.chiefscientist.gov.au

4: In the USA US Department of Commerce, STEM: Good Jobs Now and for the Future, Issues Brief No 03-11, July 2011, www.esa.doc.gov ; in the UK Royal Academy of Engineering, Jobs and Growth: the importance of engineering skills to the UK economy, September 2012, www.raeng.org.uk/jobsandgrowth and in Australia PwC, A Smart Move; Future proofing Australia's work force by growing skills in science, technology, engineering and mathematics, April 2015, www.pwc.com.au

5: Grattan Institute, Mapping Australia's higher education 2016, 7 August 2016, https://Grattan.edu.au

6: Grattan Institute, op cit

7: Prime Minister of Australia, Launch of the National Innovation and Science Agenda, Media Release, 7 December 2015, www.pm.gov.au

8: See www.roymorgan.com and www.businessinsider.com.au/ranked-australias-20-most-trusted-professions .The Roy Morgan image of professions survey consistently ranks engineers highly for honesty and ethical standards; 4th in 2016 with 78 per cent only surpassed by nurses, pharmacists and doctors.

9: Changing the Conversation: Messages for Improving Public Understanding of Engineering, National Academy of Engineering, 2008, www.nap.edu/catalog/12187.html

10: National Academy of Engineering, op cit, p2

> *"No profession unleashes the spirit of innovation like engineering. From research to real world applications, engineers constantly discover how to improve our lives by creating bold new solutions that connect science to life in unexpected, forward thinking ways."* [11]

[11] National Academy of Engineering, op cit, p46

In the United States, the National Academy of Engineering found a similar situation and when probing community perceptions found that the public did not see engineers as engaged with societal and community concerns as other professions[9]. Besides turning these views into a more positive perception of engineering, the Academy identified several other important reasons to improve community understanding of engineering, including[10]:

- Sustaining national capacity for technological innovation; a better understanding of engineering would educate policy makers and the community as to how engineering contributes to economic development, quality of life, health and national security.
- Improving technical literacy; to be capable, confident participants in a technology dependent society, people must know something about how engineering and science, among other factors, lead to new technologies.
- Attracting more young people to careers in engineering; a better understanding of what engineers do will encourage students to pursue careers in engineering.

Part of the difficulty is the distinction between science and engineering. Science begins with a physical system and aims to develop a descriptive model to explain it. Engineering starts with a descriptive model, the problem, and the engineering design to solve it, and seeks to develop a robust physical solution. In some cases, engineers are asked to solve problems dealing with matters where the science is unresolved. Successful engineers have the capacity to combine skills in science, mathematics, collaboration with other professionals including from the arts, communications and teamwork to find solutions to real world problems for the benefit of society.

Put into the context of the challenges facing Australia, Australia needs engineers to lift their game as never before to:

- Contribute to productivity growth by advancing technological progress in all industries throughout the Australian economy and by designing, constructing, operating and maintaining publicly accessible infrastructure that enables innovation and productivity created by others to thrive.
- To be at the forefront of medical technology to improve the speed and quality of medical diagnoses, to improve the quality and options for remedial treatments while simultaneously reducing costs and the application of nanotechnology, new materials and artificial intelligence to improve health and the quality of life of all Australians, not just the elderly.
- To enable Australia to meet its ambitious greenhouse reduction targets in the Paris agreement in the short time horizon available with minimum disruption to the normal functioning of society and the economy. Without engineers restructuring the electricity sector from fossil fuels to renewable and other zero or near zero technologies will not happen. Similarly, engineers will need to play pivotal roles in restructuring transport systems away from dependence on fossil fuels whether this is towards new modes of transport, improvements to the efficiency of existing ones or redesigning cities to reduce travel and improve amenity. Finally, the cheapest emissions reduction is through not using too much energy in the first place and engineers have strong comparative advantages when it comes to achieving energy efficiencies in buildings, in transport and in industry.
- Some climate change cannot be avoided because atmospheric emissions levels have already increased. Engineers can devise ways for communities and physical structures to better adapt to unavoidable changes so as to minimise the consequences and costs of climate change events.
- A growing population must be supported with a commensurate expansion of infrastructure, but much of our infrastructure is already old and under strain. New infrastructure is needed and engineers can ensure that the new technologies embodied in it can serve Australians productively well into the future, and that it is effectively managed using contemporary digital management and monitoring systems to derive maximum value from capital investments.
- Place a pivotal role in a revitalised manufacturing sector, driving innovation of benefit throughout the economy. Engineers have already embraced the change to a services based profession and are in a position to help other sectors to make similar changes and to utilise modern technologies to drive innovation and productivity so that Australia is globally competitive in a wide range of industrial products, commodities and services.

[12] UK Royal Academy of Engineering, op cit, p8

[13] Emmanuelle Wintergerst, Elena Vvedenskaia and Junaid Yamin, "Futures", Internal Research Report, Engineers Australia, December 2015

The extraordinary demand for engineers in the recent mining boom distracted attention from the fact that the skill shortage experienced at the time occurred because the demand for engineers was actually widespread across the economy and not just a phenomenon of the resources boom.

Engineers make thing happen by solving complex real world problems. “Engineering is the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire something of significant technical content for a specific purpose.”[12] The engineering profession has responded with new areas of practice in digital technologies, robotics, nanotechnology, mechatronics, new advanced materials, medical engineering, additive engineering involving 3D technologies, artificial intelligence and distributed manufacturing. Some of these areas will intersect with contemporary areas of engineering practice such as civil and environmental engineering in the continued development of liveable cities to cater for population expansion and improvements in the quality of life.[13]

*Australia’s engineering capability is an indispensable element for becoming an innovative, globally competitive nation.*

These developments mean that it is no longer sufficient to think about the engineering profession as a homogeneous body of knowledge. Nor is it sufficient to see the development of the profession simply in terms of new graduates. The engineering profession is the aggregation of engineering professionals in an expanding range of practice reflecting technological advance and the simple fact that knowledge has expanded beyond the capacity of individuals requiring new specialisations and collaboration between specialisations. New graduates become part of this landscape by successfully completing their engineering qualification and then successfully completing professional formation in their chosen area of engineering practice. Australia’s engineering capability is an indispensable element for Australia to achieve its ambition of becoming an innovative, globally competitive nation and must be valued by policy makers and the community for this reason.

## 1.3

## Australia’s innovation status

In 2012, Engineers Australia published a report on innovation in engineering to guide the development of the organisation’s public policy[14]. The report took the view that Australia’s growth potential would be determined by its innovative capacity and reviewed our recent innovation performance, barriers to innovation and the important roles played by skills and education. Recommendations for reinvigorated government policy were made in several areas: legal and regulatory frameworks, government incentive programs, collaboration for innovation, informed procurement—particularly by government agencies—and the importance of promoting innovation. Now, four years later, action is still required on most fronts even though there is bi-partisan agreement that innovation is critical for future Australian prosperity.

One of the points made by the 2012 report was that Australia ranked well behind many countries that we identify with, trade with and, critically, compete with. At the time Australia ranked 21st on the Global Innovation Index for 2011 and 22nd on the World Economic Forum Global Competitiveness Innovation Index[15]. Progress since then flowing from new government initiatives has been patchy. The 2015 INSEAD Global Innovation Index[16] shows that Australia improved its ranking to 17th, but the 2015 World Economic Forum’s innovation index[17] showed Australia slipped to 23rd.The World Economic Forum’s innovation index is built up from six factors each of which has an important bearing on our ambition to become an innovative nation. We rank poorly on most of them as this list shows:

- Australia’s capacity for innovation ranked 25th.
- The quality of Australian scientific research institutions ranked 8th.
- Australian company spending on research and development ranked 27th.
- Australian university-industry collaboration on research and development ranked 21st.
- Australian government procurement of advanced technological products ranked 70th.
- Availability of scientists and engineers in Australia ranked 17th.

Only one of these factors is consistent with government innovation policy messages and, since the rankings were compiled, key national research organisations have been affected by significant budget cuts. These factors explicitly relate to innovation and the lacklustre circumstances they point to are compounded by similar rankings for infrastructure: 18th for transport infrastructure, 13th for electricity and telephony and 16th for infrastructure overall[18].

Innovative environments do not just happen, they are the outcomes of interaction between individual and corporate ideas, entrepreneurship, risk taking and investment and government policies to foster these factors and policies that address barriers to innovation. This is why building Australia’s engineering capability must be an indispensable element of the government’s innovation strategy. Our contention is that the role of engineers is pivotal and without sufficient, and the right, engineers many good ideas will continue to be just that—good ideas that have gone nowhere.

*Government policy, R&D and improved collaboration between universities and industry will help build our engineering capability.*

14: Engineers Australia Innovation Taskforce, Innovation in Engineering, June 2012, www.engineersaustralia.org.au
15: Engineers Australia Innovation Taskforce, op cit, p5
16: See www.globalinnovationindex.org
17: See www.weforum.org
18: See www.weforum.org

# 2.

# Australia’s present engineering capability

### Source of new Engineers in 2015

**9,850** Entry level graduations

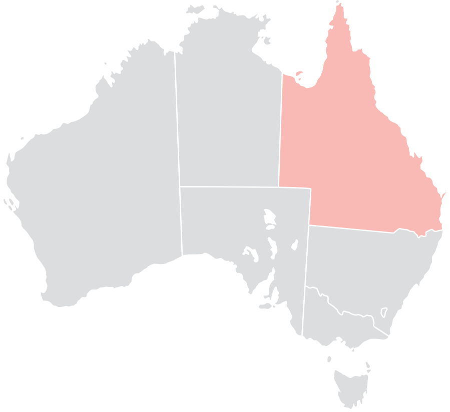
**10,778** Permanent visa holders

**5,709** Temporary visa holders

### Population born overseas

| | |
|---|---|
| **40.9%** | Other professions |
| **57.3%** | Engineering |

### Engineering practice regulated in Australia



### Engineers in engineering roles

| | |
|---|---|
| ♂ Australian born men | **70.6%** |
| ♀ Australian born women | **62.2%** |
| ♂ Overseas born men | **57.2%** |
| ♀ Overseas born women | **45.4%** |

**2006** → Between 2006 and 2011 census, **71.4%** of the increase in the supply of engineers was from skilled migration. ← **2011**

## 2.1

## Sources of Australia's engineers

Building Australia's engineering capability is about much more than the number of people with engineering qualifications. It is about entry level engineering education, acquiring the skills and competence for engineering practice, retaining experienced and competent engineers in the engineering profession and the development of diversity in the profession through skilled migration and increasing the number of women recruited to the profession. This chapter considers these issues beginning with a brief review of where our present engineers originate.

The potential stock of engineers increases when new graduates complete entry level engineering qualifications and when new migrant engineers arrive in Australia. Conversely, the potential stock decreases when older engineers retire, when younger ones leave the labour force and some engineers unfortunately die[19]. The most serious weakness in our statistics relates to losses from the stock of engineers, but quite good statistics are available on entry level education completions and on skilled migration.

The blue bars in Figure 1 illustrate the slowly rising trend in completion of engineering qualifications by Australians from 2009[20] to 2015. There was a clear, but comparatively slow upwards trend so that by 2015 completions had grown to 9,850. Completions of associate degrees and advanced diplomas were highly variable from year to year, but over time growth averaged annual increases of 3.5 per cent per year so that by 2015 there were 2,300 completions. Completions of three year degrees varied from year to year, but showed no discernible trend, and averaged about 560 per year.

The main numerical driver of the rising trend in Figure 1 was completions of four year degrees. Until about 2008, completions of these qualifications at first trended downwards and then drifted upwards so that by 2009 a base slightly higher than the 2002 level was established. This hiatus was an important contributor to the skill shortages experienced at the time. From 2009 onwards, growth averaged a robust 3.8 per cent per year and by 2015 completions increased from 5,383 in 2009 to 6,950.

Figure 1: The sources of Australia's new engineers

*Because of the long duration of engineering education, graduate numbers did not increase until the resources boom was almost over.*

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[19] Consistent statistics for these factors are problemmatic in Australia, not just for engineers but for all professions and trades where formal qualifications are required. Never-the-less, sufficient statistics can be pieced together to establish a reliable framework for policy decisions.

[20] We start our examination in 2009 because this was the first year for which statistics on the number of temporary migrant engineers working in Australia became available.

Overall, the annual increase in the engineering team from education completions increased from 7,576 in 2009 to 9,850 in 2015 at an average annual growth rate of 3.4 per cent.

The key feature evident in Figure 1 is the role of skilled migration, both permanent and temporary. The green bars in the diagram show permanent migration numbers. In 2009, permanent migration of engineers was 6,678 compared to 7,576 education completions for the engineering team. Permanent migration had undergone extraordinary growth since 2001 when 1,600 permanent visas were granted. In the years following 2009 strong growth in permanent migration continued, averaging growth of 8.4 per cent per year and by 2015 10,778 permanent migrants were granted visas. Permanent migration of engineers has been higher than university education completions for domestic students since 2009.

But the influence of skilled migration does not stop there. As well as permanent skilled migration, at any given time there are large numbers of temporary migrant engineers working in Australia on the Temporary Work (Skilled) visa (subclass 457). Temporary skilled migration is intended to operate as an automatic labour market stabiliser; when demand for engineers is high and employers experience difficulties recruiting in Australia, temporary migration is a safety valve for employers and allows numbers to increase quickly. When demand slackens, employers can allow temporary employees to return overseas, typically at the conclusion of short term contracts which can be anything from several months up to four years in duration.

*Permanent migration of engineers has been higher than university education completions for domestic students since 2009. Although temporary skilled migration has increased and fallen broadly in line with the intent of policy, permanent and temporary migration of engineers account for almost two-thirds of our new engineers.*

This pattern is evident in the red bars in Figure 1. In 2009, there were 6,241 engineers working in Australia on temporary visas, adding to the 6,678 permanent migrants who arrived that year. In all, 12,919 permanent and temporary migrant entered the engineering labour force compared to 7,576 from the completion of entry level qualifications. The number of temporary migrant engineers increased strongly to a peak of 9,358 in 2012 in response to high demand for engineers, particularly on resources sector construction projects. The engineering labour market began to deteriorate in late 2012-early 2013 and this was reflected in falling numbers of temporary migrant engineers in subsequent years. By 2015, the number of temporary migrant engineers employed in Australia had fallen to 5,709, just short of the 2009 figure when skill shortages were really biting. The difference in 2015 is that there are no shortages.

*The National Engineering Register is the benchmark of professionalism in engineering practice. The NER corresponds to the standards of competence required in legislated systems and for engineering practice.*

# 2.2

## Australia’s engineering capability

Australia’s engineering capability comprises individuals who hold recognised engineering qualifications and who work in occupations closely related to engineering. An engineering qualification per se is not sufficient. Like other professions, engineering requires new graduates to satisfactorily complete a process of professional formation in order to be recognised as a competent, practicing engineer. Many people who hold recognised engineering qualifications choose employment away from engineering. While they contribute to the general up-skilling of the Australian labour force, and in this way to Australian productivity growth, unless they are actively pursuing professional formation as an engineer, in most cases they do not contribute to Australia’s engineering capability.

In some countries the professional status and practice of engineering is legally defined and protected by law. Supporting arrangements vary and include regulation through government bodies and self-governing bodies granted powers through legislation. In Australia, only Queensland has similar legislation. Although some other Australian jurisdictions are actively considering legislated regulation of engineers, current arrangements are voluntary.

Engineers Australia’s National Engineering Register (NER) is the uniform national benchmark standard of professionalism in engineering practice. The NER is a compliance benchmark that corresponds to the standards of competence required in legislated systems and identifies individuals who satisfy the following criteria:

- Recognised academic qualifications in engineering.
- Cumulative (five years in the past seven years) and current experience in their chosen area of engineering practice.
- Commitment to and practice of ethical standards in engineering practice.
- Commitment to and practice of an appropriate standard of continuing professional development.
- Have the benefit of professional indemnity insurance and demonstrate that they can maintain this benefit throughout the provision of engineering services.

The NER is a publicly searchable database providing a voluntary national system of registration for the engineering team in both the private and public sectors in Australia. The NER is open to both members and non-members of Engineers Australia and aims to provide consistency in standards of engineering practice across states and territories and to facilitate any new legislated approaches. In our view, the NER is an important indicator of Australia’s engineering capability.

# 2.3

## Australia’s dependence on migrant engineers

Given the statistics illustrated in Figure 1, it comes as no surprise to find that between the 2006 and 2011 censuses 71.4 per cent of the increase in the supply of engineers was from skilled migration[21]. In 2006, the proportion of Australian born engineers in the engineering labour force was 51.6 per cent. Five years of strong skilled migration reduced this proportion to 46.1 per cent in 2011. Since 2011, we have observed that high rates of skilled migration have continued and statistics from the ABS Survey of Education and Work (SEW)[22] show that the proportion of Australian born engineers in the labour force had fallen further to 42.7 per cent. Conversely, the proportion of overseas born engineers in the labour force has increased from 48.4 per cent in 2006 to 53.9 per cent in 2011 and was 57.3 per cent in 2015. Although overseas born does not equate to migration in all cases[23], virtually all of the changes in these years were the result of skilled migration programs.

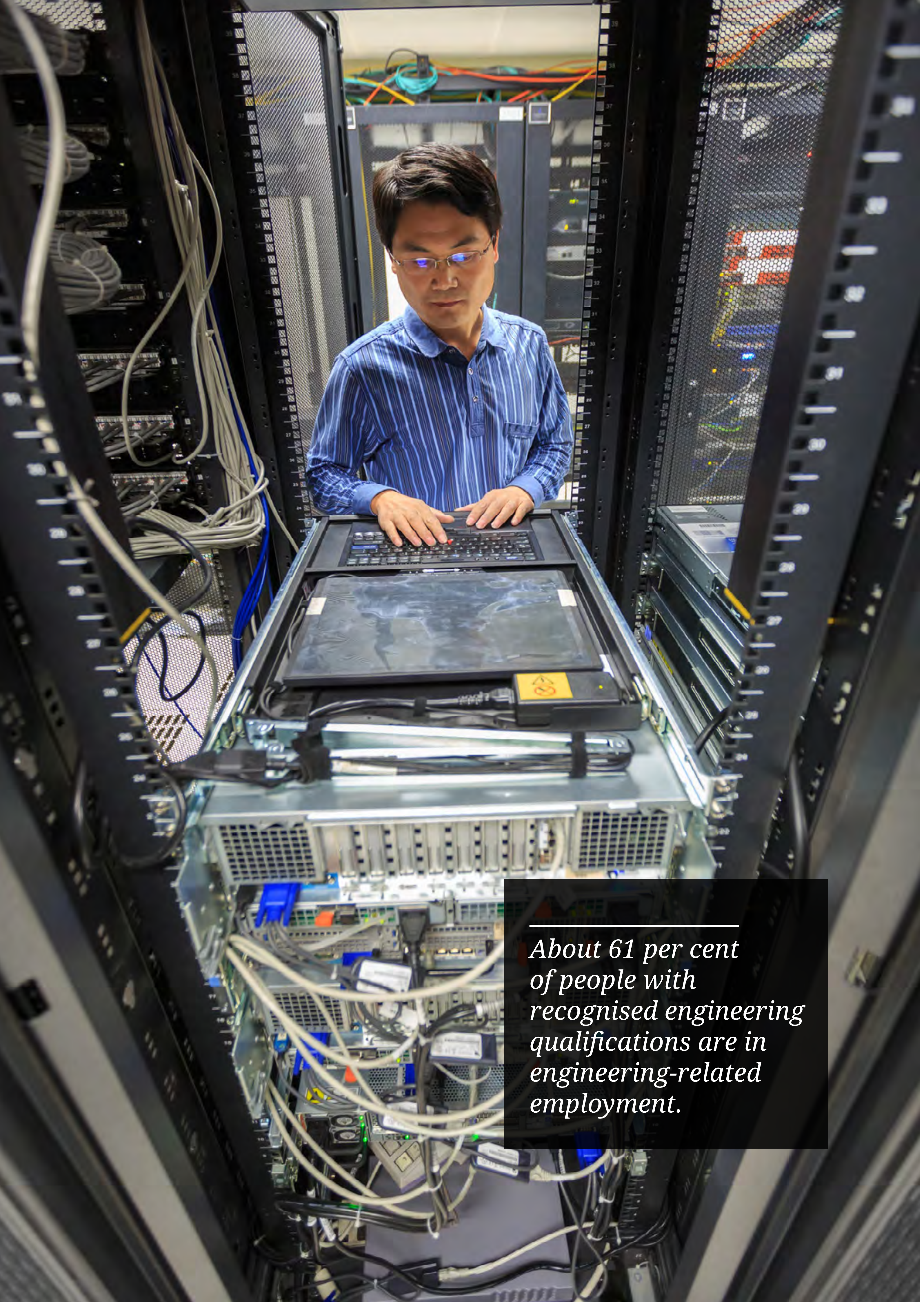
Australia’s dependence on skilled migration of engineers is much higher than in other professions. In 2011, the proportion of overseas born individuals with at least an associate degree or advanced diploma in other professions was 36.2 per cent, compared to 53.9 per cent in engineering. Although skilled migration has continued to be a feature of Australian population growth, this relationship has been maintained over time so that in 2015, the comparison was 40.9 per cent overseas born in other professions compared to 57.3 per cent in engineering.

*Australia is very dependent on skilled migration for its new engineers. This has meant that engineering is predominantly comprised of overseas born engineers, in stark contrast to other professions. Continuation of this reliance is not risk free.*

High dependence on skilled migration of engineers is not risk free. At present, large numbers of engineers resident in other parts of the world apply for permanent visas to migrate to Australia, but this may not always be the case. Global economic growth is still sluggish and recovery from the global financial crisis is incomplete. When global economic growth resumes, the demand for engineers in our source countries will also increase and more overseas engineers will prefer to remain in home countries rather than migrate. The consequences for Australia and other countries actively seeking migrants is that the pool of engineers who want to migrate will shrink. Australia will be competing with other potential host countries and both the scale and quality of our intake could deteriorate.

This argument does not mean Australia should abandon skilled migration of engineers. Skilled migration adds diversity to the composition of the engineering labour force and should be valued for this reason alone. However, a balance needs to be struck between the benefits from diversity and the potential future risk to Australia’s supply of engineers. Engineers Australia believes that the best way to achieve this balance is for Australia to produce more of its own engineers.

21: Engineers Australia, The Engineering Profession in Australia; A Statistical Overview, Twelveth Edition, 2015, www.engineersaustralia.org.au . NB the figures in Figure 1 do not include losses from the engineering labour force but these are netted out in census figures.
22: ABS, Education and Work, Australia, electronic statistics, Cat No 6227.0.30.001, www.abs.gov.au . The statistics used were provided by the ABS in response to a consultancy request from Engineers Australia
23: For example, some children of earlier generations of migrants were born overseas but effectively grew up and were educated in Australia.



*About 61 per cent of people with recognised engineering qualifications are in engineering-related employment.*

## 2.4

## Measuring Australia's engineering capability

Measuring Australia's engineering capability is complex and difficult and needs to be undertaken within the limits and constraints of available statistical information. We have argued that, to be considered part of Australia's engineering capability, the first step is completion of a recognised qualification in engineering. To assist our discussion, we need to carefully define the terms we use. Most public discussion of engineering concerns the engineering labour force and this comprises all persons with recognised qualifications in engineering actively participating in the labour market. Those belonging to the engineering labour force are referred to as "qualified engineers".

Australia's engineering capability is that part of the engineering labour force that is actively engaged in engineering. Being educated and trained in engineering is not a guarantee that an individual works in engineering. As is the case in other professions, some people who complete engineering qualifications choose not to embark on an engineering career and others change their minds at different stages of their engineering careers and move into alternative employment. The analytical and problem solving skills acquired through engineering education and training are highly valued throughout the economy.

The gap between the engineering labour force and Australia's engineering capability is the result of people exercising their choices in a free labour market. Numerous factors are involved and more research is necessary to be definitive, but several possible explanations are worth mentioning. Gender and ethnicity seem to be important and these factors are explored in more detail below. Insufficient or inadequate career opportunities in engineering compared to alternative lines of work is another. Over time an increasing share of engineering work has shifted from being regular, on-going employment to contractual employment with duration determined by completion of specific projects. Finally, personal preferences relating to location and conditions of employment also play a part.

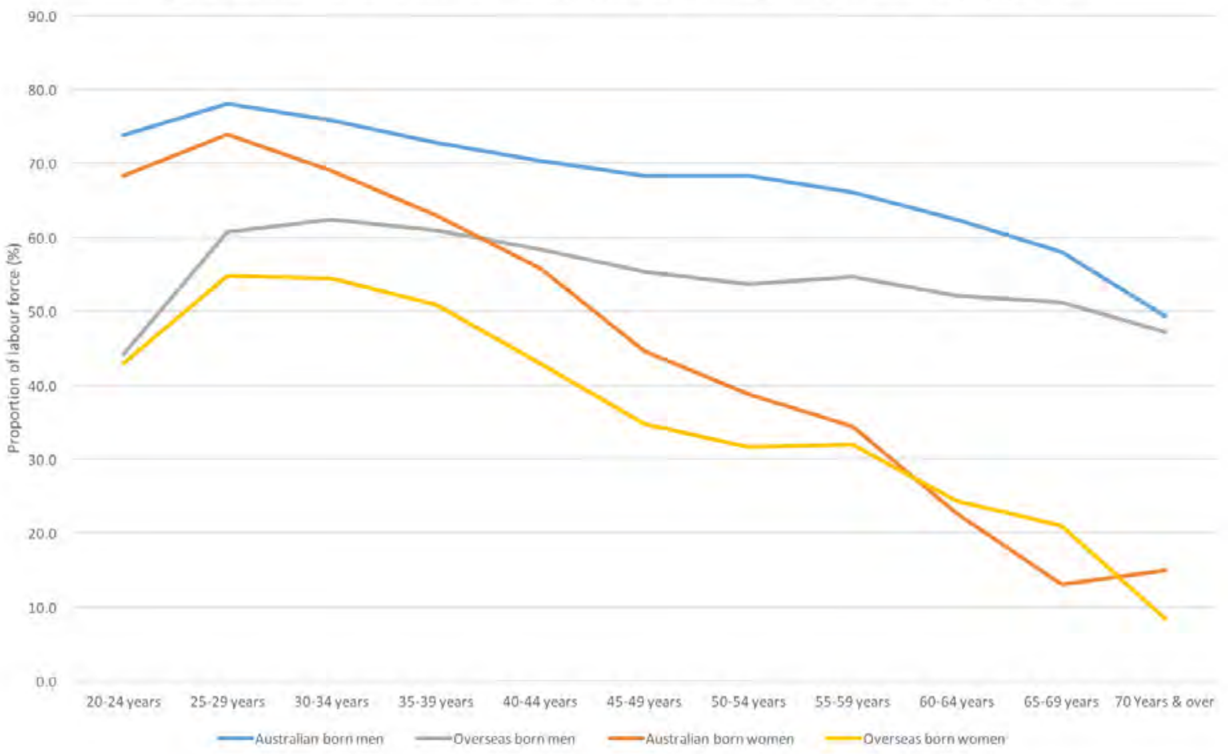


Figure 2: Proportion of the labour force employed in engineering occupations falls by age, 2011

Engineers Australia's approach to measuring Australia's engineering capability has been to identify "qualified engineers" employed in occupations closely attached to engineering and engineering careers. In 2010, research[24] by Engineers Australia identified 51 of 358 four digit occupations in the ABS ANZSCO[25] classification satisfying criteria defining close attachment to engineering. The selected occupations cover the diversity of work undertaken by engineers in industries traditionally associated with engineering and in a range of other industries that have employed more and more engineers as the Australian economy has developed and expanded. The selection process involved some subjectivity, and sensitivity analysis was used to test its effect This showed that adding or subtracting up to five marginal occupations made little difference to the results.

Using census statistics, the number of "qualified engineers" employed in engineering occupations in 2006 was estimated to be 122,258 or 60.9 per cent of the engineering labour force of 200,615. In other words, Australia's engineering capability is less than two-thirds of the pool of "qualified engineers". By the 2011 census, the number of "qualified engineers" employed in engineering occupations had increased to 163,912 or 62.1 per cent of the engineering labour force of 263,890.

Using Figure 2 we explore the nature of employment in engineering occupations further. This diagram uses statistics from the 2011 census to divide Australia's engineering capability, that is, the segment of the labour force employed in engineering occupations, by age, gender and ethnicity. Several important points emerge:

- Irrespective of gender or ethnicity, employment in engineering occupations falls with age. Typically, engineering capability is at its highest in the youngest age groups.
- The highest proportions relate to Australian born men, the historical, archetypical engineer. On average 70.6 per cent of Australian born men were employed in engineering occupations. The proportion is highest for the 24 to 29 years age group at 78.1 per cent and steadily falls thereafter. It remains above average until the 40's and falls below 50 per cent for the 70 years and over age group.
- The average proportion of Australian born women employed in engineering occupations is 62.2 per cent, some eight percentage points lower than for male counterparts. Again the highest proportion occurred in the 24 to 29 years age group with 73.9 per cent, about five percentage points lower than male counterparts. However, the rate of decline with age for this group is substantially faster and by age 40 the gap between men and women has opened up to 15 percentage points and continues to widen thereafter.
- The average proportion of overseas born men employed in engineering occupations is 57.2 per cent, substantially, less than Australian born engineers of either gender. The highest proportion occurred in the 30 to 34 years age group, favoured by the immigration points test, with 62.4 per cent. This was well below the maximums recorded for either gender of Australian born engineers, but the rate at which the proportion falls with age is slower, converging towards the profile for Australian born men. Until age group 40 to 44 years, the proportion of Australian born women employed in engineering occupations is higher than the proportion of overseas born men.
- The average proportion of overseas born women employed in engineering occupations is 45.4 per cent. The highest proportion for this group were in the 25 to 29 and 30 to 34 age groups with 54.7 per cent and 54.5 per cent respectively, well below each of the three other categories reviewed. The fall in the proportion with age is faster than for overseas born men but slower than for Australian born women.

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[24] Engineers Australia, The engineering profession in Australia; A profile from the 2006 population census, September 2010, www.engineersaustralia.org.au

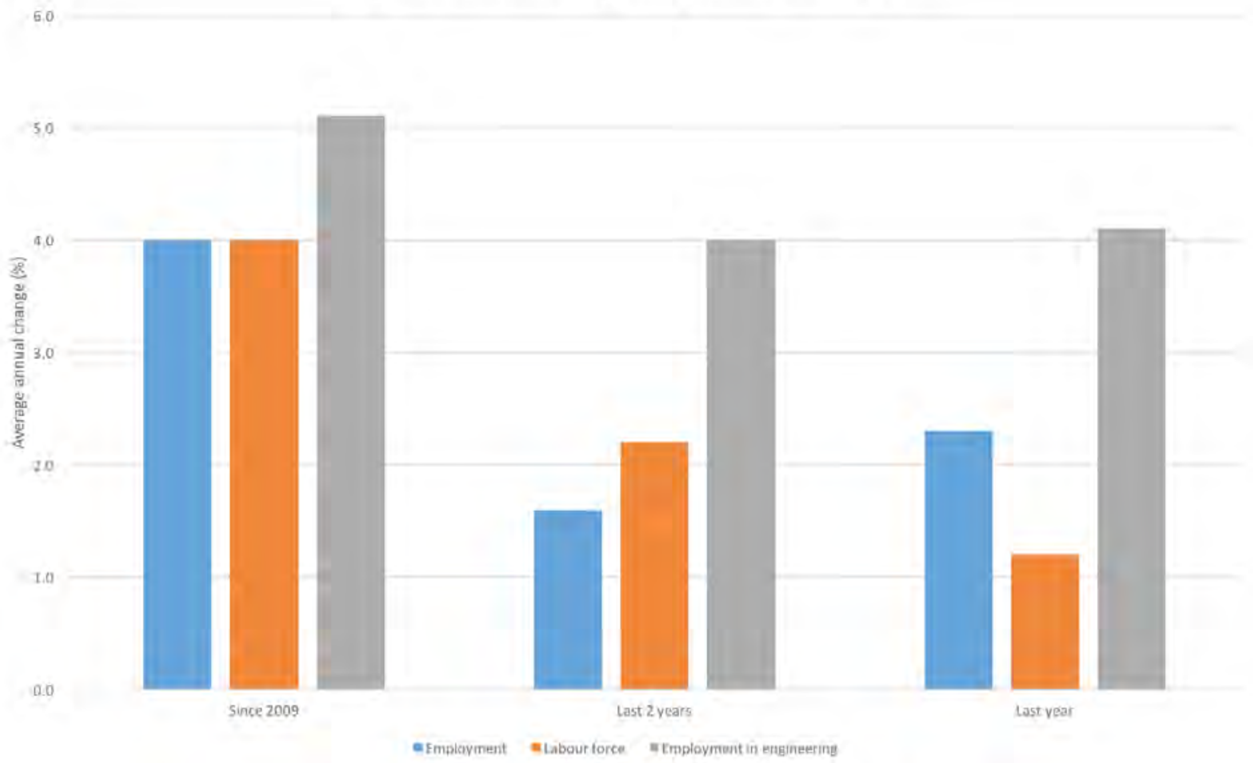
[25] Australian and New Zealand Standard Classification of Occupations (ANZSCO)

Australia's engineering capability relies on retaining "qualified engineers" in engineering. This analysis shows that retention falls with age, suggesting that increased retention requires improvements to career opportunities for engineers to encourage more engineers in middle to older age groups to stay in engineering longer to enable Australia to capitalise on their experience and expertise. Engineers are lost to the profession at a time when the benefits of that experience in advancing innovation and technological progress in Australia are most needed.

The analysis also shows that skilled migration policies are not as effective in contributing to Australia's engineering capability as they could be. Present selection methods favour relatively new graduates, often those who have not consolidated professional formation. As well as focusing primarily on entry level qualifications, current policies provide no assistance for migrant engineers to adapt to Australian labour market conditions or to bridge the gap between text-book English and colloquial work place English. Some regard is paid to work experience, but these considerations falls well short of the requirements necessary to qualify as a fully competent, practicing engineer. Migrant engineers are among Australia's most innovative engineers and too many leave the profession[26].

Gender cannot be ignored. The proportion of women in the engineering labour force continues to be low. In the 2011 census it was 11.8 per cent and just 9.7 per cent for women employed in engineering occupations. The rates of decline with age for women employed in engineering occupations as illustrated in Figure 2 suggest well embedded structural issues that need to be addressed. Australia cannot fully capitalise on its engineering capability by recruiting most engineers from one gender especially given that Australia's women engineers are on average more highly qualified than men.

Figure 3: Indicators of engineering demand and supply



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[26] See Engineers Australia, Who are Australia's most innovative engineers 2016, Create Magazine, Vol2 No 6 July 2016

## 2.5

## Recent adjustments in the engineering labour market

Like the Australian economy, the engineering profession has experienced a roller-coaster ride over the past decade. The resources boom led to widespread shortages of engineers which in the pre-GFC period was exacerbated by substantial public sector infrastructure development in most states and territories. In late 2012, the demand for engineers began to collapse with vacancies falling for almost thirty successive months. The resources boom was over and so too was public sector infrastructure investment, leading to a major realignment of the engineering labour market.

A sense of the changes that occurred can be found in Figure 3. Let us remind ourselves what happened to the supply of engineers. The three elements increasing the supply of engineers shown in Figure 1, education completions, permanent migration and temporary migration combined, have grown by an average 4.5 per cent per year since 2009. Not included in Figure 1 is retirements from the engineering labour force. All four factors are included in the statistics in Figure 3 based on statistics from the ABS Survey of Education and Work (SEW). Figure 3 shows that the supply of "qualified engineers" increased by an average 4.0 per cent per year since 2009. The difference between these figures shows that even though there was robust growth in supply, some "qualified engineers" were retiring. If we look at averages since 2009, the demand for "qualified engineers" matched growth in supply at 4.0 per cent per year. But the growth in demand for Australia's engineering capability was far higher averaging 5.1 per cent per year. It is this difference that gave rise to engineering shortages. During 2014 and 2015, growth in both the supply of and demand for "qualified engineers" slowed abruptly; demand grew by an average 1.6 per cent per year and supply by an average 2.2 per cent per year. However, we have observed that education completions and permanent skilled migration have been adding near record numbers to the supply of engineers. How do we reconcile this observation with the slowdown in supply? Part of the answer is due to the automatic stabilising effect of temporary skilled migration. The collapse in demand for engineers meant that temporary skilled migration moved into reverse as more and more employers did not renew contracts for temporary migrant engineers. However, another key factor was that large numbers of engineers retired or left the labour force.

Contemporary age statistics for engineers are not available to put an accurate figure on this change. However, its scale can be inferred from census statistics. In the 2011 census 73,931 engineers were aged 50 or more years, 28 per cent of the engineering labour market. Now some five years later, this group is aged 55 or more years. Similarly, 46,500 engineers were aged 55 or more years in 2011 and are now aged 60 and over years and 24,289 engineers were aged 60 or more years in 2011 and are now aged 65 or more years. Moving forward another five years to 2021, engineers aged 50 and over in 2011 will be aged 60 and over, indicating that further retirements are imminent. Two different pieces of evidence point to retirements as an important adjustment mechanism:

- SEW statistics show labour force participation rates for engineers fell during the adjustment period.
- Although growth in the supply of "qualified engineers" averaged 2.2 per cent per year, discounting temporary skilled migration showed that the combined growth of permanent migration and education completions averaged 6.2 per cent per year.

During 2014, the unemployment rate for "qualified engineers" increased to 5.4 per cent compared to an average 3.7 per cent over the previous five years, adding a third element to the adjustment process. Unemployment fell back to 4.4 per cent in 2015, an improvement but still higher than for the five years from 2009.

Although the adjustments in the growth of supply of and demand for “qualified engineers” have been large and confirm anecdotal impressions of change in the engineering labour market, the underlying demand for engineering capability, that is, the demand for “qualified engineers” to work in engineering occupations, has remained far more robust. Average growth of 5.1 per cent per year since 2009, slowing to 4.0 per cent per year over the past two years and continuing into 2015 with 4.1 per cent growth.

Two points are important here. First, the flexibility and adaptability of “qualified engineers” has enabled many to move into non-engineering work and this has assisted adjustment to present economic circumstances. Second, skilled migration adds less to engineering capability than it does to the number of “qualified engineers” and this has scaled the inflow of migrant engineers to a level the market has been able to absorb.

We have found a plausible explanation for macroeconomic adjustment of the engineering labour market but this obscures the extraordinary changes that have taken place for individual engineers, at project level and geographically. Rather than being a negative factor, the large share of older engineers has meant that significant adjustment took place without a large increase in the unemployment rate for “qualified engineers” as might have been expected. Similarly, large numbers of “qualified engineers” continue to be absorbed into Australia’s general skilled labour force. This is demonstrated by the scale difference between the supply of “qualified engineers” and Australia’s engineering capability; 378,600 compared to 232,00 in 2015.

## 2.6

## Looking to the future

Present indications suggest that employment growth, including the employment of engineers will slowly and gradually recover towards long term averages. This is already happening to some extent in NSW and Victoria. The resources sector construction boom is unlikely to resume and the number of engineers employed in the resources sector production phase will be fewer than employed in the construction phase. Business and other interest groups have joined Engineers Australia’s call for increased infrastructure investment, particularly in large cities and towns where most population growth is expected to be. It is important to remember that to function as enablers of productivity growth, infrastructure services need to be available ahead of requirements. Just in time does not work for infrastructure and providing it late is counter-productive to productivity growth. Unfortunately, governments can be reluctant to get on with the job.

The pace of adjustment in the engineering labour market has been rapid and the adjustment is to the conditions now prevailing in Australia’s economy. Skilled migration has served Australia well over past decades, but in engineering we have become over-dependent on it and we need to reduce our reliance to return balance to how we source new engineers.

Many “qualified engineers” who move away from engineering work do not return, nor will many retired engineers return to the labour market unless exceptional circumstances affect their lives. What this means is that in a year or two when adjustment is more-or-less complete, Australia will have an engineering capability compatible with our present slow levels of economic growth. This is some way short of the technological and innovation ambitions expressed by the government. If Australia is to become an innovative nation, our engineering capability must expand to match that ambition.

The rest of this report examines factors that affect the capacity of Australia to develop more of its own engineers. The work we look at is broadly consistent with revitalised emphasis on STEM subjects in Australian education. However, for Engineers Australia STEM studies in schools are a means to an end. Our principle concern is to ensure that Australia’s engineering capability matches our national ambitions to be a prosperous and innovative nation. Successful engineers use their skills in science and mathematics in conjunction with skills in communication, teamwork, collaboration with other professionals and engineering practice to unleash the spirit of innovation.

Policies for Australia to develop more of its own engineers begin with the groundwork for engineering education and this is in high school. In the next chapter we examine how prevailing school trends affect this ambition.

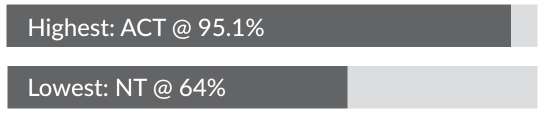
*Engineering has experienced short term adjustment pains caused by the end of the resources boom and patchy investment.*

# 3.

# Developing Australia's engineering capability

Students retention to year 12 (2015)

Student retention to year 12 (2015)



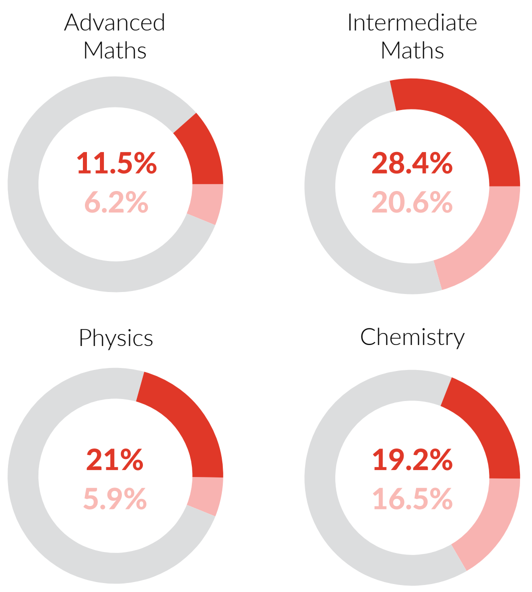
Applications to university direct from school (2015)

Applications to university by application type

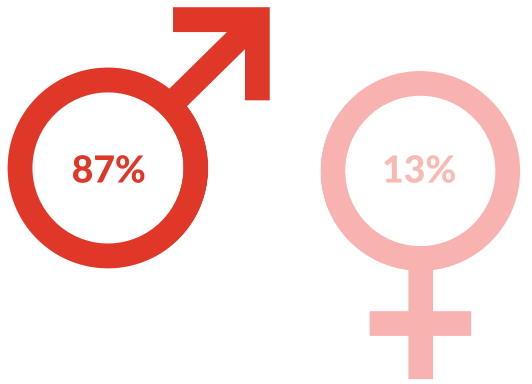
**16,414**
Via the tertiary Admissions Centre process

**4,873**
Direct to universities

Student at year 12 in each subject (2015)



Gender profile of profession (2015)



🟥 Male 🟥 Female ⬛ Cohort

## 3.1

## Introduction

Australia's capacity to produce its own engineers begins at school. Most of the public commentary and discussion of school trends has been qualitative or, if statistical, confined to the schools sector. For Australia to develop more of its own engineers we need a sufficient flow of high school students who are interested in engineering and who have studied the subjects that engineering relies on. Similarly, if engineering is to increase the number of women in the profession we need a sufficient flow of young women with these attributes. In this chapter, we explore the quantitative links between the flow of potential engineers from school to engineering education. We look at the issue of falling participation in year 12 foundation subjects for engineering courses and how this issue intersects with increased high school retention to year 12. We compare the number of students in foundation subjects with acceptances of places in engineering courses to investigate how much of a difficulty is posed by falling foundation subject participation. The final part of the chapter considers what policy options are available to address the obstacles found.

Engineering courses are long in duration and subjects studied rely on students acquiring firm foundations in mathematics and science in the later years of high school. The recent widespread discussion of the importance of science, engineering, technology and mathematics (the so called STEM subjects) for the future development of the Australian economy[27] has been very general and contrasts with our interest. Engineers Australia is concerned about the development of Australia's engineering capability and current high school trends in STEM subjects are a means towards this end.

Mathematics, physics, chemistry and other sciences are the tools that engineers use to solve real world problems and to convert good ideas into productive and valuable products suitable for home and international markets. The reasons why fewer high school students study these subjects are numerous and complex and are not explored in this report. However, given their importance to engineering, it is important to develop insights into the relationship between current trends and tertiary education to emphasise why current trends could impede development of Australia's engineering capability.

> *Participation in high school STEM subjects is a means to an end: mathematics and science are the tools used by engineers to solve real world problems.*

Falling participation in year 12 STEM subjects has been discussed for almost two decades, but accurate statistics, particularly in respect to gender participation, have been a serious problem[28]. Kennedy, Lyons and Quinn[29] stepped into this breach and have produced fresh statistics compiled directly from enrolment data held by state and territory boards of education. This substantial undertaking built on earlier work about the alignment of the myriad mathematics and science courses offered by state and territory education systems. In this report, we use these statistics and extend them to construct a quantitative link between high school STEM studies and acceptances of places in university engineering courses.

Our intention is to add to qualitative analyses by exploring quantitative insights about how present trends in high school STEM participation could affect building Australia's engineering capability. Following personal correspondence, Mr Kennedy generously provided Engineers Australia with statistics for year 12 STEM subject participation rates and gender ratios[30]. Without this assistance the work described in this chapter would not have been possible.

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[27] See for example Chief Scientist, Science, Technology, Engineering and Mathematics: Australia's Future, 2 September 2014, www.chiefscientist.gov.au and more recently Chief Scientist and the Australian Academy of Sciences, The Importance of Advanced Physical, Mathematical and Biological Sciences to the Australian Economy, January 2016 also available from the Chief Scientist's web address.

[28] D Goodrum, A Druhan and J Abbs, The Status and Quality of Year 11 and 12 Science in Australian Schools, 2011, Australian Academy of Science, Canberra

[29] J Kennedy, T Lyons and F Quinn, The Continuing Decline of Science and Mathematics Enrolments in Australian High Schools, Teaching Science, Volume 60, Number 2, June 2014, available from www.eprints.qut.edu.au/73153/1/Continuing_decline_of_science_proof.pdf

[30] Personal correspondence with Mr John Kennedy.

## 3.2

## The importance of high school retention

For decades, Australian governments have encouraged high school students to complete year 12. Various policies were tried, but a key milestone was standardisation of the minimum school leaving age at 17 years across all states and territories in January 2010. There was some flexibility in this arrangement to enable year 12 to be completed at TAFE or from a registered training provider, but most of the impact was evident in the form of increased high school retention as shown in Figure 4.

Retention of both young men and young women has increased and some narrowing of the gender gap has occurred. Unfortunately, the remaining gap is still very large with far fewer young men completing year 12. In 2015, 83.1 per cent of high school students completed year 12; 79.8 per cent of young men and 86.5 per cent of young women.

High school retention is important because of the interaction Kennedy, Lyons and Quinn observed between falling subject participation rates and the increasing student population. This important observation points to a window of opportunity during which relative stability in student numbers offers policy makers the time necessary to implement policies to reverse subject participation rates. With retention already at 83.1 per cent and continuing to increase, this window of opportunity is not likely to be available for long and taking advantage of it requires urgent attention. In the absence of increased retention, falling subject participation rates would hold sway creating a very difficult environment from which to build Australia's future in an increasingly technical world.

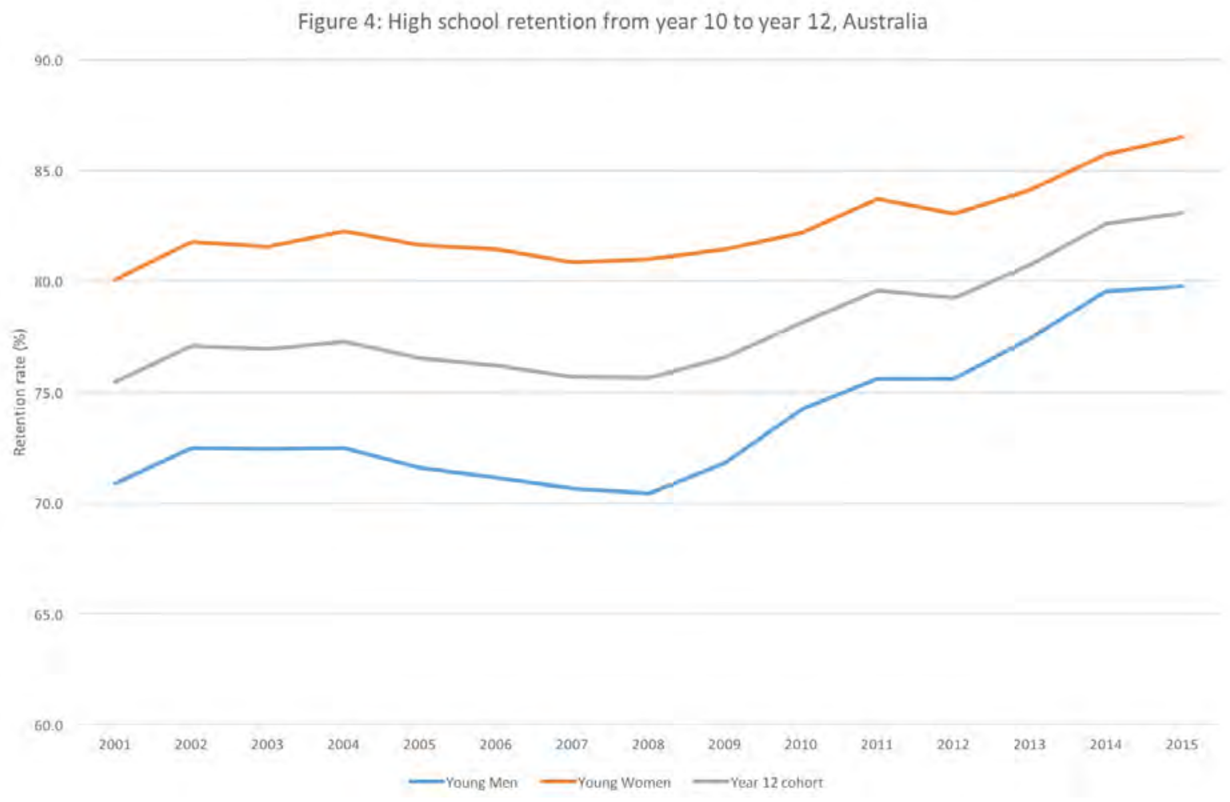
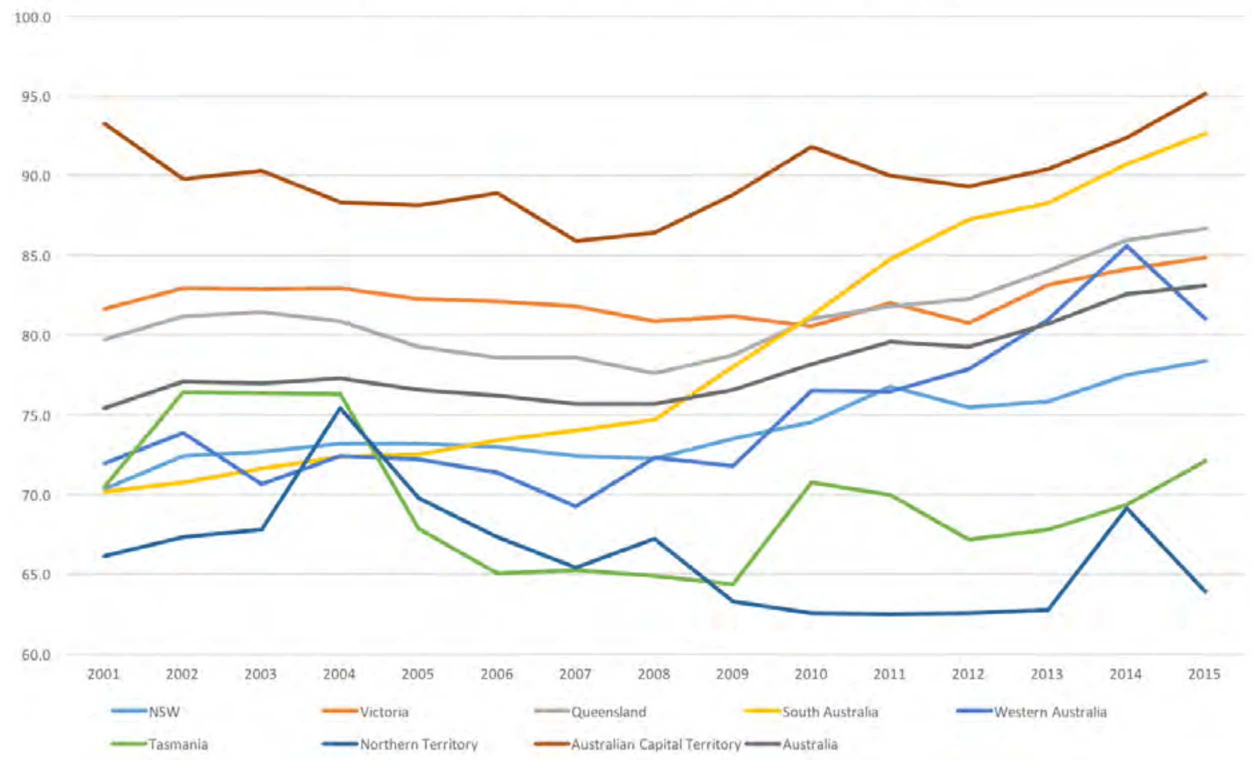


Figure 4: High school retention from year 10 to year 12, Australia

Figure 5: School Participation Rates from Year 10 to Year 12



## 3.3

## State and territory differences in high school retention are excessive

As is the case in many other areas, there are extraordinary differences in high school retention rates between states and territories. These are illustrated in Figure 5 and give rise to a number of observations:

- The highest retention is in the ACT; in 2001, retention was already 93.3 per cent, but by 2015 it had increased further to 95.1 per cent with 92.2 per cent for young men and 98.1 per cent for young women.
- In 2015, retention in NSW, the largest jurisdiction, Tasmania, and the Northern Territory was below the national average and this was the case for the entire period illustrated.
- In 2015, retention in Victoria, Queensland and the Australian Capital Territory was above the national average a relationship that prevailed the entire period illustrated.
- The big improver was South Australia which increased retention from 70.2 per cent in 2001 to 92.7 per cent in fifteen years.
- From 2011, the retention rate in Western Australia passed the national average and continued to increase for several years before reversing in 2014. This change is explained by the so-called “half cohort effect” caused by an increase to the school starting age by six months in 2001. This reduced numbers by about 10,000 students and as this cohort has moved through the school system it has distorted statistics. This group was in year 12 in 2014 and a more normal trend similar to South Australia is expected to resume in future years.

Simply reducing the variability in state and territory high school retention would result in an increase in national retention. The experiences of South Australia and Western Australia point the way and demonstrate that substantial improvements are possible relatively quickly.

## 3.4

## The gender issue

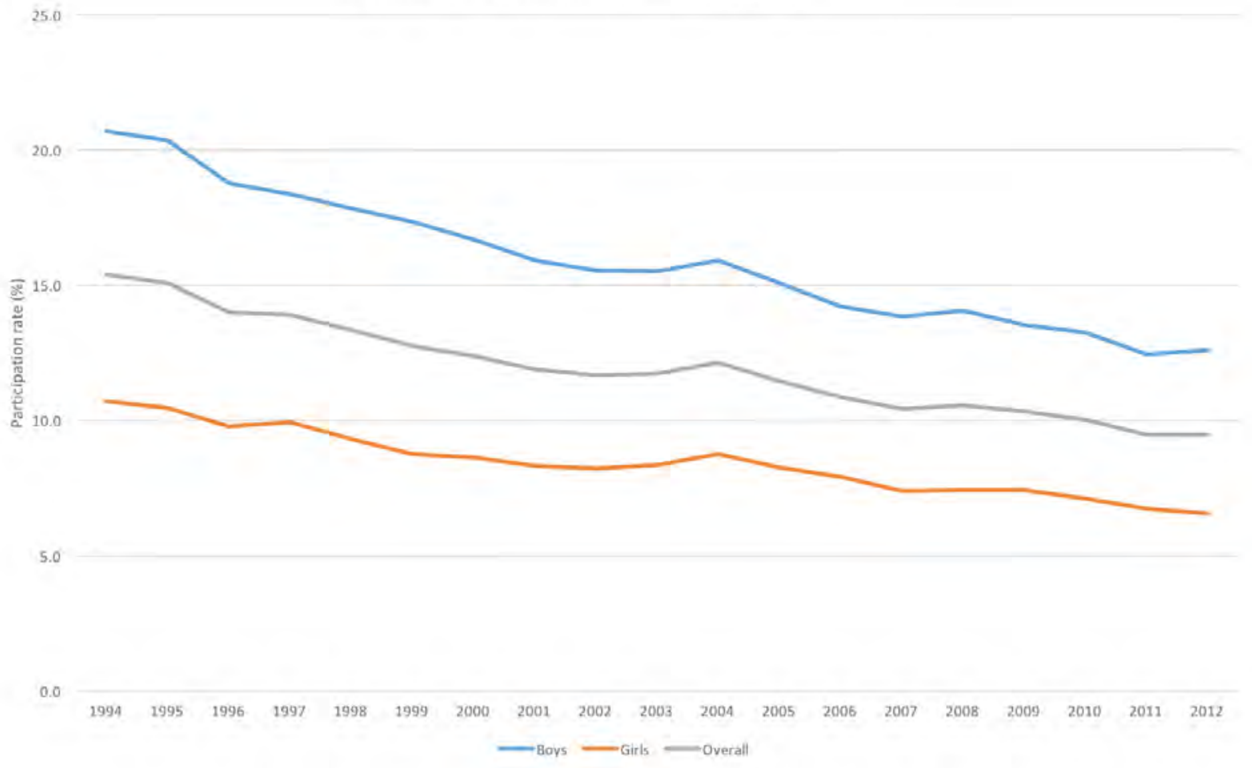
The difference in retention between young men and young women observed in Figure 4 is replicated in each state and territory, even in the ACT where retention is highest. For a long time, engineering has been a male dominated profession and the trends in Figure 4 emphasise the difficulties associated with building a profession predominantly from one gender. In following sections, the issue is explored more thoroughly by examining the consequences of particularly severe falls in STEM subject participation rates among young women.

## 3.5

## STEM participation in high schools

The statistics provided by Mr Kennedy covered the period 1992 to 2012. We extended these statistics to 2015 by combining the Kennedy, Lyons and Quinn subject participation rates[31] and subject sex ratios[32] to estimate gender participation rates for each of four subjects; advanced mathematics, intermediate mathematics, physics and chemistry. These participation rates were updated to 2015 using ordinary least squares regression[33].

Figure 6: Year 12 participation in advanced mathematics



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[31] Kennedy, Lyons and Quinn used overall subject participation rates and sex ratios (the number of girls per 100 boys) derived from examination of raw enrolment statistics from the Boards of Studies in each state and territory. The number of boys was estimated as p/(1+0.1r) where p is the number in year 12 and r is the subject sex ratio. Having estimated the numbers of each gender, gender specific participation rates could be calculated.

[32] Kennedy, Lyons and Quinn estimated the retention rate from year 10 to year 12 by combining Board of Studies year 12 statistics with ABS year 10 statistics. Our objective here required updating statistics from 2012 to 2015 and to do this we applied the Kennedy, Lyons and Quinn gender divided subject participation rates to ABS year 12 statistics. There were small differences between their year 12 statistics and ABS statistics, typically less than 0.5 per cent, which did not affect observed trends.

[33] This was achieved through simple ordinary least squares regression techniques. In the case of advanced and intermediate mathematics and physics, the coefficients of determination were very high, over 90 per cent, and the estimated participation rates for 2013 to 2015 were closely related to the trends for earlier years. Unfortunately, in the case of chemistry, the time trends were non-existent and instead it was assumed that the 2012 value continued over the following three years.

[34] Kennedy, Lyons and Quinn, The Continuing Decline, op cit, p36

### 3.5.1 Advanced mathematics

Historically, year 12 advanced mathematics has been an important foundation subject for entry to engineering degrees. This is consistent with how this subject is treated in the literature where it is described as “courses that provide a specialised knowledge-base for tertiary studies in courses such as engineering and physical science”[34]. The trends in participation in this are illustrated in Figure 6.

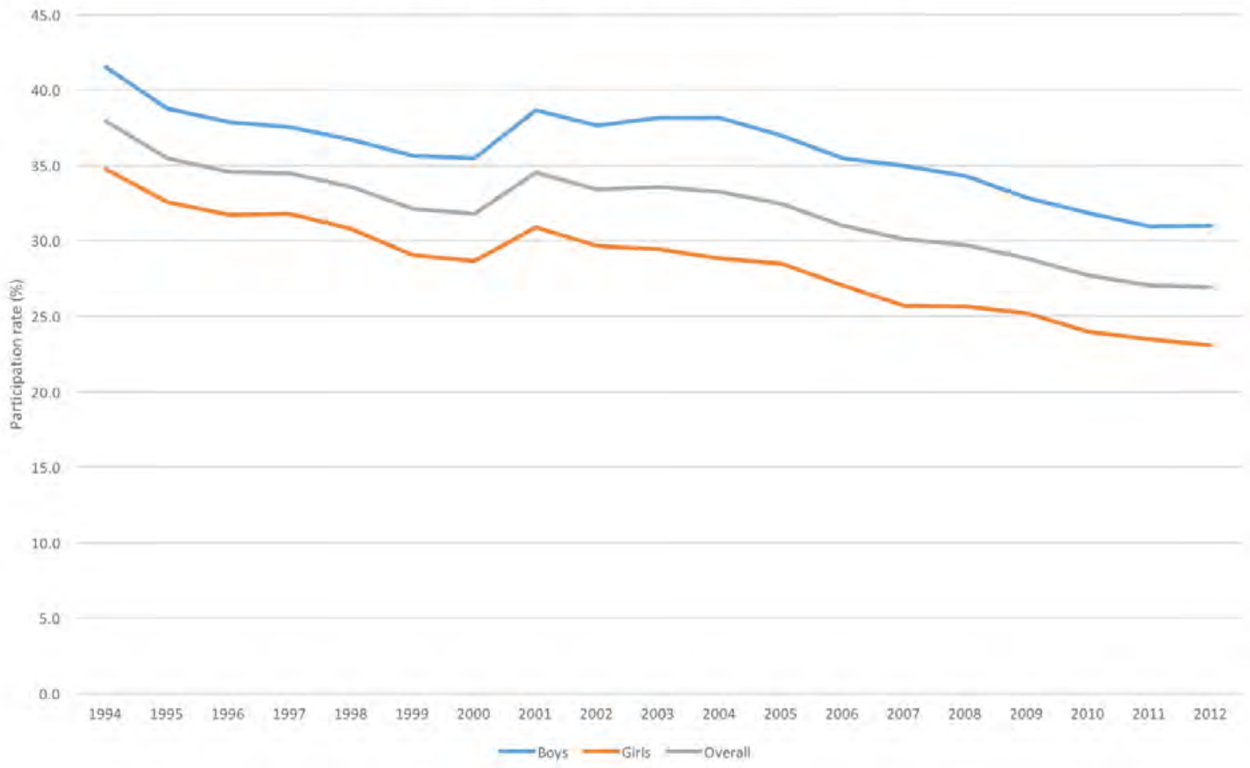
In advanced mathematics, the participation rate for young men in year 12 was 15.9 per cent in 2001. By 2012, the last year of the Kennedy, Lyons and Quinn statistics, the participation rate had fallen to 12.6 per cent. Using the methodology described in footnote 33 by 2015 the participation rate falls to 11.5 per cent. The number of young men studying year 12 advanced mathematics is the outcome of two countervailing trends, increasing retention to year 12 and falling advanced mathematics participation. The result is that the number of year 12 advanced mathematics students has not fallen as fast as suggested by the participation rate itself. In 2001, 14,224 young men studied advanced mathematics; this fell to 13,608 in 2012 and we estimate that in 2015 there were 13,008 young men studying advanced mathematics.

> *Participation rates for advanced mathematics are alarmingly low, particularly for young women.*

Participation of young women in advanced mathematics was already particularly low at 8.3 per cent in 2001. By 2012, participation had fallen to 6.5 per cent and we estimate that by 2015 it had fallen further to 6.2 per cent. Since retention of young women was already very high in 2001, further increases in retention did not offset falling subject participation to the same extent as for young men. In 2001, there were 8,228 young women studying advanced mathematics, falling to 7,458 in 2012 and our estimate is that in 2015 there were 7,223.

There are substantial differences between young men and young women studying year 12 advanced mathematics. When the focus is on cohort participation these differences can easily be overlooked. There is no doubt that overall numbers studying this subject is a serious problem, but the number of young women is at crisis level.

Figure 7: Year 12 participation in intermediate mathematics



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[35] Op cit, p36

### 3.5.2 Intermediate mathematics

In the literature intermediate mathematics courses "provide a satisfactory knowledge-base for tertiary courses requiring minimal understanding"[35]. Figure 7 shows that participation rates for these courses have also fallen but not as rapidly as for advanced mathematics.

In 2001, 38.6 per cent of young men and 30.9 per cent of young women studied year 12 intermediate mathematics, an overall participation rate of 34.5 per cent. Translated into numbers, 34,518 young men, 30,537 young women and 64,984 students overall studied this subject. Although there were almost three times as many students as in advanced mathematics, the standard of these courses means that universities accepting these students would need to consider additional course material to bridge any gaps.

By 2012, participation of young men had fallen to 31.0 per cent, participation of young women to 23.1 per cent and overall participation to 26.9 per cent. The countervailing effect of increasing year 12 retention was insufficient to prevent a slide in numbers; to 33,460 for young men; to 26,343 for young women and to 59,803 overall.

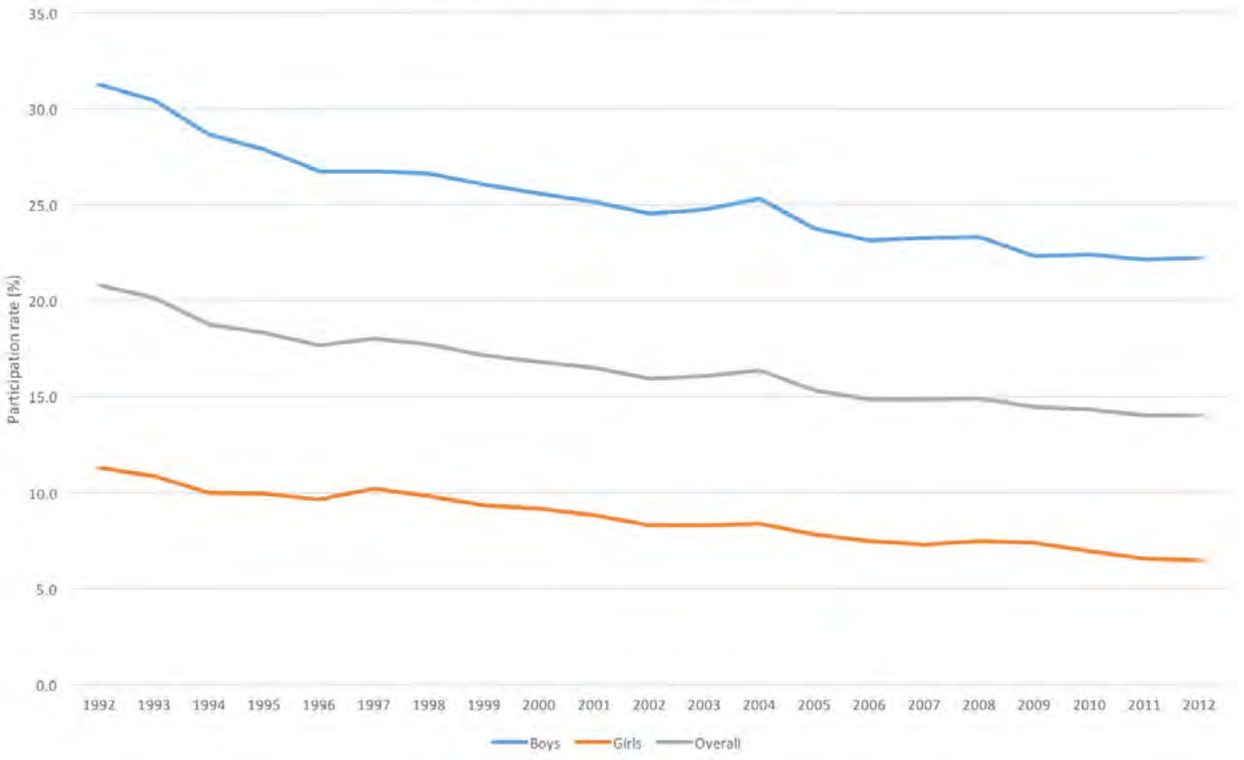
> *In intermediate mathematics participation rates continue to fall, with lower participation among young women than young men.*

Our estimates show that in 2015, participation of young men in intermediate mathematics fell to 28.4 per cent, participation of young women fell to 20.6 per cent and cohort participation fell to 24.4 per cent. Numerically the number of young men studying intermediate mathematics fell to 32,194 young men, the number of young women fell to 24,120 and the cohort to 56,314.

### 3.5.3 Physics

The participation rates for year 12 physics have much in common with those for advanced mathematics as the trends in Figure 8 show. In 2001, 25.1 per cent of young men studied year 12 physics, falling to 22.3 per cent in 2012 and we estimate a further fall to 21.0 per cent in 2015. The retention countervailing effect was quite strong and between 2001 and 2012 and increased the number of young men studying physics from 22,461 to 24,007. This effect weakened in the following three years and the number of young men studying physics fell to 23,742 in 2015.

Figure 8: Year 12 participation in physics



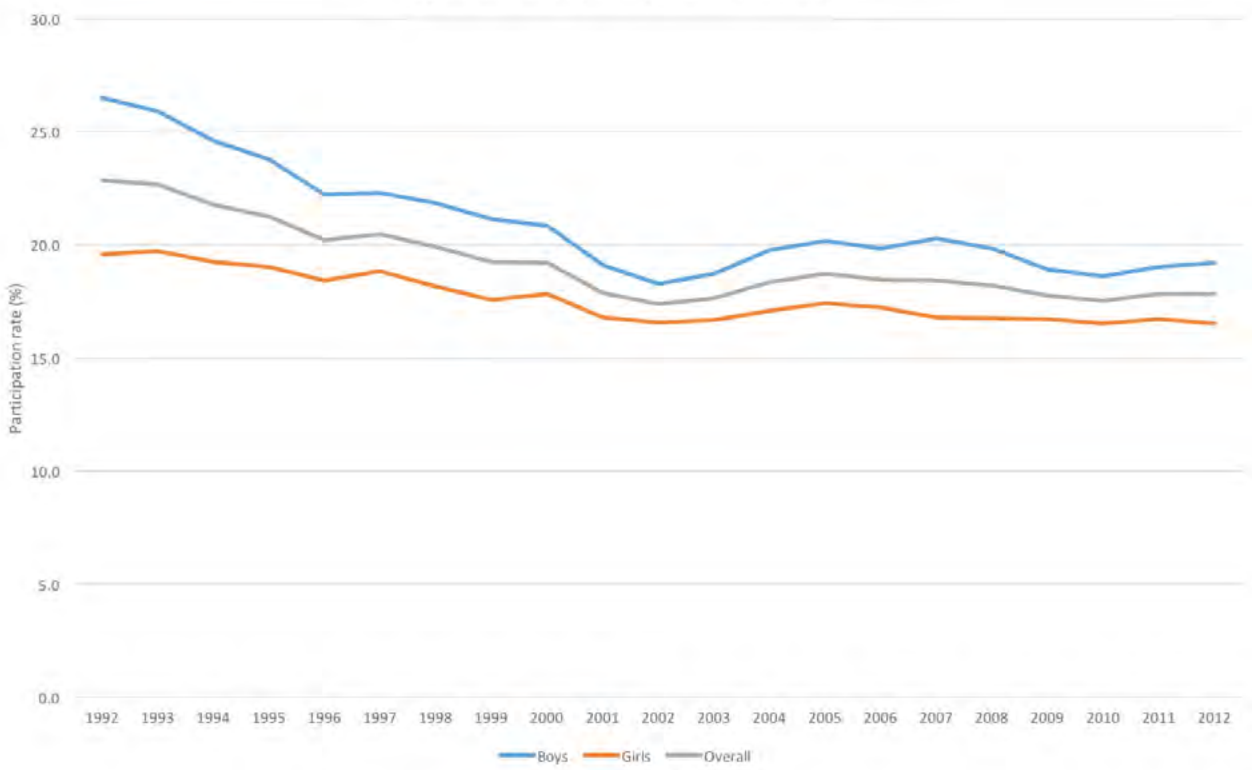


Figure 9: Year 12 participation in chemistry

***The fall in year 12 participation in physics has much in common with the situation in advanced mathematics; the fall has been large and sustained over time with substantially lower participation by young women than young men. Increased retention slowed the decline in the number of young men in this subject but the number of young women is now alarmingly low.***

Participation of young women in physics was substantially lower. In 2001, the participation rate was 8.8 per cent, almost one third that of young men. Participation fell to 6.6 per cent in 2012 and to 5.9 per cent in 2015. The number of young women in this subject reflected these rates; 8,748 in 2001, 7,376 in 2012 and 6,935 in 2015. As was the case with advanced mathematics, focusing on cohort participation rates for physics obscures the serious deterioration in the number of young women studying physics.

### 3.5.4 Chemistry

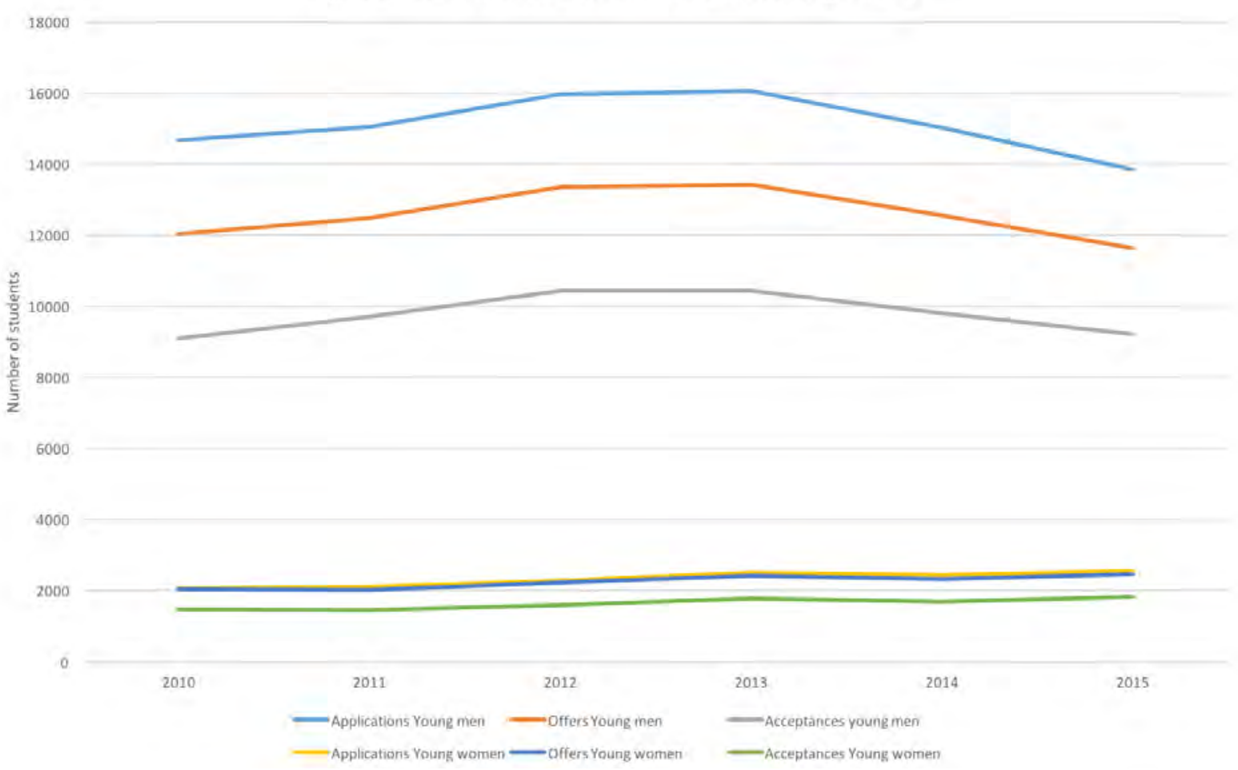
The situation in year 12 chemistry is not as clear cut as was the case for advanced mathematics and physics. The trends illustrated in Figure 9 show that participation fell until early last decade and has since stabilised. Another difference is that the difference in gender participation is far smaller.

*Participation in year 12 chemistry has stabilised in recent years and gender participation is far more balanced.*

In 2001, the participation rate for young men was 19.1 per cent which translated to 17,066 students. Despite the fluctuations evident in Figure 9 the participation rate in 2012 was substantially unchanged at 19.2 per cent. The number of young men studying this subject increased to 20,743 in line with increased retention. We estimate an unchanged participation rate for 2015 with a further increase in student numbers to 21,738.

The participation trend for young women was very similar but about 2½ percentage points lower. In 2001, the participation rate was 16.8 per cent and 16,604 young women studied chemistry. In 2012, the participation rate was slightly lower at 16.5 per cent but the number of students increased to 18,845. We estimate unchanged participation in 2015 and a further increase in the number of students to 19,312.

Figure 10: The TAC university entrance process in engineering



## 3.6

## The university engineering entrance process[36]

Our objective is to link the number of year 12 students studying advanced mathematics, intermediate mathematics, physics and chemistry to acceptances of places in university engineering courses. Before doing so it is helpful to briefly review the university entrance process.

Applications for places in engineering courses come from two distinct groups. The larger group comprises students moving from school to university through procedures administered by Tertiary Admissions Centres (TACs). The second group comprises students who apply directly to universities for places under procedures administered by individual universities. For a long time, this group has been small, but since 2010 it has doubled in size. Our review is confined to the shorter period since 2010 because relevant statistics date from then.

For our purposes, only students who participate in the TAC process are relevant. These are students who move from year 12 into a university engineering course based on Australian Tertiary Admission Ranks (ATARs) and other considerations specific to their preferred institution. Briefly, year 12 students apply for places, universities consider applications and respond with offers of places and the final stage is acceptance of offers by students. Figure 10 illustrates the trends in these stages for engineering since 2010.

The historical skew towards men is clearly evident in Figure 10. In 2010, 14,655 young men applied for places in engineering. Applications increased steadily to peak at 16,046 in 2013, but have fallen in each of the past two years to 13,848 in 2015. Between 82.1 per cent and 84.1 per cent of applicants receive offers of places, resulting in a similar trend, but at a lower level. In turn, between 62.1 per cent and 66.6 per cent of original applicants accept places. In 2010, 9,099 young male applicants accepted places, rising to a peak of 10,431 in 2013 and falling to 9,217 in 2015.

Applicants from young women increased from 2,058 in 2010 to 2,566 in 2015. To address the low share of women in engineering and in recognition of the strong academic qualities of young women, universities have offered places to almost all applicants with offer rates between 95.2 per cent and 99.6 per cent. Acceptance rates from young women are also higher, ranging between 68.4 per cent and 72.5 per cent. In 2010, 1,492 young women accepted places in engineering, increasing to 1,845 by 2015.

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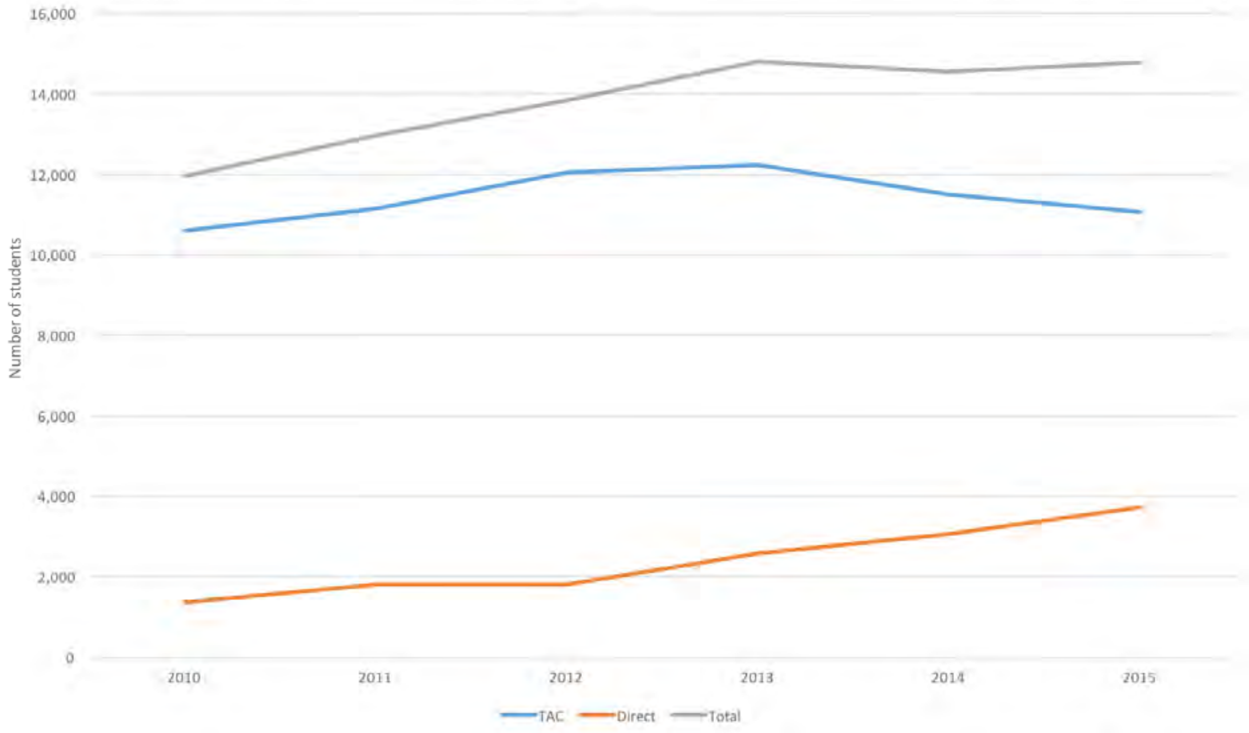
[36] The issues discussed in this section are covered in more detail in Engineers Australia, Acceptances of Places in Engineering: Sources, Characteristics and Changes, Policy Note, 2 June 2016, www.engineersaustralia.org.au

Figure 11: Rising acceptances from direct applicants stabilise overall acceptances of engineering places



The TAC admission process is strongly geared to student ATARs. Earlier in 2016, the University of Sydney responding to perceived problems in relying on ATAR indicated that advanced mathematics would become compulsory for a range of degrees including engineering[37]. On 1 August 2016, the Australian National University announced that it was broadening its admission processes away from reliance on ATARs towards broader selection criteria[38]. These decisions reflect the long held view that ATAR can be gamed through the selection of subjects. Often when this occurs, high ATARs do not necessarily mean that students have the combination of subjects best suited to the courses they apply for. At this stage the majority of universities still rely on ATAR, but clearly change is in the wind.

***Universities recruit new students through processes administered by Tertiary Admissions Centres and through processes administered by individual institutions. ATAR ranks remain the dominant selection factor in the former where engineering numbers have fallen. The basis for selection directly by institutions is more varied, but numbers in engineering are rising rapidly. Overall numbers are stable.***

In engineering, change is already evident in the increased numbers of students participating in direct application processes with universities of their choice. Since 2010, the number of direct applications to universities for places in engineering has increased substantially. In 2010, there were 2,038 direct applications, 1,812 from men and 226 from women. Direct applications were 10.9 per cent of total applications. By 2015, direct applications had more than doubled, increasing to 4,873 (4,209 men and 664 women), and their share of applications increased to 25.1 per cent.

These changes are illustrated in Figure 11. Although acceptances of places in engineering in the TAC process have fallen since 2013, this has been offset by the increase in acceptances from direct applicants. The overall result is that total acceptances since 2013 have been static rather than declining.

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[37] Sydney University Makes Mathematics Compulsory for 62 Degree, Sydney Morning Heaarld, 24 March 2016, www.smh.com.au
[38] ANU to Abandon ATAR as Sole Entry Requirement, Canberra Times, 1 August 2016, www.canberratimes.com.au

## 3.7

## High school STEM subjects and developing Australia's engineers

In this section we link participation in the four high school STEM subjects discussed to acceptances of places in university engineering courses. In earlier sections we observed that in 2015, 9,217 young men and 1,845 young women who just completed year 12 accepted offers of places in university engineering courses. Both advanced mathematics and physics are important foundations for these courses. In 2015, 13,008 young men and 7,223 young women studied advanced mathematics, and 23,742 young men and 6,935 young women studied physics. Similar comparisons can be made for intermediate mathematics and chemistry.

Although some students studying STEM subjects will be pre-disposed towards engineering, many other course options are also available to them and some may choose to forego tertiary studies. Simply inspecting these numbers shows that engineering acceptances account for very large shares of these year 12 subjects.

We aim to put this crude comparison into a standardised framework by estimating the ratio of the engineering share of each STEM subject to the engineering share of total university course acceptances. This ratio is referred to as the 'degree of difficulty' for engineering for the subject concerned.

See 'Determining the degree of difficulty' graphic on page 60 for detail on how this is determined.

***The 'degree of difficulty' is a measure of the percentage of high school STEM students who universities must recruit if current engineering student intake is to be maintained. For example, the fewer the students studying maths, the higher the degree of difficulty.***

To apply this measure, we assume that advanced mathematics, intermediate mathematics, physics and chemistry, in turn, are formal requirements for admission to engineering courses. In practice, this may not always be the case; universities can accept lower requirements and remediate the situation through additional university course content.

The lower the degree of difficulty, the more straightforward it is to attract acceptances of places in an engineering course from students studying one or other of the four STEM subjects under consideration. Given the pre-disposition of year 12 students studying STEM subjects towards engineering we would expect the degree of difficulty to be more than one, and possibly two or three. However, at some point the degree of difficulty outweighs students' pre-disposition towards engineering and it becomes increasingly difficult to attract acceptances of places. This point is difficult to identify objectively and, as a surrogate, we employ ranges of possible values for the degree of difficulty to assist assessment as follows:

- Low degree of difficulty occurs when the degree of difficulty is three times or less than the engineering share of all course acceptances.
- Moderate degree of difficulty occurs when the degree of difficulty is more than three times the engineering share of all course acceptances and up to and including six times this share.
- High degree of difficulty occurs when the degree of difficulty is more than six times the engineering share of all course acceptances and up to and including 10 times this share.
- Extreme degree of difficulty occurs when the degree of difficulty is more than 10 times the engineering share of all course acceptances.

In other words, the degree of difficulty increases as the share of a STEM subject that is required to sustain the level of acceptances in engineering increases.

The pre-disposition of students with STEM subjects to consider engineering is reflected in the criterion for low degree of difficulty which suggests that the challenge of commanding STEM subject shares up to three times the engineering share of total acceptances is not particularly note-worthy. However, attracting subject shares between three and six times the engineering share of acceptances requires course administrators to attract students with STEM subjects well beyond what might be termed a "natural attraction" to engineering. Two further criteria have been included to describe two groups of highly disproportionate shares of STEM students.

*Advanced mathematics is the most appropriate foundation for engineering studies.*

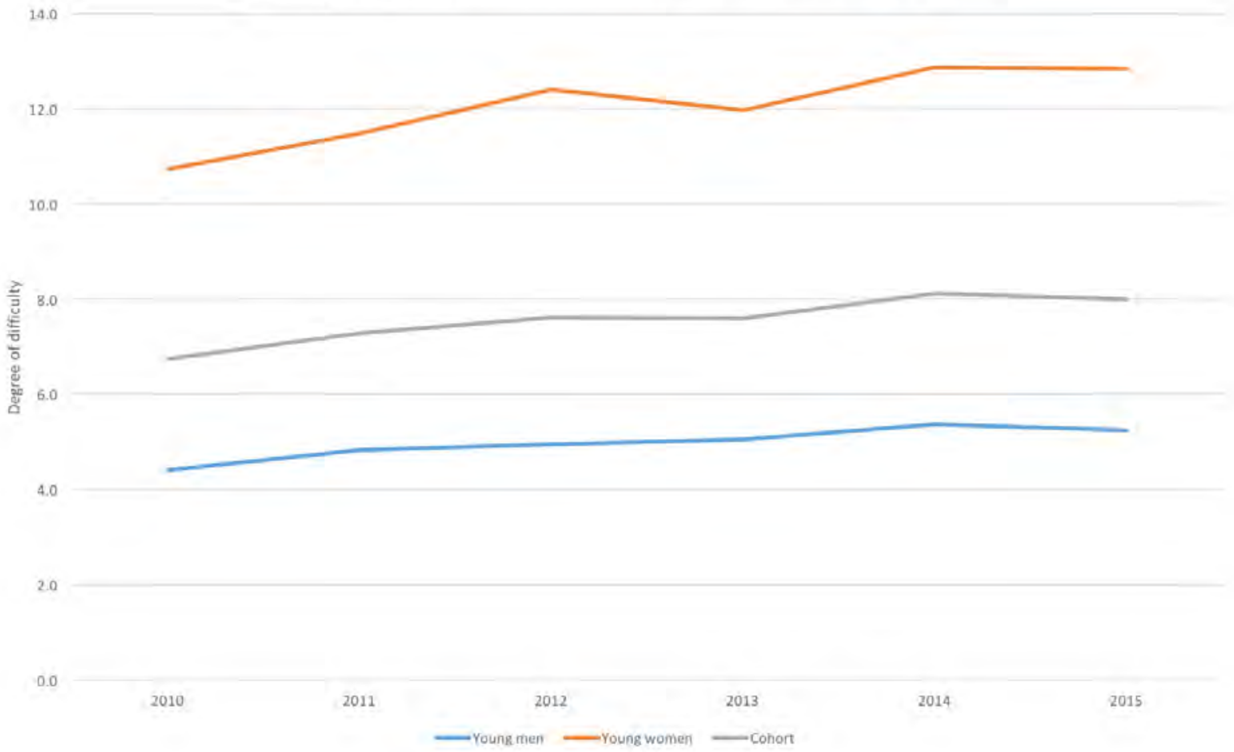
### 3.7.1 Advanced mathematics

Educationalists see advanced mathematics as the most appropriate basis for engineering courses. For this subject the measures of the degree of difficulty were comparatively high as illustrated in Figure 12.

The degree of difficulty associated with young men was moderate and slowly increasing for the period considered. In 2010, the degree of difficulty was 4.4 and it peaked at 5.4 in 2014, falling back to 5.1 in 2015. For young women the degree of difficulty was severe for the entire period. In 2010, it was 10.7 and increased to 12.8 in 2014, decreasing slightly to 12.8 in 2015. An important factor in this result was that while the number of young women studying advanced mathematics was about half the number of young men, the number of young women accepting places in university courses is more than one third higher than young men.

At cohort level, the smaller proportion of young women reduces the degree of difficulty downwards to a position intermediate between the two gender curves. However, throughout the years 2010 to 2015 the cohort degree of difficulty is in the high range. More important, focusing analysis only on the cohort overlooks the dire situation of young women in this subject.

Figure 12: The degree of difficulty associated with year 12 advanced mathematics



### 3.7.2 Intermediate mathematics

Intermediate mathematics provides a "satisfactory knowledge-base for tertiary courses requiring minimal understanding"[39] of mathematics. Given this characterisation, this level of mathematics is a less satisfactory basis for engineering studies, but an option for institutions is to bridge the gap between this subject and advanced mathematics with additional course material. We do not consider the implications of this approach here.

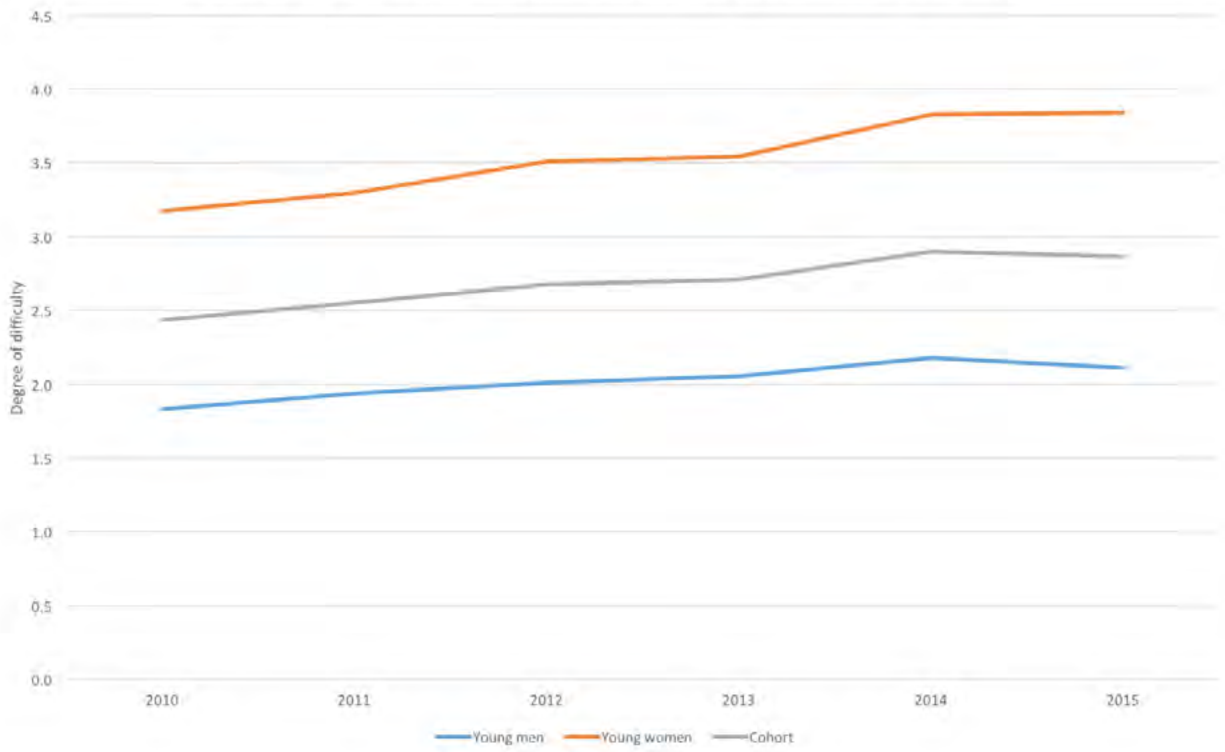
The number of young men studying this subject in year 12 was over twice as large as advanced mathematics and the number of young women was over three times the number studying advanced mathematics. Accordingly, it is no surprise that the measures of degree of difficulty are lower than for advanced mathematics. These measures are illustrated in Figure 13.

For young men, the degree of difficulty was in the low range and slowly increasing between 2010 and 2015. The degree of difficulty for young women was in the moderate range and increased faster than for young men, peaking at 3.9 in 2014, falling slightly to 3.8 in 2015.

Fewer young women in this subject and the lower degree of difficulty for young men reduced the cohort measure down from the moderate to the low range. The larger number of students studying intermediate mathematics was an important aspect of these results.

Intermediate mathematics is a less suitable basis for engineering courses, but an option that institutions could consider. Year 12 numbers in this subject are almost three times those in advanced mathematics and the degree of difficulty for young men is low, but moderate for young women.

Figure 13: The degree of difficulty associated with year 12 intermediate mathematics



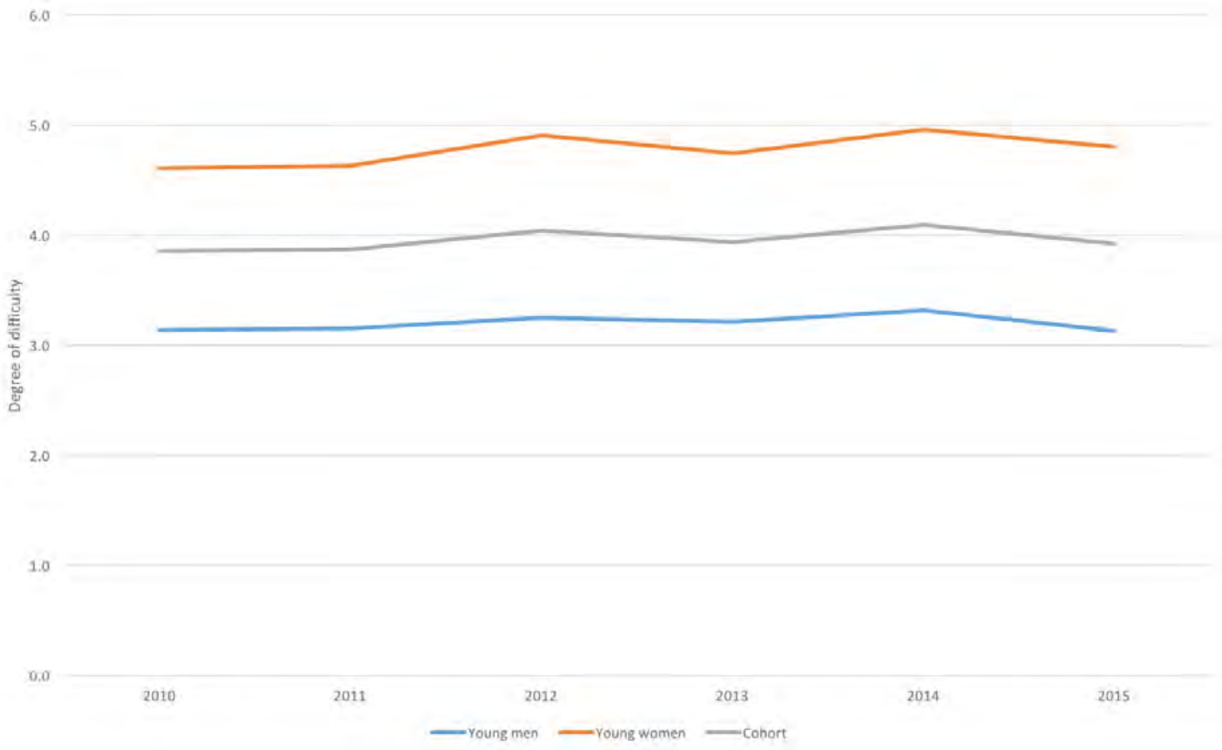
### 3.7.3 Chemistry

More year 12 students studied chemistry than advanced mathematics, but fewer than intermediate mathematics. Gender participation in chemistry was the most balanced of the four STEM subjects considered. These features are reflected in measures of degree of difficulty illustrated in Figure 14.

In all cases, measures of the degree of difficulty for chemistry were in the moderate range and the lower number of young women in this subject meant the degree of difficulty for this group was higher.

***More year 12 students studied chemistry than advanced mathematics. Gender participation in chemistry was the most balanced of the four STEM subjects considered. The degree of difficulty for this subject was moderate in all cases.***

Figure 14: The degree of difficulty associated with year 12 chemistry



[39] Kennedy, Lyons and Quinn, p36

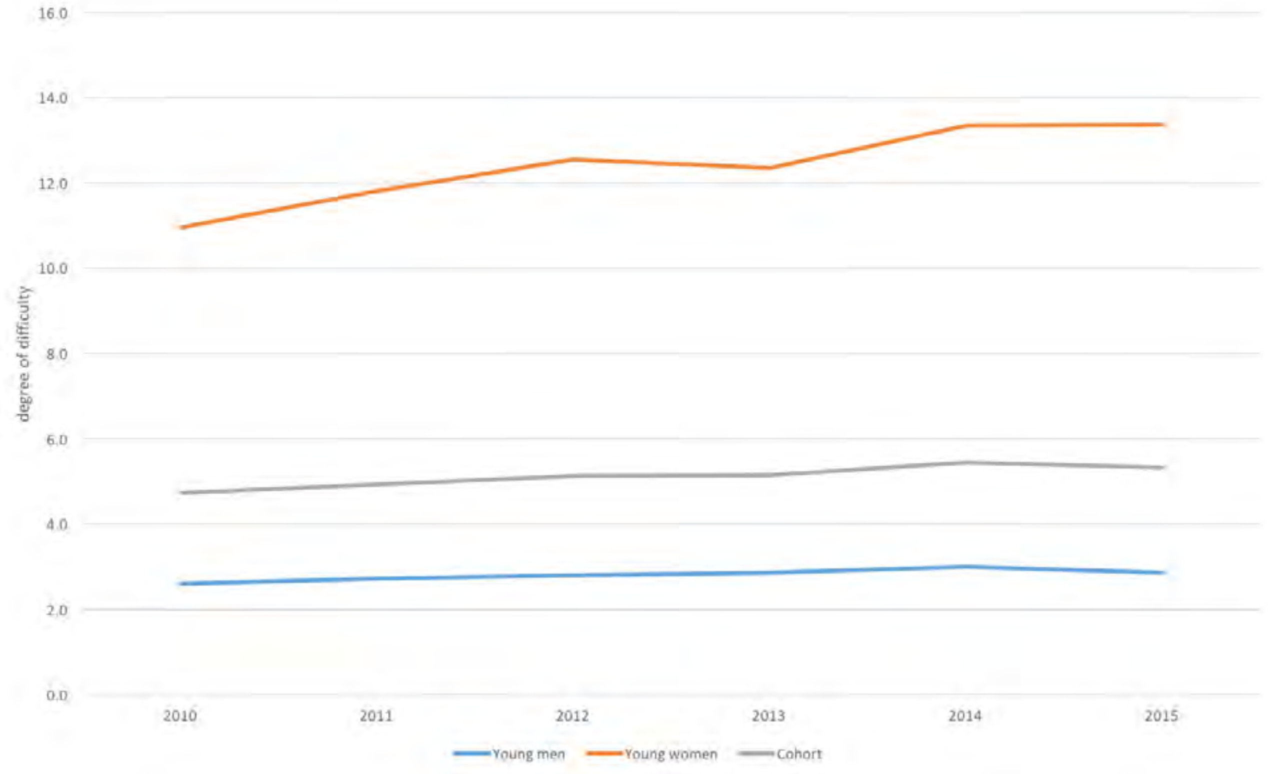
### 3.7.4 Physics

Although more year 12 students studied physics than advanced mathematics, the difference was almost entirely comprised of young men and this subject had the most pronounced male participation. The number of young women in physics was on par with advanced mathematics, but the number of young men was 80 per cent larger. This skew was reflected in measures of degrees of difficulty illustrated in Figure 15. The comparatively large number of young men studying physics resulted in the degree of difficulty for this group being in the low range throughout 2010 to 2015 even though it increased slowly.

However, the degree of difficulty for young women was severe and increasing in severity, a result that reflects the low number of women studying this subject in an environment where the number of university course acceptances by women was about one third higher than the number of young men.

At cohort level the low proportion of young women studying physics produced a degree of difficulty in the moderate range. This result and the corresponding one for advanced mathematics emphasise the importance of examining statistics for both genders. Focusing only on cohort statistics overlooks the alarming situation for young women.

Figure 15: The degree of difficulty associated with year 12 physics



*More young men study physics than advanced mathematics. The number of young women is alarmingly low.*

# 3.8

## Overview

This chapter has highlighted the importance of increased high school retention in offsetting falling participation in some year 12 STEM subjects. Retention has increased substantially over the past 15 years but there is still scope for further improvements, particularly by eliminating excessive variability between states and territories. The experiences of South and Western Australia shows that large increases in retention are possible over a comparatively short period. There are important arguments to support retention of high school students until year 12 per se. Higher retention increases the intellectual maturity of students and gives them more individual choices in their lives and a better educated workforce improves the productivity potential to the economy.

Increased retention is especially important for Australia's ambition to be part of the digital technological revolution. Without more technically and scientifically literate people in the labour force, this ambition will not materialise.

However, the argument we are emphasising in this report is that, in the face of falling rates of participation in STEM subjects, increasing retention to year 12 would stabilise numbers in STEM subjects. A window of opportunity for policy makers would therefore be created in which new policies to reverse falling STEM participation could be implemented.

Studying STEM subjects at school is about mathematical and scientific literacy and understanding, it rarely is an end in itself. For Engineers Australia, the study of year 12 STEM subjects is the means to build Australia's future engineering profession. Unless Australia has a competent engineering profession in the decades ahead our ambition to become a productive, technologically advanced, economy will not be realised. Australia will always need some skilled migrant engineers, but our present over-reliance on this source is unsustainable and we need to produce more of our own engineers.

The numbers of students in four year 12 STEM subjects—advanced mathematics, intermediate mathematics, chemistry and physics—were examined and linked to the current level of acceptances of places in engineering courses. The objective was to consider the implications of falling year 12 STEM participation for Australia's capacity to produce its own engineers. The degrees of difficulty summarised in Table 1 suggest mixed prospects.

*An important message from these results is that cohort analyses of year 12 STEM participation risks obscuring some of the problems.*

This impression is created by a combination of better results and higher STEM participation by young men. As the Table shows, the degrees of difficulty for young men range from low to moderate. These results owe a lot to increased year 12 retention of young men which has stabilised, and in some cases increased, numbers even though participation rates have fallen. For the present, we observe falling acceptances of places in engineering courses and should year 12 numbers in STEM courses fall, these falls could accelerate.

It's a more difficult story for young women. Their participation rates in STEM subjects is typically lower than young men, in the case of advanced mathematics and physics, substantially lower. Indeed, it is not out of place to call the participation of young women in these subjects alarmingly low. Table 1 shows that this situation translates into degrees of difficulty ranging from moderate to severe for young women. Higher education participation by young women is substantially higher than for young men. This means the much smaller numbers of young women studying year 12 STEM subjects are distributed more thinly across the study options available to them.

*There appears to be a direct connection between the persistence of low numbers of women in engineering and severe degrees of difficulty in attracting young women with required year 12 advanced mathematics and physics backgrounds*

*The study of year 12 STEM subjects is the means to build Australia's future engineering profession, not an end in itself.*

There appears to be a direct connection between the persistence of low numbers of women in engineering and the results in Table 1. In order to increase the number of women engineers, educational institutions need to overcome moderate to severe degrees of difficulty in attracting students with the required year 12 STEM background. This is possible in two ways; one way is by increasing the attractiveness of engineering courses sufficiently to overcome current degrees of difficulty, in effect attract candidates away from other course and non-course options. The alternative is to increase the number of young women studying year 12 STEM subjects and so reducing the degree of difficulty of attracting them into engineering courses.

The participation of young women in advanced mathematics and physics is particularly low. High school retention for young women has been high for some time and, even though it continues to increase, this is occurring at a much slower pace than for young men. This means that the capacity of rising retention to offset falling subject participation is much weaker than for young men. Any window of opportunity to reverse participation trends for young women is much narrower and it is far more urgent that the situation is addressed. Australia cannot hope to develop an effective future engineering profession by recruiting from half the population.

**TABLE 1:**
DEGREE OF DIFFICULTY ASSOCIATED WITH YEAR 12 STEM SUBJECTS AND ENGINEERING COURSE ACCEPTANCES IN 2015

| SUBJECT | Young Men | Young Women | Cohort |
|---|---|---|---|
| Advanced Mathematics | MODERATE | **SEVERE** | HIGH |
| Intermediate Mathematics | LOW | MODERATE | LOW |
| Physics | LOW | **SEVERE** | MODERATE |
| Chemistry | MODERATE | MODERATE | MODERATE |

**DETERMINING THE DEGREE OF DIFFICULTY:**

$S=Ae/Si$

*where "S" is the share of subject "i" accepting places in engineering*
*"Ae" is acceptances of places in engineering*
*"Si" is the number of students in year 12 subject "i"*

*Engineering's share of total course acceptances is:*

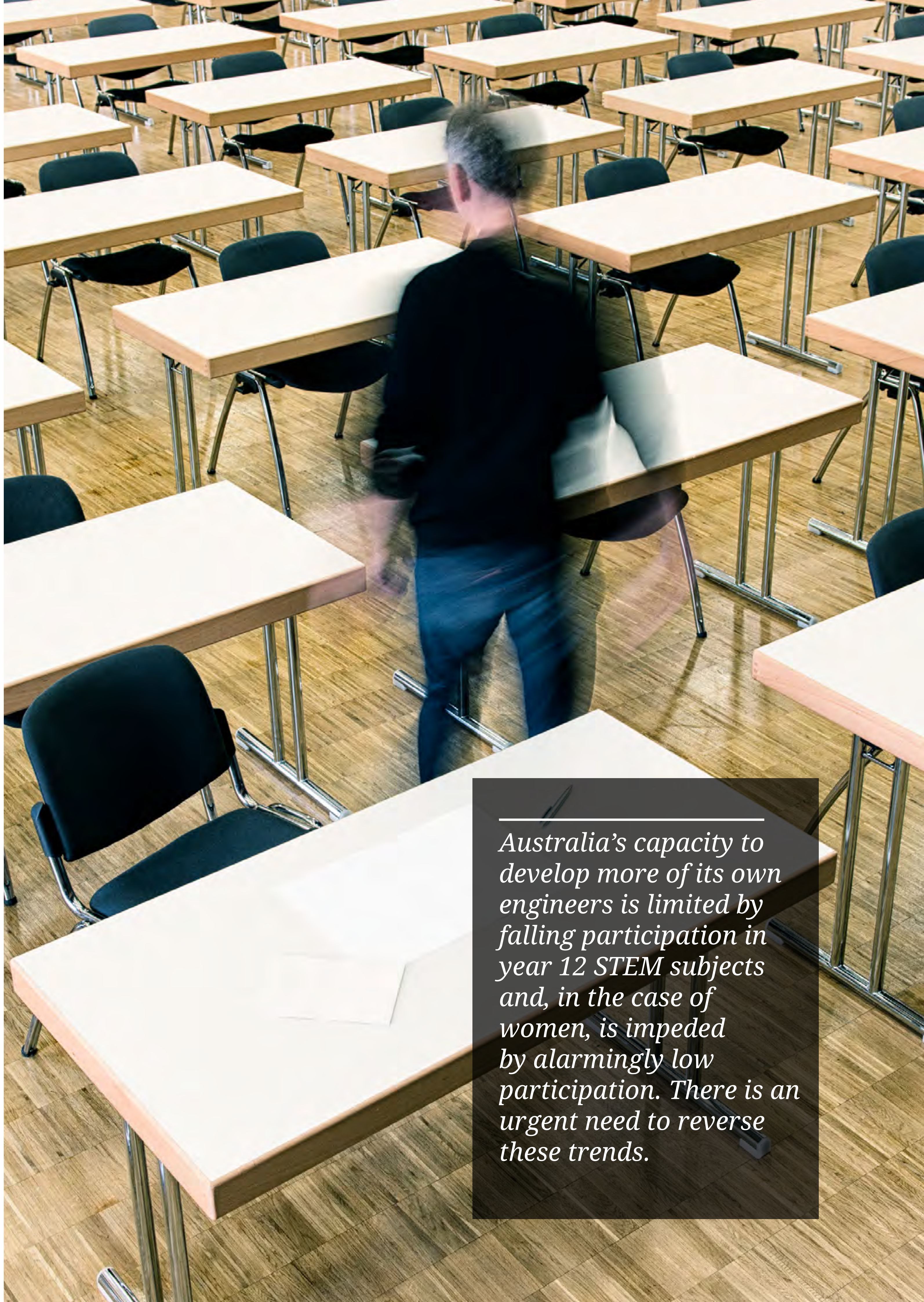
$E=Ae/At$

*where "At" is total university course acceptances*

*We then define the subject degree of difficulty as:*

$D=S/E$

*where "D" is the degree of difficulty*



*Australia's capacity to develop more of its own engineers is limited by falling participation in year 12 STEM subjects and, in the case of women, is impeded by alarmingly low participation. There is an urgent need to reverse these trends.*

# 4.

# Conclusion and recommendations

## 4.1

## Ambition

The medium to longer term challenges for Australia are enormous. They start with transition from a resources based economy to a diverse, innovative and technologically based one. It includes absorbing a rapidly growing population over coming decades, solving community and economic problems associated with an aging population, transitioning to a low carbon economy, and all while preserving—and preferably increasing—our standard of living.

The difficulties experienced by some Science Technology Engineering and Maths (STEM) graduates in finding full time employment demonstrates that Australia's economic development policies still have a long way to go to meet our aspirations.

In a modern society, practically every good and service consumed or used in production embodies engineering. New and innovative ideas are the beginning of technological advance, but it is engineers who translate new ideas into practical and commercially valuable new products and services.

Australia's engineering capability is an indispensable element for Australia to achieve its ambition of becoming an innovative and globally competitive nation. It must be valued by policy makers and the community for this reason.

Given our national ambitions, Australia ranks poorly against most global innovation indexes and this must change through government policy. As well as more Research and Development and improved collaboration between universities and industry, the report has shown that Australia needs to do more to build its engineering capability.

## 4.2

## A global search for talent

During the early years of the resources boom, Australia produced fewer engineers each year. This trend changed in about 2006 but, because of the long duration of engineering education, an increase in the number graduating did not occur until the resources boom was almost over.

Permanent migration of engineers has been higher than domestic student university education completions since 2009. Although temporary skilled migration has increased and fallen broadly in line with the intent of policy, permanent and temporary migration accounts for almost two-thirds of our new engineers.

Australia is therefore excessively dependent on skilled migration. This has meant that engineering is predominantly comprised of overseas born engineers, which is in stark contrast to other professions. Continuation of this reliance is not risk free.

Australia's engineering capability comprises engineers judged competent to practice engineering. Our best measure shows it to be about 61 per cent of people with recognised engineering qualifications who are active in the labour market.

However, the report has shown that Australia's skilled migration programs for engineers do not contribute to building our engineering capability as effectively as they could because selection emphasises entry level qualifications but does not assess capacity to practice engineering.

## 4.3

## The STEM gap

Engineering has experienced short term adjustment pains caused by the end of the resources boom and patchy investment in essential public infrastructure.

Adjustment has been facilitated by the retirement of many engineers and the flexibility and adaptability of others. These factors moderated the increase in unemployment rates and will continue to play out over another year or so. When complete, we will have sufficient engineers to sustain the present low-growth Australian economy.

If Australia is to become an innovative nation, however, our engineering capability must expand. This should be done by lessening reliance on skilled migration and producing a greater number of home-grown engineers.

For engineering, participation in high school STEM subjects is a means to an end because mathematics and science are the tools used by engineers to solve real world problems.

High school retention is important because increased retention offsets falling subject participation rates, so that the number of students is more stable. This provides a window of opportunity in which policy to reverse declining participation rates in STEM subjects can be implemented.

It is noted that differences in high school retention to year 12 between states and territories are excessive. Governments should urgently consider how to overcome this situation to maximise the window of opportunity to reverse STEM subject participation.

Participation rates for advanced mathematics are alarmingly low. This is particularly true for young women who participate in this subject at a much lower level than young men. Increased high school retention for young men has slowed the decline in numbers, but retention was already high for young women and their numbers in advanced mathematics continued to decline at past rates.

In intermediate mathematics participation rates continue to fall, with lower participation among young women than young men. The countervailing effect of increased retention to year 12 slowed the fall in numbers to some extent, and the numbers studying this subject are higher than for advanced mathematics.

The fall in year 12 participation rates in physics has much in common with the situation in advanced mathematics; the fall has been large and sustained over time with substantially lower participation by young women than young men. Increased retention to year 12 slowed the decline in the number of young men in this subject but the number of young women is now alarmingly low.

Participation in year 12 chemistry has stabilised in recent years. Gender participation in this subject is far more balanced than in the three other subjects considered. In chemistry, increased retention has led to increases in the number of young men and women studying the subject.

## 4.4

## Degrees of difficulty

From the examination of the STEM gap, the report introduced the concept of a 'degree of difficulty.' It is a measure of the percentage of high school STEM students who universities must recruit if current engineering student intake is to be maintained. For example, the fewer the students studying maths at school, the higher the degree of difficulty for universities to recruit sufficient numbers.

Advanced mathematics is the most appropriate foundation for engineering studies. At present, engineering is experiencing moderate degrees of difficulty in recruiting sufficient young men with this background and severe degrees of difficulty in recruiting sufficient young women.

Intermediate mathematics is a less suitable basis for engineering courses, but an option that institutions could consider. Year 12 numbers in this subject are almost three times those in advanced mathematics and the degree of difficulty for young men is low, but moderate for young women.

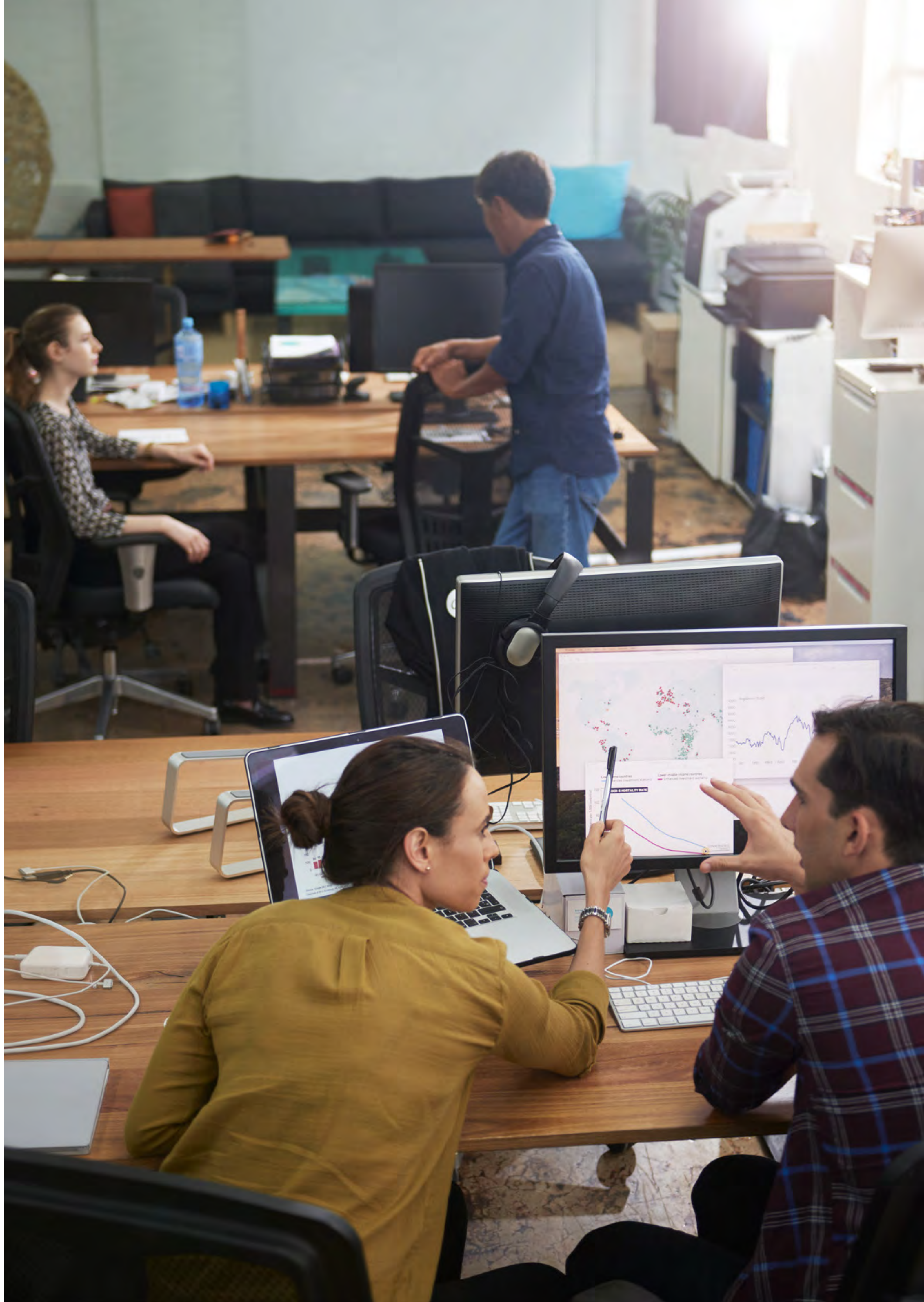
More year 12 students studied chemistry than advanced mathematics, but fewer than intermediate mathematics. Gender participation in chemistry was the most balanced of the four STEM subjects considered. The degree of difficulty for this subject was moderate in all cases.

More young men study physics than advanced mathematics and this results in low degrees of difficulty for this group. However, the number of young women is alarmingly low and male participation is the most dominant of the STEM subjects examined resulting in severe degrees of difficulty for young women.

There appears to be a direct connection between the persistence of low numbers of women in engineering and severe degrees of difficulty in attracting young women with required year 12 advanced mathematics and physics backgrounds.

The argument we emphasised in this report is that, in the face of falling rates of participation in STEM subjects, increasing retention to year 12 would stabilise numbers in STEM subjects, which would buy policy makers time to take action.

For Engineers Australia, the study of year 12 STEM subjects is the means to build Australia's future engineering profession, not an end in itself.



# 4.5

## Recommendations

The results suggest that Australia's capacity to develop more of its own future engineers is limited by falling participation in year 12 STEM subjects. Creating a more gender-balanced profession is impeded by alarmingly low STEM subject participation by girls in school.

There is an urgent need to reverse these trends because engineering is already a majority overseas born profession, and further reliance on skilled migration carry unnecessary risks for the supply of engineers.

Engineers Australia recommends a range of action be taken, with a focus on skilled migration, school education and workforce development more generally.

### 4.5.1 Skilled migration:

- Recognise and acknowledge the risks of over-dependence on skilled migration to Australia's future engineering capacity.
- The objective and selection methodologies for permanent migration of engineers should be reconfigured to focus more closely on building future engineering capability.
- Permanent migration selection policies for engineers should be changed to focus on skills requirements in areas of emerging technology.
- Permanent visas granted to migrant engineers should be accompanied by assistance packages to help adjustment to Australian labour market conditions.
- Review inconsistencies between the objective and practice of temporary migration policies, especially with regard to the large number of engineers employed on 457 visas despite the absence of a widespread skills shortage.
- Include mandatory skills assessments for temporary work visas.

### 4.5.2 School education:

- Encourage more students to study advanced and intermediate maths and science to year 12 so as to build the necessary technical educational foundation for Australia's innovation revolution.
- The development of more specialist teachers of maths and science.
- Encourage more young women to participate in school-level advanced and intermediate maths and science.

### 4.5.3 Workforce development:

- Implement policies that encourage more Australians to undertake and complete engineering courses.
- Implement policies and programs to retain competent experienced engineers in the profession.
- Use innovation policies to recognise and highlight the critical role of engineers in turning ideas into products and services with social, economic and environmental value.
- Implement policies and programs to ensure sufficient competent, practising engineers to realise opportunities created by the inventiveness of Australians.
- Align policies and programs that foster innovation with the educational requirements and professional development necessary to become an engineer.
- Recognise the costs to society and innovation policy associated with low retention of qualified engineers in engineering work, and find ways to improve retention, especially for women and migrants.
- Recognise the importance of continual technological progress and commit to long term and stable innovation policies and programs.

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