Office of the **Queensland Chief Scientist**

Heartbeat of Queensland science 2019

March 2020

Queensland Government

#31975 | 0420

Preface

Heartbeat of Queensland science 2019 is the fourth report in a series compiled by the Office of the Queensland Chief Scientist.

It is a collation of data about Queensland's science strengths and opportunities.

It explores the importance of science, technology, engineering and mathematics (STEM) in Queensland's community and overall economy, and identifies recommendations to improve return on investment in STEM.

Contents

Key findings

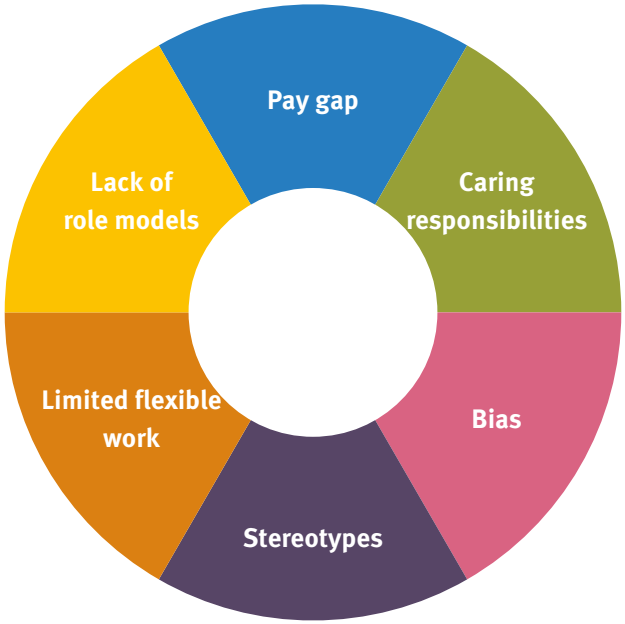
Science is important to Queenslanders

72% believe science is critical to our economy

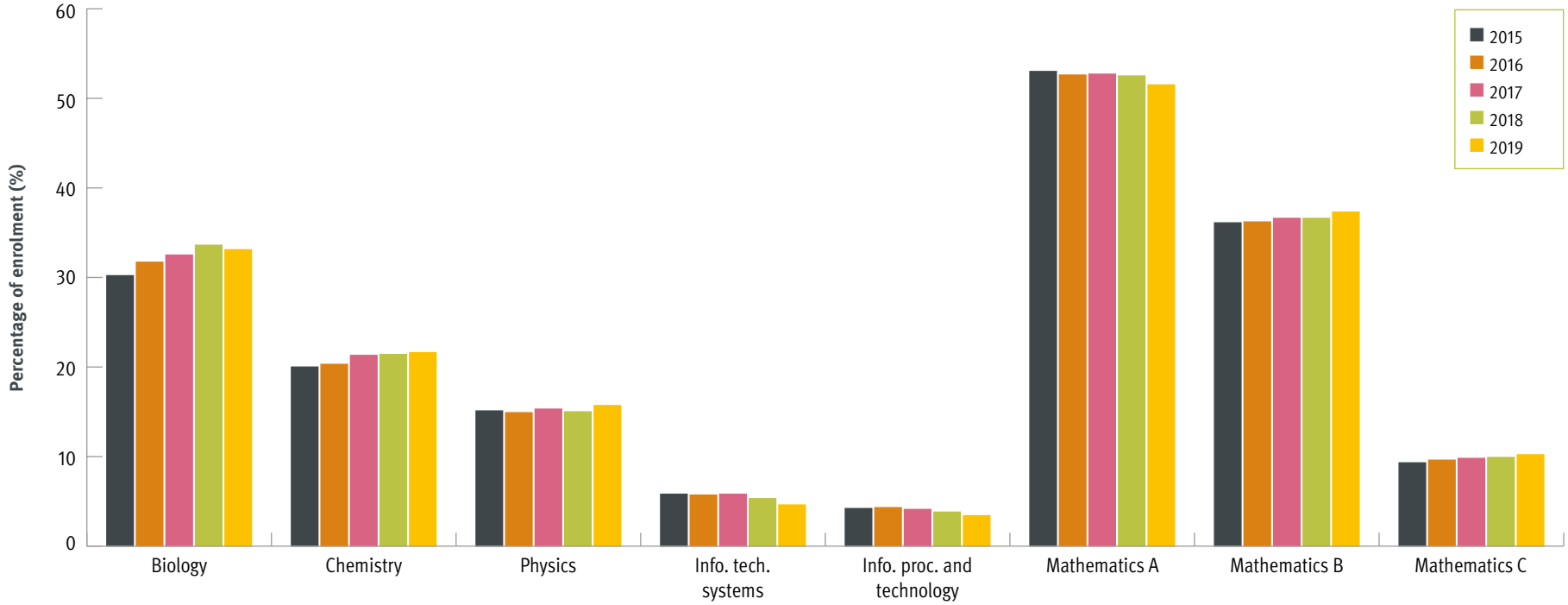
1 in 2 expressed interest in attending science-based events in the future

Only **3%** of Queenslanders are aware of citizen science without prompting

Some issues preventing gender balance in STEM careers



Enrolment of students in STEM subjects as a percentage of total Year 12 enrolment (2015–19)



Key findings

Future jobs will need STEM within five years

Healthcare

13.4%

Professional, scientific and technical services

9.8%

Agriculture, forestry and fishing

1.1%

In 2019:

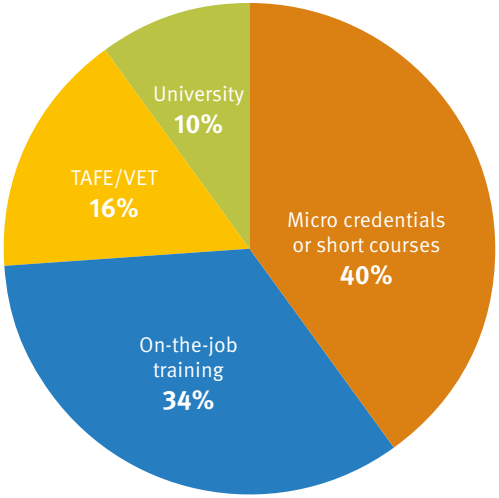
77.6%
STEMM undergraduates in full-time employment

84.4%
STEMM postgraduate coursework in full-time employment

83.8%
STEMM postgraduate research in full-time employment

* STEMM is defined as Science, Technology, Engineering, Mathematics and Medicine.

Survey responses to 'How should the workforce be upskilled to engage with Industry 4.0?'**

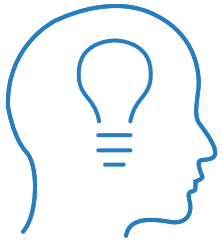


** Data taken from PwC report, 'Transforming Australian Manufacturing'.

Recommendations

1 Grow our STEM-knowledgeable community

Greater STEM literacy for Queenslanders leads to increased engagement in STEM-related issues



2 Build diverse and inclusive STEM-student participation and workforce

Increasing the number and diversity of STEM-qualified people increases STEM-student performance resulting in a diverse STEM workforce

3 Well-prepared transition to Industry 4.0

Australian STEM graduates are fully skilled and qualified in their chosen fields to enable a well-prepared transition to Industry 4.0

Recommendation 1:

Grow our STEM knowledgeable community

What is science and STEM?

The Cambridge English Dictionary defines science as being *'knowledge from the careful study of the structure and behaviour of the physical world, measuring, and doing experiments, and the development of theories to describe the results of these activities'*.

Schools of the Future: A Strategy for STEM in Queensland State Schools acknowledges STEM touches every aspect of today's world.

STEM is the acronym for science, technology, engineering and mathematics.

Integrating
STEM subjects
creates evidence-based knowledge that is powerful and reliable

Science can be used to generate new ideas and develop new technologies.

It underpins our ability to solve practical problems that improve quality of life, create new business opportunities, and entice new industries.

It helps us make informed decisions and deal with emerging issues that affect us all, for example, climate change and water resource management.

Why does Queensland need science and STEM?

Understanding more about science and STEM can help Queenslanders make informed decisions about their day-to-day lives, treat our environment responsibly, and generally keep up with the rapid progress of modern technology. It is also vital to the state's economic prosperity and our current and future wellbeing.

STEM plays an important role in shaping today's workforce, and will become increasingly important to job creation opportunities as Queensland transitions to Industry 4.0.[1]

Queensland's **STEM researchers** are international leaders at the forefront of many breakthroughs and discoveries that have a significant impact on our health, economy, environment and everyday lives.

"Science forms part of the broader research ecosystem that also includes the humanities, arts and social sciences. Together, this research drives advancements in knowledge and improvements in living standards, as discoveries are understood, developed and applied.

It makes businesses more innovative and productive, driving economic and jobs growth. It also underpins the social wellbeing of Australians by improving health outcomes, maintaining the quality of the environment, and contributing to solving signficant social issues."[1]

Where Queensland needs STEM

Queensland's own Great Barrier Reef is an example of how STEM is helping to protect an international icon that is precious to all Australians. STEM provides the knowledge and tools needed to understand how complex and valuable the Great Barrier Reef really is—knowledge that we can use to protect the reef.

STEM allows us to measure and monitor the Great Barrier Reef

The eReefs Initiative uses the latest software to collate data and produce visualisation, communication and reporting tools.

The Australian Institute of Marine Science has monitored the health of coral reefs for over 20 years—the longest continuous record of change across such a large area of reef communities as part of the Reef Restoration and Adaption Program.

STEM is used to develop practical solutions

RangerBot, an autonomous underwater vehicle that uses real-time computer vision with 99.4% accuracy, detects destructive coral-destroying crown-of-thorns starfish and administers a fatal injection.

A $2 million Advance Queensland Boosting coral abundance on the Great Barrier Reef challenge is seeking novel solutions to boost coral abundance and restore reefs exposed to the impacts of a changing climate.

STEM helps us:

DETERMINE the health of the reef and how it is changing over time

DISCOVER potential and emerging threats to the reef

UNDERSTAND the effect climate change and major weather events like cyclones are having on the reef

IDENTIFY actions to reduce pollution flowing from catchments near the reef

STEM is helping decision makers

Government is working with the community, including farmers, businesses and tourists, to protect the Great Barrier Reef for future generations through careful management and planning.

Using knowledge of soils, pesticides and fertilisers, **scientists are developing decision support tools** to help primary producers reduce their impact on the reef.

Scientific research and management associated with the reef **supports science jobs and promotes citizen science** projects by utilising the observations of visitors and recreational users of the reef.

Most Queenslanders think STEM is important

In 2016, and again in 2018, the Office of the Queensland Chief Scientist commissioned research to better understand the current awareness, perceptions and attitudes to science and STEM among Queensland adults.

It also aimed to understand current engagement and participation levels, and importantly, level of parental encouragement and support for the next generation to study science or choose a science-based career.[2]

In 2016 and 2018

72%

believe science is critical for our economy

1 in 2

expressed interest in attending science-based events in the future

In 2018

51%

felt there was not enough science news and information available in the media or online—up from 45% in 2016

In 2018

1 in 4

could spontaneously name a Queensland scientist or scientific discovery—an increase from 1 in 5 in 2016

In 2016 and 2018

78%

of Queensland parents encouraged students to study science at school, but only **59%** encouraged science as a career

2016 2018

In 2018

74%

were interested in science—an increase from **68%** in 2016

What science activities do Queenslanders attend?

The most commonly attended science-based activities for Queenslanders are visiting the museum, zoo/animal park or aquarium, botanic garden, or participating in a guided nature tour.[2] There has been a significant increase since 2016 in the number of people from remote/outback Queensland participating in science-based activities including nature tours, or visiting botanic gardens.[2]

In 2018–19

the Museum of Tropical Queensland received **97,565 visitors**—a 4% increase on 2017–18[3]

and the **Cobb+Co Museum** received a record-breaking **138,149 visitors**—an increase of 19% on 2017–18[3]

Queensland Museum

2.2m people
visited the museum at Southbank in 2018–19

97% visitors
were satisfied with their museum experience[3]

National Science Week 2019

... in Maryborough, the Office of the Queensland Chief Scientist delivered events for **>2500 students** in **19 schools**, and recruited **11 trainers** to deliver **27 activities** per day

World Science Festival Brisbane 2019

... in Brisbane, welcomed **205,229** visitors —a 2% increase on 2018[3]

... in Gladstone, welcomed **7,100** visitors —a 47% increase on 2018[3]

How do Queenslanders take part in STEM research?

In 2019, the Office of the Queensland Chief Scientist published its *Queensland Citizen Science strategy*[4] and created the Queensland chapter of the Australian Citizen Science Association.[5]

Citizen science involves public participation and collaboration in scientific research with the aim to increase scientific knowledge.[5] Citizen science provides a way for Queenslanders from all walks of life to get involved in science and contribute to scientific research—increasing overall scientific knowledge.

Anyone can get involved and decide how much or how little to contribute. From homes, schools, and hospitals, to the reef, rainforest and desert, there are so many opportunities to become involved.

Citizen science is key to building a science-literate community. Increasing engagement in science improves understanding of important issues such as climate change and water resource management.

Thousands of people were introduced to citizen science during the 2019 World Science Festival Brisbane *Street Science!* event.

The Queensland Citizen Science grants encourage community groups and researchers across Queensland to increase awareness of, and participate in, citizen science projects.

Unprompted awareness of citizen science is
3%[2]

After prompting, awareness rose to
18%[2]

Of those, only
27%[2]
have participated in a citizen science project

Currently, there are more than 130 citizen science projects running in Queensland, including:

- monitoring the health of the Great Barrier Reef
- finding and eradicating weeds as a biosecurity measure
- monitoring and reducing the risk of mosquitoes spreading the Zika virus
- protecting native vegetation.

Grow our STEM knowledgeable community

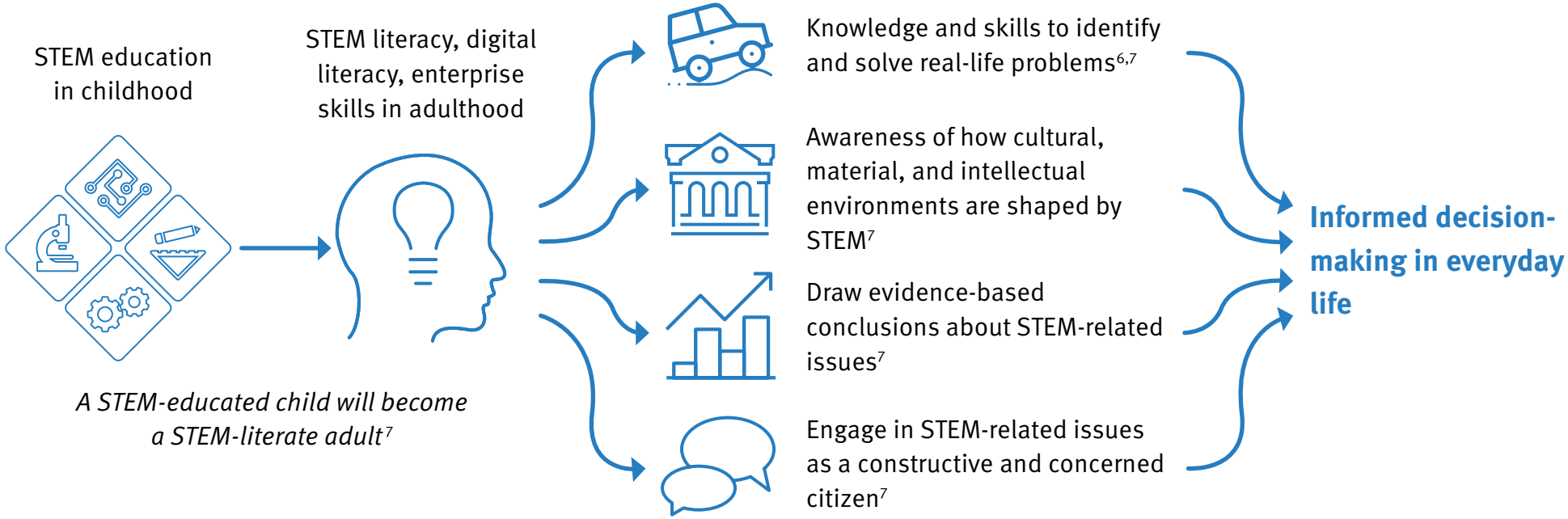
Our community must be more STEM literate to navigate our increasingly complex and technology-driven world.[6,7]

As we transition to Industry 4.0, 92% of all future jobs will require some form of digital literacy.

STEM knowledge is not only integral to jobs of the future, but also for growing an informed and engaged community.

The Queensland Department of Education is focusing on improving participation in STEM education in childhood to lead to greater STEM literacy in adulthood, with the flow-on effect of Queenslanders being able to draw evidence-based conclusions about the world and culture around them.

The Office of the Queensland Chief Scientist supports STEM literacy and outreach through funding initiatives such as *Engaging Science Grants*, *Queensland Citizen Science Grants*, *World Science Festival Brisbane*, and by running the *Flying Scientists*, *Queensland Women in STEM Prize* and *Partner Up Queensland* programs, as well as holding annual STEM events in regional areas during *National Science Week*.



Recommendation 2:

Build diverse and inclusive STEM student participation and workforce

STEM in schools

STEM education is designed to encourage collaboration, problem-solving, critical analysis and creative thinking through instruction, investigation, inquiry and event-based learning.[8,9]

Three key goals have been identified to inspire STEM learning in Queensland students:

- lift student achievement
- increase student participation
- build teacher capacity.[8]

A wide variety of STEM initiatives are being implemented in Queensland schools where teachers, students, parents and the community are being engaged.[10]

External partnerships, such as with local universities, research institutes, and industries, have demonstrated an ability to enhance all three of the key goals.[8]

2019 National Science Week in Maryborough

STEM Girl Power

The Department of Education's STEM Girl Power initiative is designed to encourage Year 10 girls from across Queensland to participate and achieve excellence in STEM subjects and career pathways.

Students participate in a 12-month program where they:

- experience real-world STEM and meet STEM role models at the STEM Girl Power Camp
- develop leadership and communication skills as regional STEM Ambassadors
- implement STEM projects to promote STEM in their local community during National Science Week
- continue to connect and inspire girls on their STEM journey during senior- and post-school life as STEM Girl Power Alumni.

Aboriginal Summer School for Excellence in Technology and Science (ASSETS) program

ASSETS is a nine-day residential program for Aboriginal and/or Torres Strait Islander Year 10 students who are interested in STEM subjects.

The program was created by CSIRO with an ongoing leadership and support program to nurture these students through Years 11 and 12.

Solid pathways

Solid Pathways is a Department of Education initiative designed to academically support and empower high-achieving Aboriginal and/or Torres Strait Islander students in STEM through Years 4–12.

The initiative consists of the:

- Critical and Creative Thinkers program (Years 4–7)—online lessons and camp experiences with a focus on the environment to develop teamwork and leadership skills in students
- Aboriginal and Torres Strait Islander Aspirations program (Years 8–9)—online and state-wide challenge in STEM to encourage participation and enhance post-school aspirations
- Indigenous Student Academic Achievement Network (Years 10–12)—ensures students continue to lift their academic performance to pursue tertiary study through celebration and leadership opportunities, and support through an enduring student network.

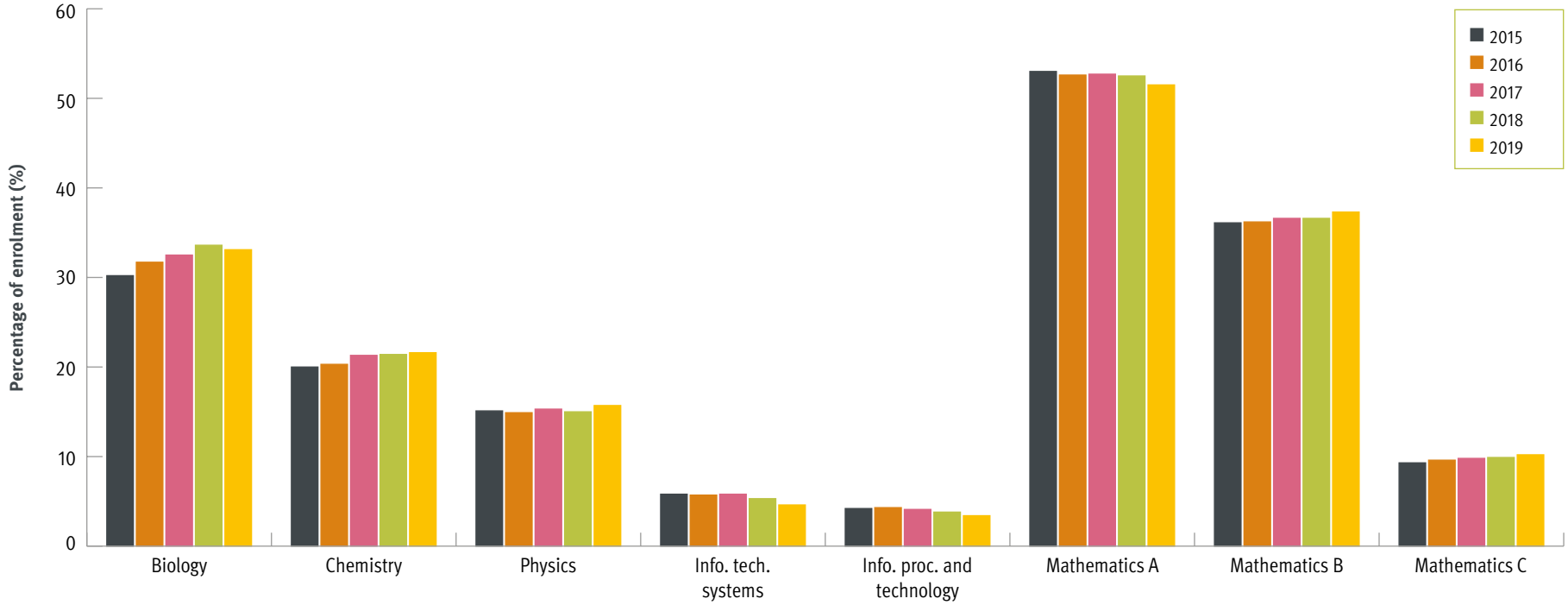
Due to programs such as these, Queensland's Aboriginal and/or Torres Strait Islander students are completing Year 12 at almost the same rate as other seniors in the state.[11]

How many school students study STEM subjects?

In Queensland, there has been an overall improvement in the eight STEM subjects, with the exception of the two Information Technology subjects and Mathematics A that has shown an overall decline in enrolment numbers between 2015 and 2019.

Although a lower number of students was enrolled in the Year 12 cohort for 2019 due to the introduction of the non-compulsory prep year in 2007, the percentage participation was strong in STEM subjects such as Biology, Chemistry, Physics, Mathematics B and C. The non-compulsory prep year is an additional year of education for Queensland students prior to Year 1. Further, in 2008, the Year 1 starting age was raised by six months. Consequently, a smaller cohort of students, often referred to as the half cohort, was introduced in Queensland state schools. Over subsequent years, this smaller cohort of students has grown to approximately two-thirds the size of a full cohort accounting for the small cohort size in Year 12 in 2019.[12]

Enrolment of students in STEM subjects as a percentage of total Year 12 enrolment (2015–19)

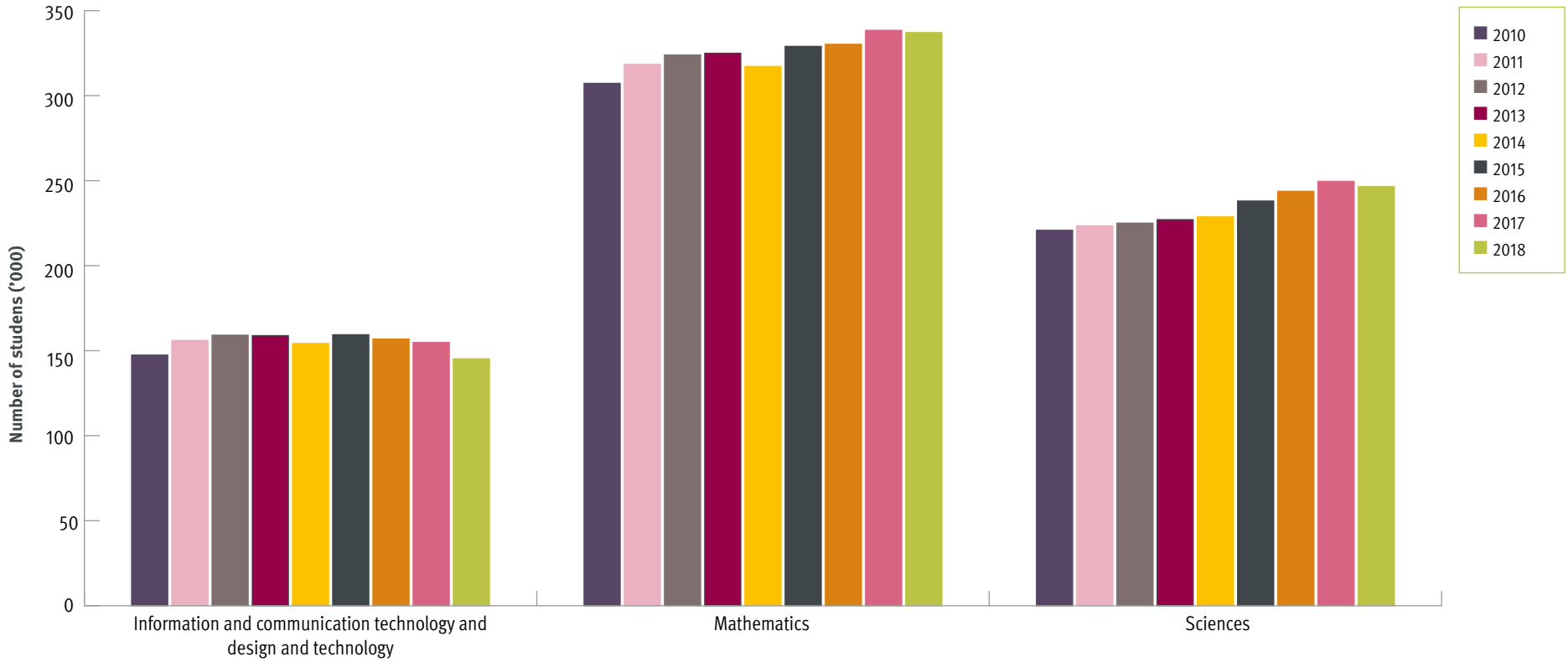


How many school students study STEM subjects?

In Australia, since 2010, Year 12 enrolment numbers in STEM subjects have increased or stabilised. However, there has been a decrease in enrolment numbers between the years from 2010 to 2018 in Information Technology. As mentioned earlier, a similar trend has been observed in Queensland in this subject and Mathematics.[13]

This may be because students fear reducing their overall ATAR scores, and fewer tertiary courses require these subjects as prerequisites than in the past.[7] Therefore, we need to ensure that all students finish school with strong foundational knowledge in STEM and that they are inspired and capable to take more challenging STEM subjects.

Number of Australian Year 12 students enrolled in STEM subjects (2010–18)

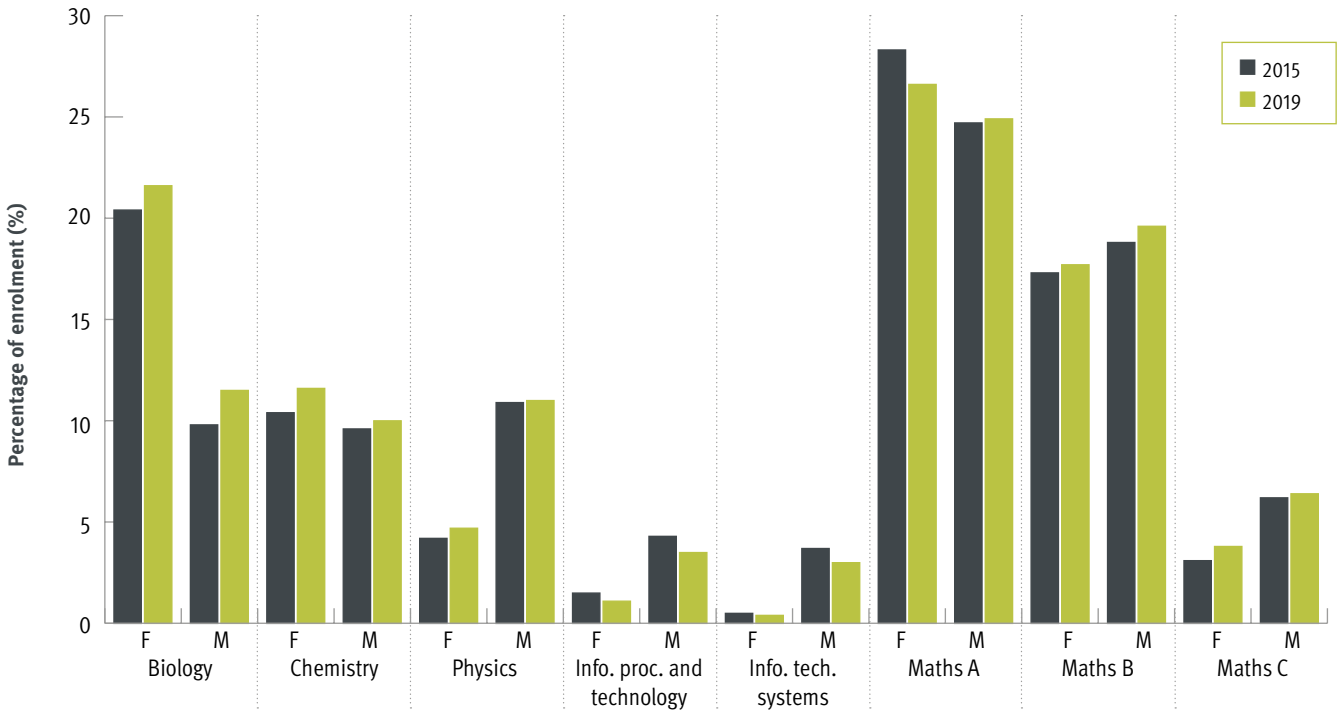


Who studies STEM at school?

In Australia, male students are three times more likely to aspire to a STEM career than female students.[14] In Queensland, both male and female enrolments in most of these eight STEM subjects increased between 2015 and 2019. The only decline in enrolments were in females participating in Mathematics A, and both males and females in the Information Technology subjects.

Females are more likely to enrol in STEM subjects such as Biology, Chemistry and Mathematics A, while percentage male enrolment is higher in Physics, Information Technology subjects, Mathematics B and C.[12]

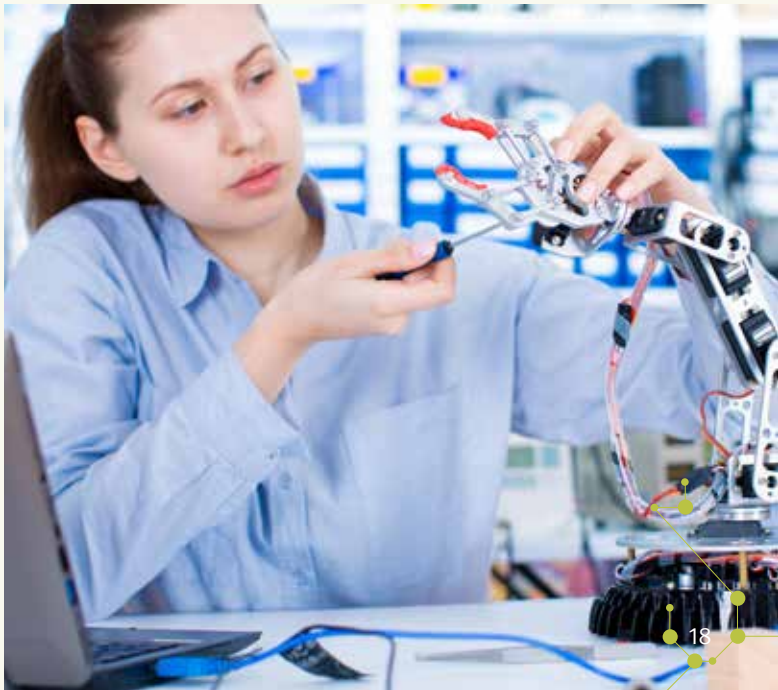
Percentage of Year 12 students enrolled in STEM subjects by gender (2015 and 2019)



#codingcounts

The Queensland Government's plan for coding and robotics in Queensland state schools are preparing our students for the jobs of the future where technology, critical thinking, creativity, collaboration and innovation are essential skills.

An estimated 75% of the fastest growing occupations require STEM skills and knowledge.



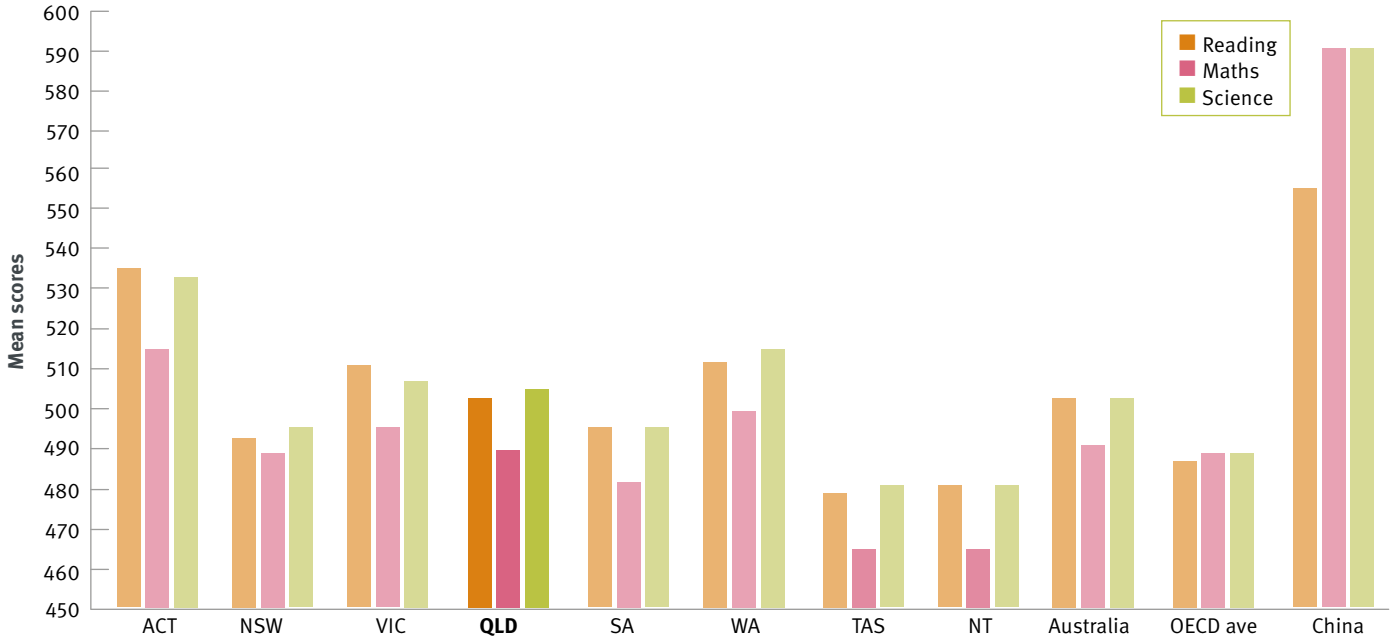
Australian student performance

The Programme for International Student Assessment (PISA) is an international comparative study of student performance directed by the Organisation for Economic Co-operation and Development (OECD).[15] It is completed every three years, and in 2018 reported student performance in 79 countries or economies, including both OECD and partner countries. It assessed a random sample of around 600,000 15-year-old students and examined capability in reading, maths and science, focussing on reading* in a digital environment in 2018.

PISA is a comprehensive and reliable indicator of students' capabilities and a powerful tool that countries and economies can use to fine-tune their education policies. However, it is based on a two-stage random sampling method and conducted so that the sample provides estimates about the population of 15-year-old students. This means that the results are representative of a proportion of the total number of students and may be subject to selection bias.

* Each PISA assessment focuses on one of the three priority areas (maths, reading and science) and 2018 focussed on reading.

Mean scores by state and territory in 2018



While PISA is not compulsory and only a proportion of students participate in the assessment, in Australia, 740 schools and a total of 14,273 students (out of a possible 600,000 students worldwide) participated in the 2018 assessment.

B-S-J-Z* (China) was the highest performing region, and Singapore was the highest performing country. Chinese and Singaporean students start pre-school at two or three years of age.[16] They complete six years at primary school and 12 years overall in formal education.[16]

Australia performed above the OECD average in all three capability areas, despite its overall decline over successive reports. More notably, averaged across reading, maths and science, only 57% of Australian students attained the National Proficient Standard.[17]

When averaged across reading, maths and science, the ACT was the highest performing state where 69% of students attained the National Proficient Standard.[17]

Despite representing only 20% of the PISA sample school students overall, independent school students performed higher than students in Catholic schools (24% representation) that in turn performed higher than government school students (56% representation).[17]

* Beijing-Shanghai-Jiangsu-Zhejiang

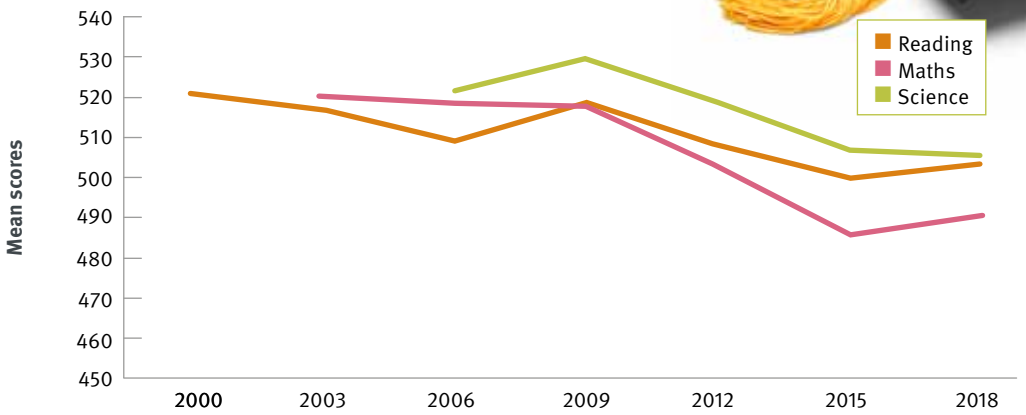
Queensland student performance

In 2018, of the 740 schools assessed in Australia, 133 Queensland schools (including government, Catholic and independent schools) were part of the PISA assessment. Of the 14,273 15-year-olds from across Australia who participated in the three assessment PISA domains, only 2,525 were from Queensland. Hence, it is obvious that the performance results are based on a small cohort of Queensland students and should not be considered as the sole measure of performance.[17]

The mean reading performance for Queensland students declined from 2000 to 2006, picked up in 2009, and then declined to its lowest score in 2015 with a slight improvement in 2018. Performance in Maths was stable from 2003 then sharply declined from 2009 to 2015 with a slight improvement in 2018. Science was first measured in 2006 and showed improvement in 2009, with constant decline to 2018.[17]

All three subjects declined from 2009, which may be attributed to the introduction of the national curriculum in 2009 with adjustments required to meet full implementation in 2014.[18]

Mean scores over seven PISA cycles in Queensland



From 2009, all three subjects assessed adjusted downward which may be attributed to the introduction of the national curriculum.[18] Full implementation was required by 2014. Queensland schools may continue to use the Queensland Curriculum for learning areas that have not yet been replaced by the Australian Curriculum until the end of 2020, when the next review of the Australian Curriculum is expected.[18]

From the 2015 PISA assessment, maths and reading performance improved while science dropped slightly.

See Appendices 1 and 2 for trends across all Australian states and territories.

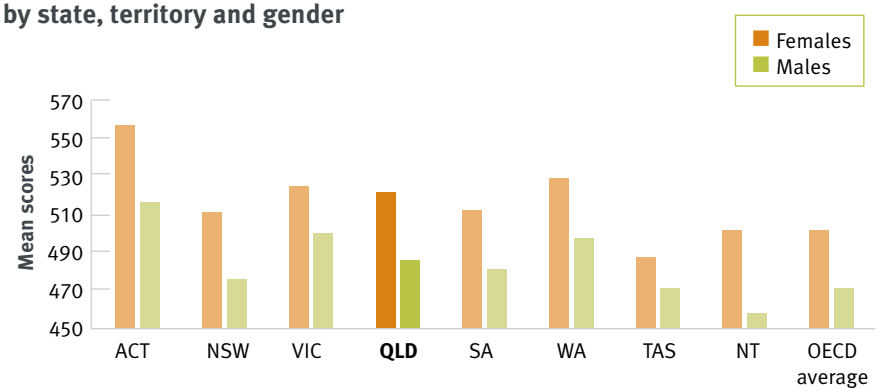
Focus not only on participation and achievement, retention is underpinned by teacher capability and university pre-requisites—both important factors for long-term student success.

Australian student performance by gender

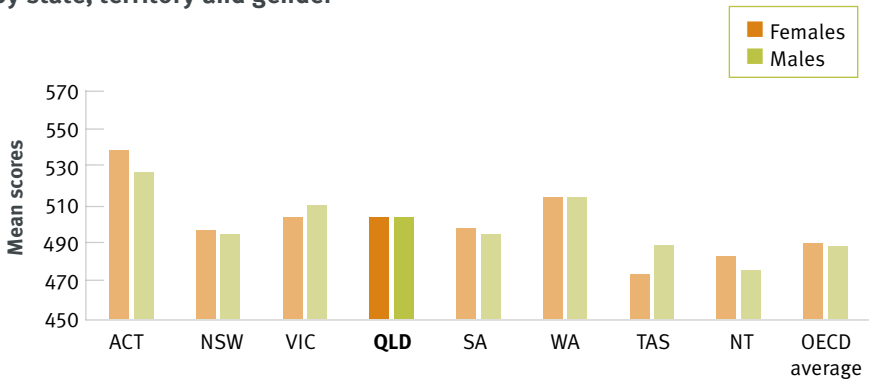
In Australia, there were equal proportions of female and male students in two states (SA and TAS), while the proportion of male students (52%) was higher than female students (47%) in ACT. In NSW, VIC, QLD and WA there were 49% female and 51% male. The proportion of female students was higher than the proportion of male students in NT (51% female, 49% male).

When exploring reading performance by gender, female students outperformed male students across every state to a degree that is equivalent to around one year of schooling.[17] Performance among males and females was similar across states in science literacy with the exceptions of the ACT and NT where females performed slightly higher. Similar to the OECD average, males outperformed females in every state in maths literacy, with the exception of ACT where females scored two points higher than males.[17]

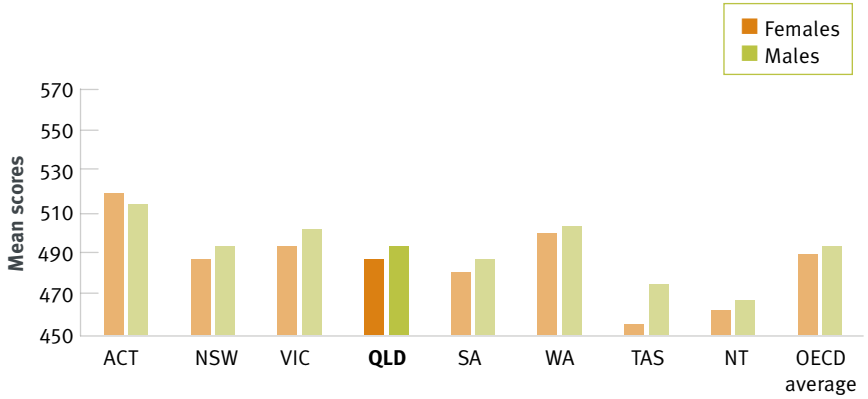
Student performance on the READING literacy scale by state, territory and gender



Student performance on the SCIENCE literacy scale by state, territory and gender



Student performance on the MATHS literacy scale by state, territory and gender



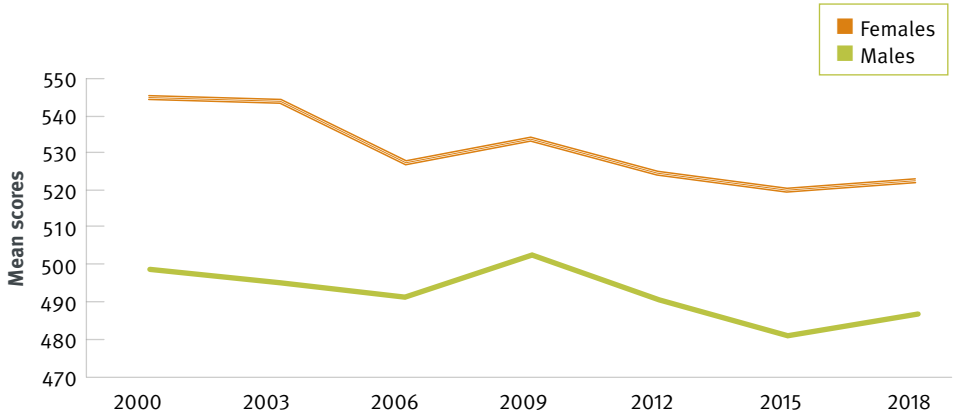
Queensland student performance by gender

As mentioned previously, while Queensland is performing above the OECD average, a number of programs and initiatives have been implemented to ensure gender equity and competitiveness on a global scale.[17]

Queensland figures reflect the findings for Australia, where females consistently outperformed males in reading across all years. Maths and science literacy are more closely aligned between genders.[17]

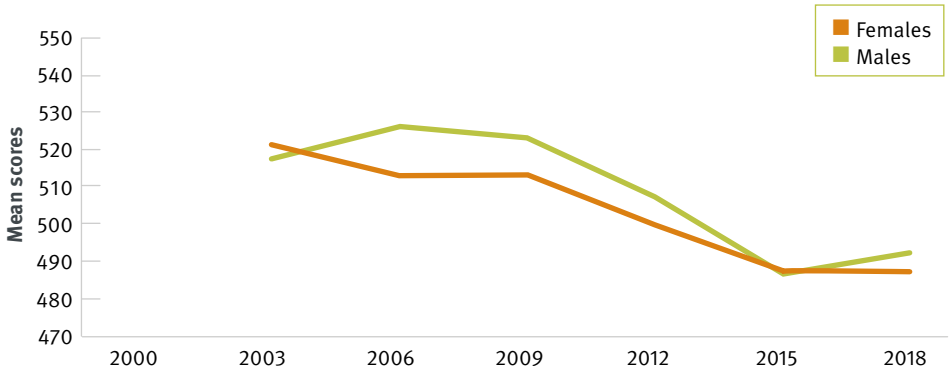
> 'This decline has been described by the Australian Council for Education Research as a *20-year slide* when performance results are compared with countries such as the United States and the United Kingdom. Curriculum that is not covering the right content, and struggles to incorporate *learning progression* in particular areas due to the breadth of STEM fields, have been linked to this decline in standards, in addition to an under-supply of teachers with STEM qualifications.'[19]

Mean performance on the READING literacy scale by gender



Mean performance on the SCIENCE literacy scale by gender

Mean performance on the MATHS literacy scale by gender



Longitudinal Queensland student performance

Since 2008, Queensland Year 9 students were, on average, achieving numeracy results below the national mean, as assessed by the National Assessment Program –Literacy and Numeracy (NAPLAN) in 2018.[20]

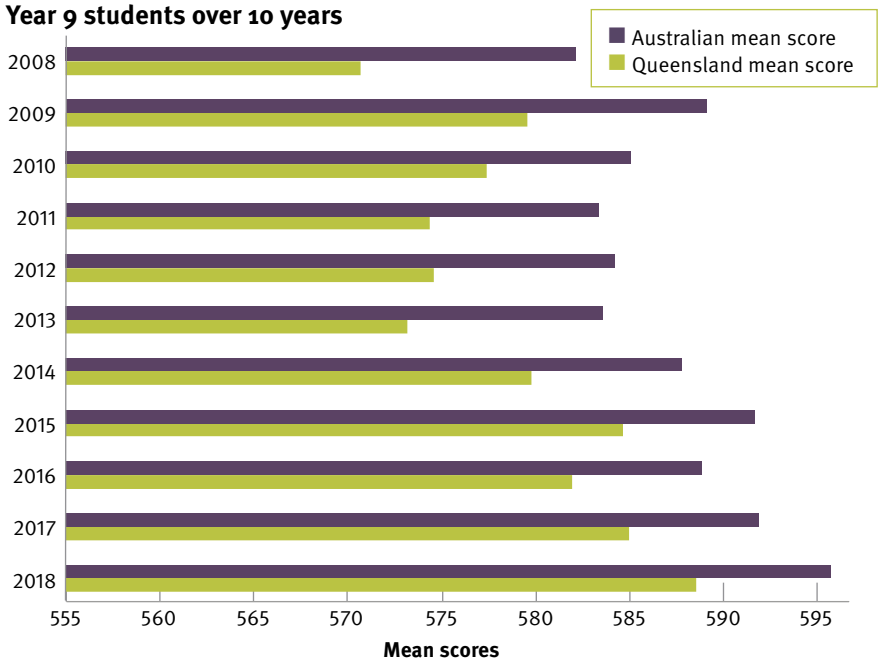
Interestingly, students with parents with a Bachelor level of education achieved higher results than all other groups.

In 2018, 12.3% of students who identified as Aboriginal and/or Torres Strait Islander performed below the national minimum standard, and on average scored 54 scale points below their non-Indigenous counterparts.

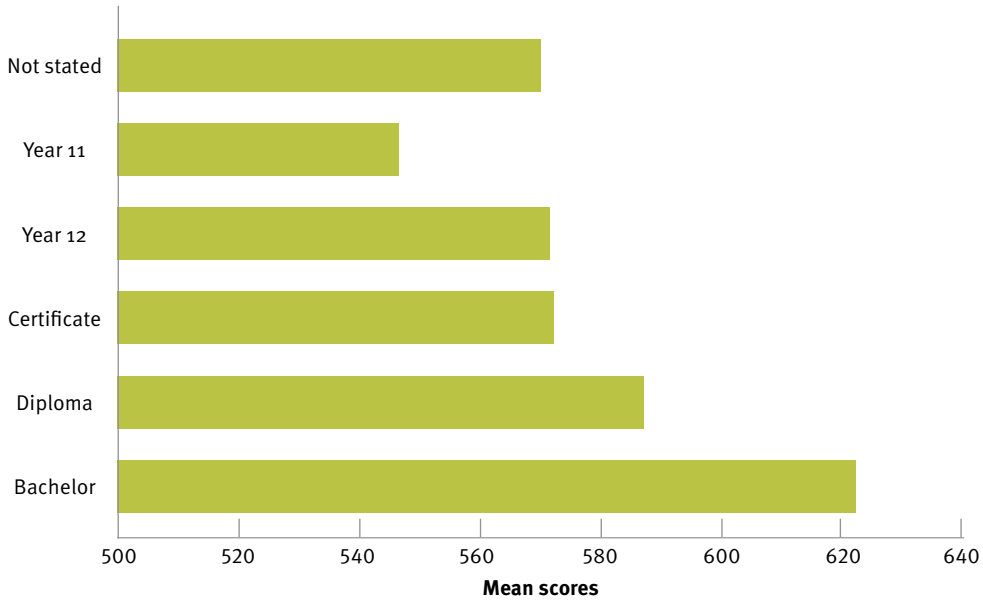
Limitations to Aboriginal and/or Torres Strait Islander student performance have been identified as:

- poor attendance at school
- being taught in English-speaking curriculums when English is a second language
- limited teacher capacity to teach Aboriginal and/or Torres Strait Islander students
- low representation of Aboriginal and/or Torres Strait Islander teachers.[21]

Mean numeracy achievement in NAPLAN of Year 9 students over 10 years



Level of parental education influences achievement of Year 9 students in numeracy in Queensland in 2018[23]



Teacher quality is key to STEM outcomes for students

The Department of Education published the 'Review of STEM education in Queensland state schools 2015–2017'[8] and found STEM education can be strengthened by:

- teachers accessing professional development to acquire STEM-specific content knowledge and pedagogical practices
- students having positive experiences in STEM throughout their schooling
- targeted STEM programs for under-represented groups in senior secondary school
- effective and sustainable professional development embedded within schools focussed on curriculum goals, conceptual knowledge and active learning strategies
- curriculum-based decision-making strategies to assess available STEM resources in the community.

The department will continue to deliver and promote a suite of comprehensive STEM tools and opportunities that provide strategic and practical school based approaches to support the high-quality, real-world and innovative teaching and learning of STEM in Queensland state schools.

The study of STEM is undoubtedly a gateway to the future for Queensland students. Now is the time to get excited about STEM. It's time to consolidate and scale-up Queensland's STEM capacity.'

The Hon. Grace Grace MP, Minister for Education, Minister for Industrial Relations, *Review of STEM education in Queensland state schools 2015–2017*

Teachers key to student success in STEM

Research consistently shows that teachers' knowledge and practice plays a critical role in student engagement and achievement in STEM.

Since 2015, the Department of Education has implemented a variety of innovative STEM initiatives that support schools, enhance opportunities for teachers and spark students' curiosity and passion in STEM. Initiatives include online learning resources, competitions to excite outstanding students, and activities to engage under-represented groups such as girls and Aboriginal and Torres Strait Islander people and rural and remote students.

Achievement of state school primary students between 2012 and 2017 has increased in Mathematics and Science, and there has been an increase in the proportion of state high school students in Years 11 and 12 studying Mathematics and Science subjects (not part of the PISA assessments).

Non-science-qualified teachers are often required to teach science subjects.

Classes in remote schools or locations with a low socio-economic status are more likely to be taught by an out-of-field teacher.[22]

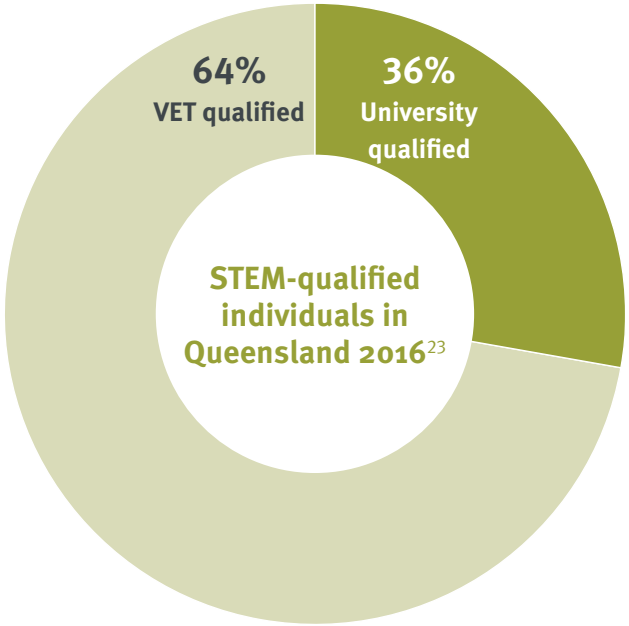
More Queenslanders gain STEM skills through VET

Queensland has one of the highest vocational education and training (VET) participation rates in Australia. Of working age Queenslanders, 27% are VET qualified compared to the natural average of 24%.[23]

The proportion of Queenslanders who gain their STEM skills through VET is 64%, with only 36% gaining STEM qualifications through a university. Across Australia, 70% of Australians gain their STEM skills through VET.[23]

Although VET was usually synonymous with qualifications for traditional trades vital to Queensland's economy, VET allows Queenslanders to up-skill or re-skill to transition into new jobs in Industry 4.0 such as emerging technological and science industries.[24,25]

As Queensland already has a high-VET participation rate there is the opportunity to build on this established education path to train more Queenslanders in STEM skills.



Since 2019 the Queensland Government has offered **free TAFE for year 12 students** to study high-priority subjects including aviation, engineering, electrotechnology and laboratory science.

The Advance Queensland—TAFE Queensland Indigenous Pathways Scholarships initiative focuses on growing the economy and supporting students to obtain qualifications to pursue their chosen careers in science, technology, engineering, arts and mathematics industries.
The scholarships offer $5,000 toward study costs.

Australian STEM qualifications

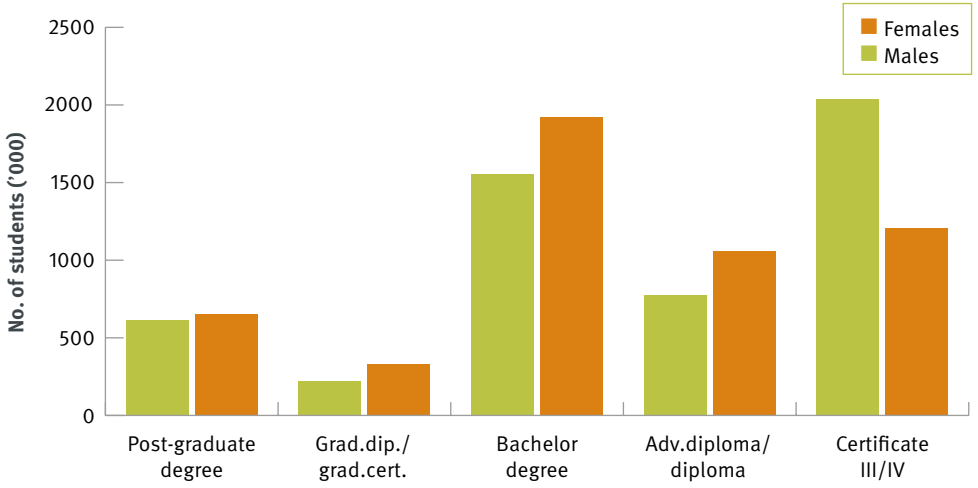
Females tend to study in more formal environments such as universities or colleges, graduating with degrees, or graduate diplomas/ certificates than males. At almost double the number of females, males are over-represented in the Certificate III/IV qualification pathway.

The fields of study highlight the gender differences. STEM courses are over-represented by male students. For example, engineering has just over 1.7 million male students to around 153,000 females.[26] Architecture and Information Technology also reflect this imbalance.

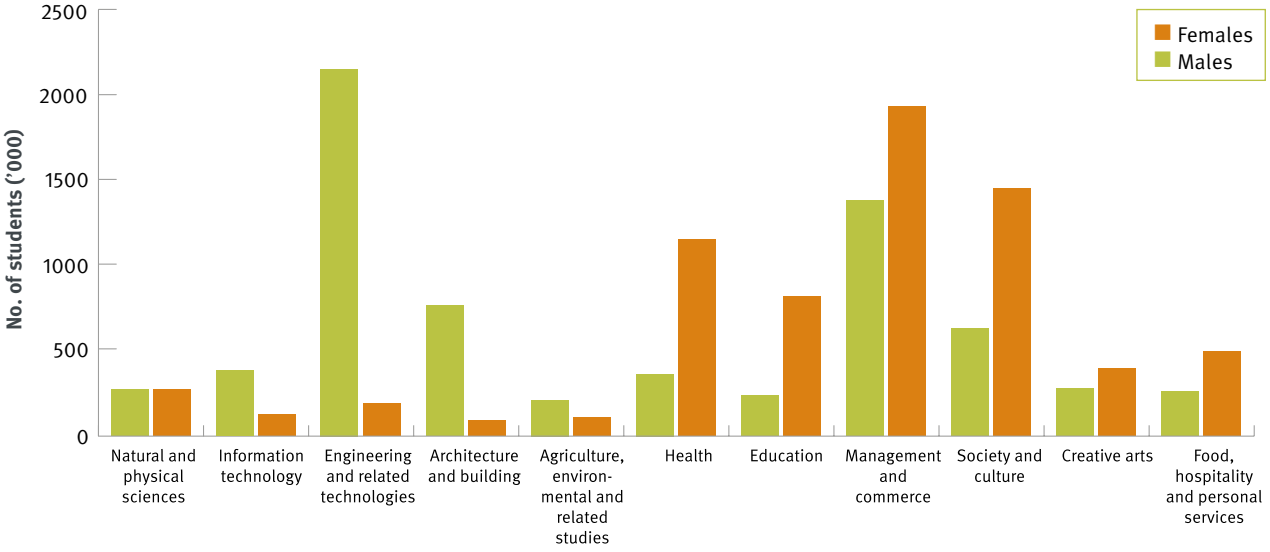
Conversely, humanity fields such as health, education, management/commerce, society and culture has an over-representation of female students. This may be due to a number of factors including gendered views of education choices and disengagement due to content being perceived as not inclusive or relevant. Australian industry has identified a STEM skills gap, and improving diversity will contribute positively to addressing the issue.[19]

The Australian Academy of Science's Women in STEM decadal plan identifies a number of opportunities to improve equity in STEM career fields, including increasing number of role models, education support, and industry action to drive inclusive and respectful workplaces.[27]

Number of students with qualification by gender



Number of students with STEM and non-STEM qualification by gender



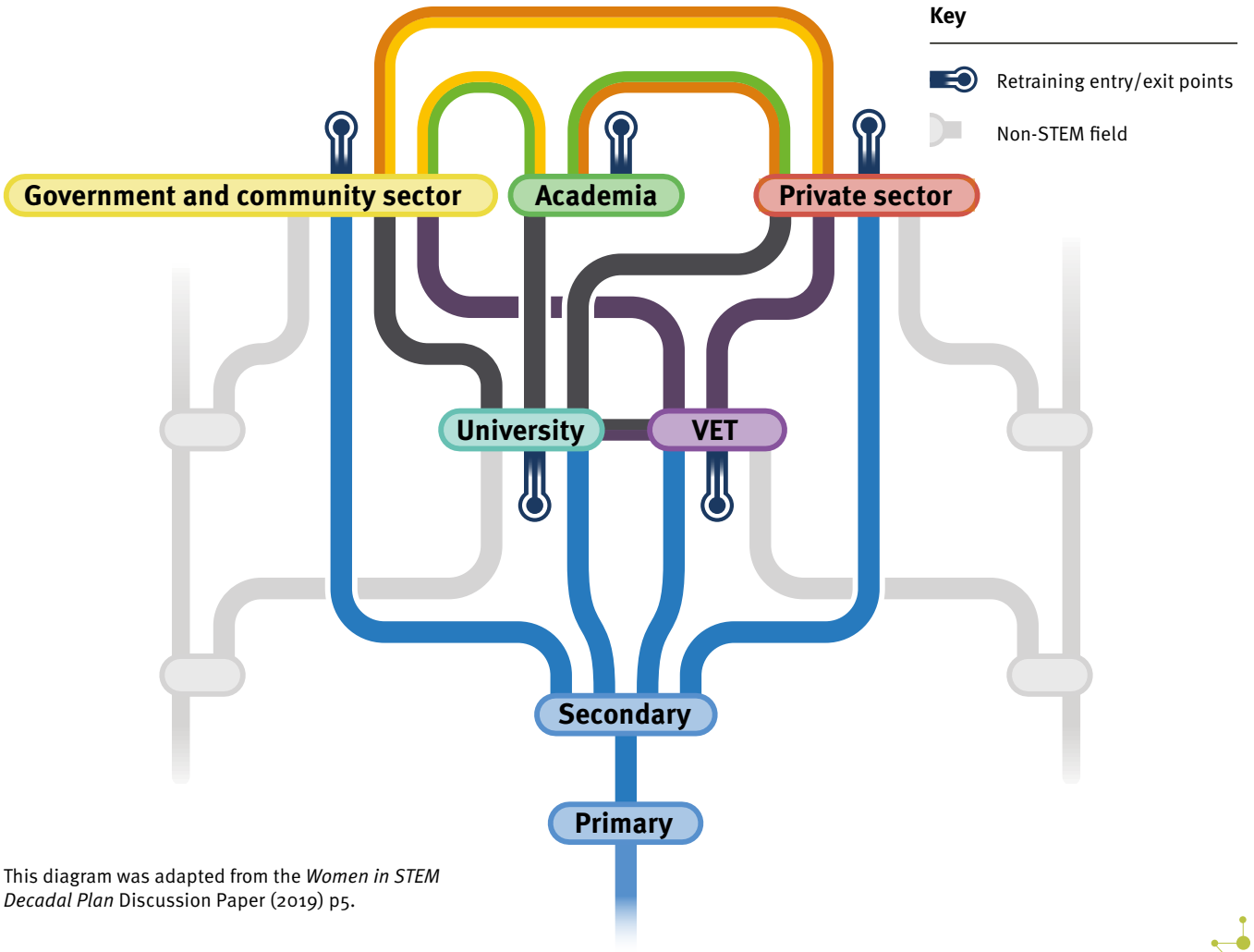
Pathways to employment

Primary and secondary school education is compulsory (Year 1 to Year 9 or 10) in Australia, and this rule is similar across states and territories with only minor variations. Education can be delivered in a formal school setting, or at home with well-established home schooling support networks and state or territory authority permission.[28]

Tertiary education includes both higher education (including universities) and vocational education and training (VET). Secondary school, university or VET education provides flexibility to graduates to enter employment. To pursue a career in academia, graduates must have a university qualification.

Government, industry and academia have a symbiotic relationship where government and industry look to academia for qualified candidates to add to its workforce. Educational institutions tend to recruit the brightest minds with the promise of gainful employment. For example, companies are using academic labs as incubators for long-term and exploratory research.

This is a strategy to promote innovation, collaboration, entrepreneurship and investment opportunities, therefore contributing to workforce development. Government agencies promote, fund, or facilitate partnerships in various ways creating further employment opportunities.[27]



This diagram was adapted from the *Women in STEM Decadal Plan* Discussion Paper (2019) p5.

Australian STEM workforce

The Australian STEM workforce in 2016 was predominantly non-Aboriginal and/or Torres Strait Islander, Australian-born citizens, with the gap in the workforce filled by skilled immigrants.[23]

Between 2006 and 2016, 4.9% of those who migrated to Australia were employed in a professional, scientific or technical role.[23]

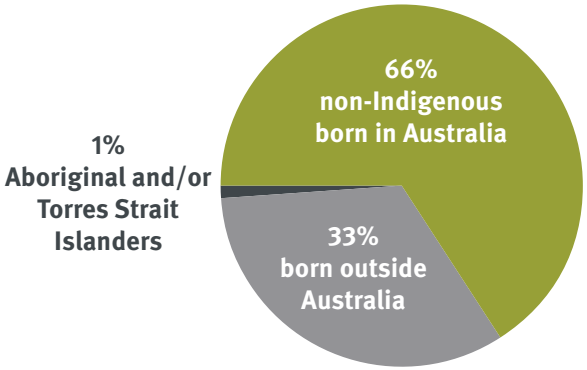
Less than 1% of the STEM workforce consisted of those who identify as Aboriginal and/or Torres Strait Islander. During this time, 4.7% of Queenslanders that self-identified as needing assistance with core activities were employed in a STEM industry, compared with 6.3% of the able community.[23]

Organisations, such as Queensland Health, have set diversity targets to ensure those with diverse backgrounds do not face systemic or attitudinal barriers to career progression.[29]

Data from the United States indicated that within STEM workplaces, LGBTQIA+ employees were more likely to be out about their sexuality when there was gender parity. Early career academics were less likely to be open about their sexuality than later career academics.[30]

Retaining diverse students studying STEM needs consideration in relation to the STEM workforce. A United States study of STEM university students found that 71% of heterosexual students were still pursuing a STEM degree four years later compared to 64% of students from a sexual minority, even though students from a sexual minority are more likely to participate in undergraduate research (49% vs 41%).[31]

Proportion of ethnic groups working in professional, scientific and technical services



Australian STEMM* graduate employment

In 2019, medical undergraduates were the highest cohort to gain full-time employment. At 91%, almost all graduates found a full-time job within four months of graduating. Engineering graduates followed closely behind with almost 85% securing full-time employment upon graduation. Computing and Information Systems was almost 76% and Science and Mathematics was just over 63%.

* STEMM is defined as Science, Technology, Engineering, Mathematics and Medicine.

The overall full-time employment rate for STEMM undergraduates was 77.6% in 2019, a slight increase from 77% in 2018. The overall employment rate for STEMM postgraduate students remained consistent between the two years, i.e. down from 85% in 2018 to 84% in 2019 for postgraduate (coursework) students and up by 0.5% from 83.3% in 2018 to 83.8% in 2019 for postgraduate (research) students.[32]

See Appendix 3 for employment by Australia's top universities, and Appendix 5 for employment status of graduates from universities versus non-university higher education institutions (NUHEIs).

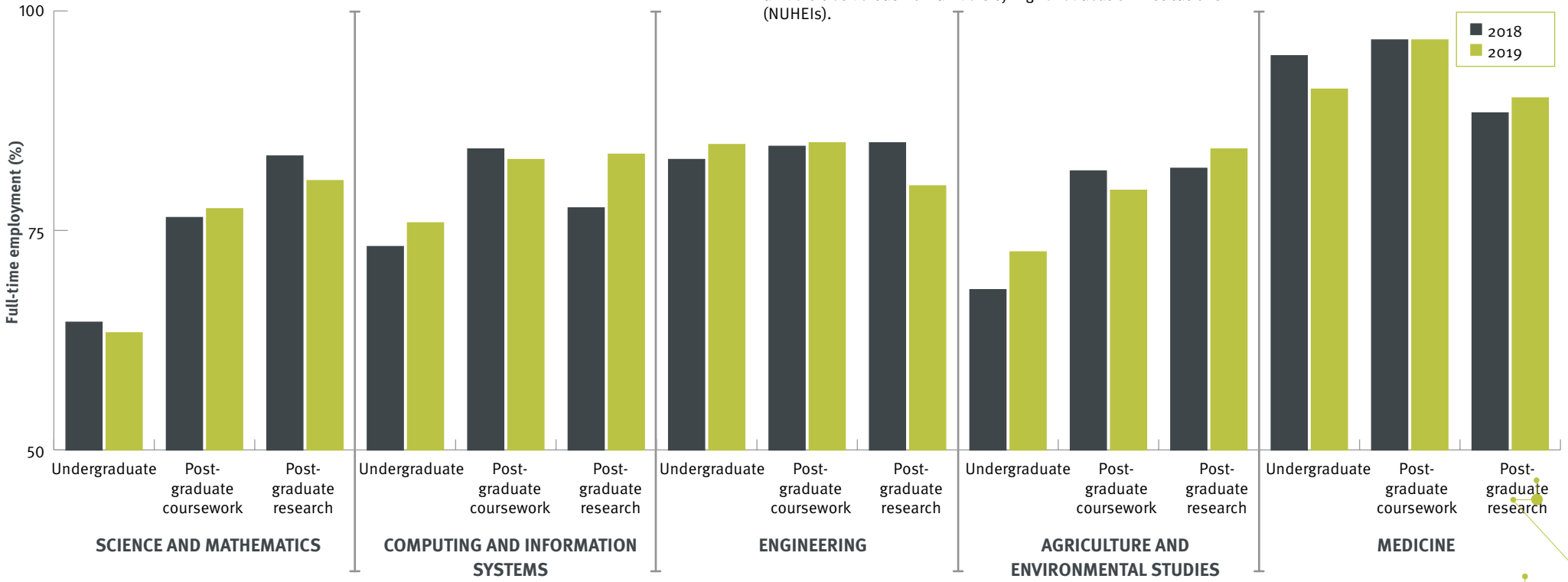
In 2019:

77.6%
STEMM undergraduates in full-time employment

84.4%
STEMM postgraduate coursework in full-time employment

83.8%
STEMM postgraduate research in full-time employment

Percentage of STEMM graduates in full-time employment



Australian STEMM salaries by gender

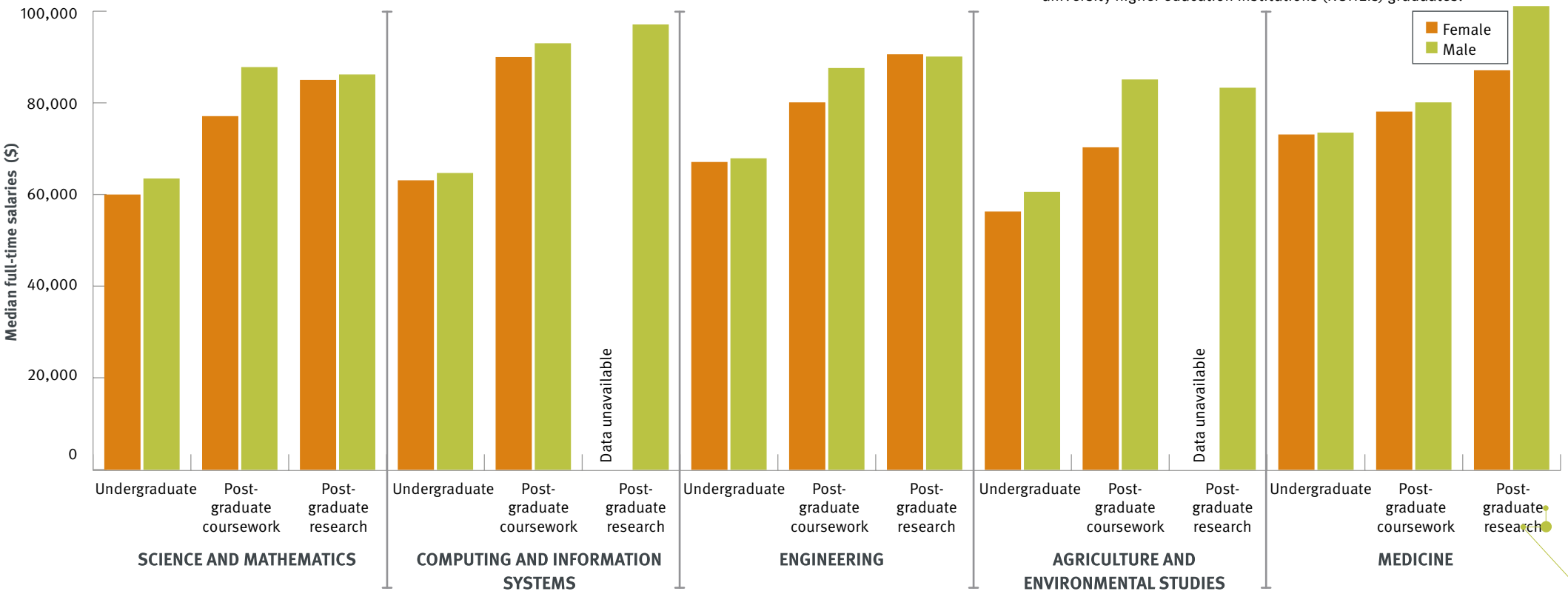
In 2019, a median STEMM undergraduate full-time salary for females ranged from $56,200–$73,000, and $60,500–$73,400 for males. Medicine and Engineering topped the salary range, and Agriculture and Environmental, Science and Mathematics studies reflected the lowest undergraduate salaries for both genders.

STEMM postgraduate coursework full-time salaries in 2019 ranged from $70,200–$89,900 for females, and slightly higher for males, from $80,000–$92,900. The highest full-time median postgraduate coursework salaries for both genders were Computing and Information Systems, and Engineering. The lowest postgraduate coursework salaries were for Agriculture and Environmental studies across both, and females in Science and Mathematics, and Medicine for males.

Median STEMM post-graduate research full-time salaries for females ranged from $84,900–$90,500 and again, slightly higher for males from $83,200–$101,000. Post-graduate research data was unavailable for females in Computing and Information Systems, and Agriculture and Environmental studies. Engineering had the highest full-time salary for females, and Science and Mathematics had the lowest. Males were paid highest in the Medicine field, and lowest in the Agriculture and Environmental field.[32]

See Appendix 4 for salaries by top universities and Appendix 5 for employment status and salaries of universty graduates versus non-university higher education institutions (NUHEIs) graduates.

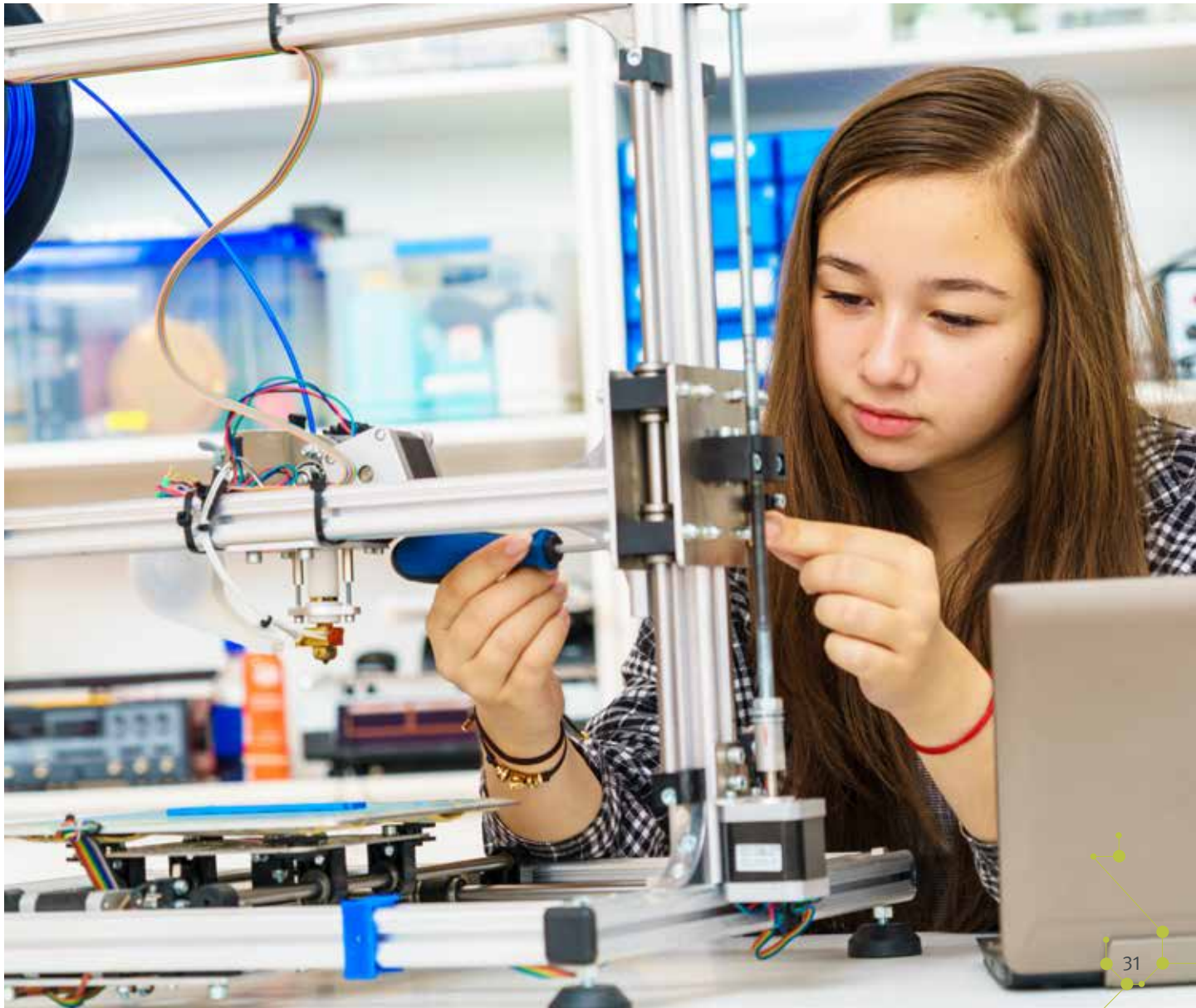
STEMM graduates median full-time salaries by gender



Undergraduate students in further full-time study

In 2019, four months after graduation, almost 19% of undergraduates were engaged in further full-time study (slight decrease from 19.4% in 2018). Science and Mathematics was the highest proportion continuing study at 39.5% and the lowest was 11.3% in Computing and Information Systems.[32]

Both postgraduate coursework (6%) and research (5.8%) graduates were less likely to move into further study after graduating. Undergraduates who had completed Vocational Education and Training (VET) in certain study areas such as Nursing and Pharmacy, also did not pursue further full-time study in these areas in 2019.[32]



How many women are STEM qualified?

In 2016, **29% of all STEM-qualified people in Queensland were women—5% lower than the national proportion of 34%.**[23]

When Queensland women with medical qualifications (STEMM) are included, this proportion increases to 51%. Of these, 32% have a university postgraduate degree, which increases to 42% with the inclusion of medical qualifications (STEMM).[23]

There is a problem nationwide with retaining women with STEM qualifications in academic positions.[33]

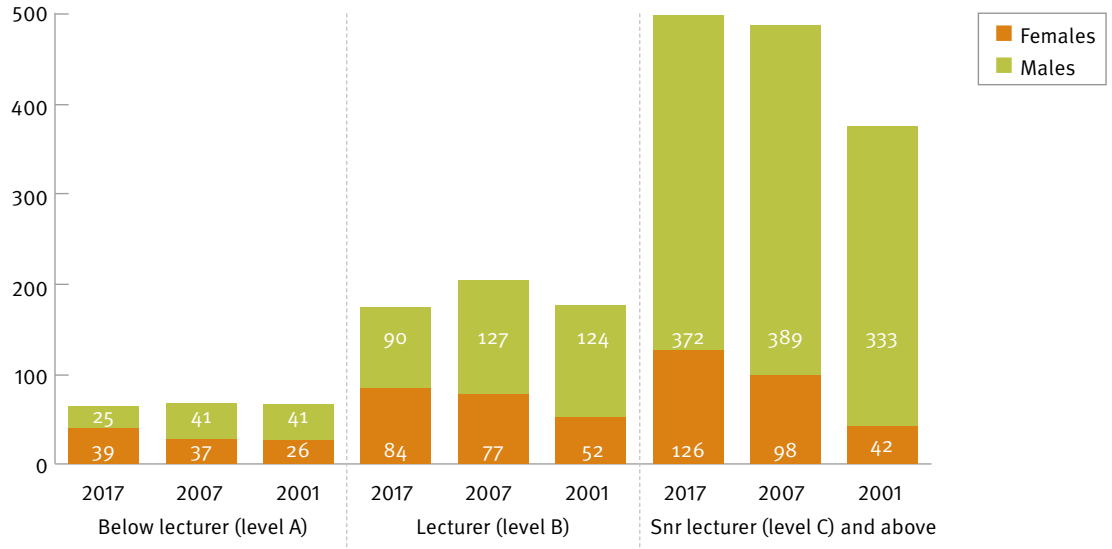
In Queensland, the number of females in below lecturer or lecturer positions has increased from 2001 to 2017, and reached approximate parity, however, these proportions are not reflected at higher levels where males still hold 74% of all positions at the senior lecturer level and above.

The Women on Boards Initiative aims to increase the number of women on boards in the public, private, and not-for-profit sectors, which would in turn **improve productivity of the Queensland population by $87 million.**[34]

Queensland Women's Strategy
2016–21

Increasing the number of women on public, private, and not-for-profit boards to reach gender parity would translate into an $87 million increase in productivity gains for Queensland.[34]

Number of Queensland academics in natural and physical sciences



Why do women leave STEM careers?

Women with degrees in Information Technology and Natural and Physical Sciences experience the highest unemployment rates and reduced satisfaction with employment opportunites.[35,36]

Many do not choose to leave their STEM careers: they are instead discriminated against and eventually pushed out by systemic or unconscious bias regardless of 'merit', as well as sexual harassment and gender stereotypes regarding unpaid caring responsibilities.[27]

Job seekers have been known to remove female pronouns, take out date of birth, or even anglicise a surname to circumvent potential unconscious bias.[37]

The loss of female STEM professionals is a significant waste of expertise, talent and investment. Lifting the number with STEM qualifications and keeping them in equally paid employment would help increase workforce diversity—a driver of innovation.[38]

The Merit Trap: self-labelled meritocracies showed greater bias towards hiring men over equally qualified women[39]

In 2019, Australian females working in professional, scientific and technical services earned 24.4% less than males[36]

>50% of the gender pay gap in OECD countries is due to an 'unexplained component' associated with factors including gender stereotyping, social conventions and discrimination against women[40]

SAGE in Queensland

Gender inequity in academia will not be fixed by time alone. The proportion of women in senior academic roles has stagnated, exemplified in 2013 when no women were elected to the Australian Academy of Science Fellowship.

In response, The Australian Academy of Science with the support of the Australian Office of the Chief Scientist, held a Science in Australia Gender Equity (SAGE) Forum in 2014.

There was widespread support for the establishment of the SAGE Initiative modelled after the Athena SWAN Charter first created in the United Kingdom.

The SAGE Initiative aims to improve gender equity and inclusiveness in Australian STEMM higher education and public research institutions. As at 2019, SAGE has 45 members from Australian universities, medical research institutes, and publicly funded research organisations.[41]

Barriers to progression

Industry demand for STEM graduates is greater than the number of available graduates, particularly for females in STEM.

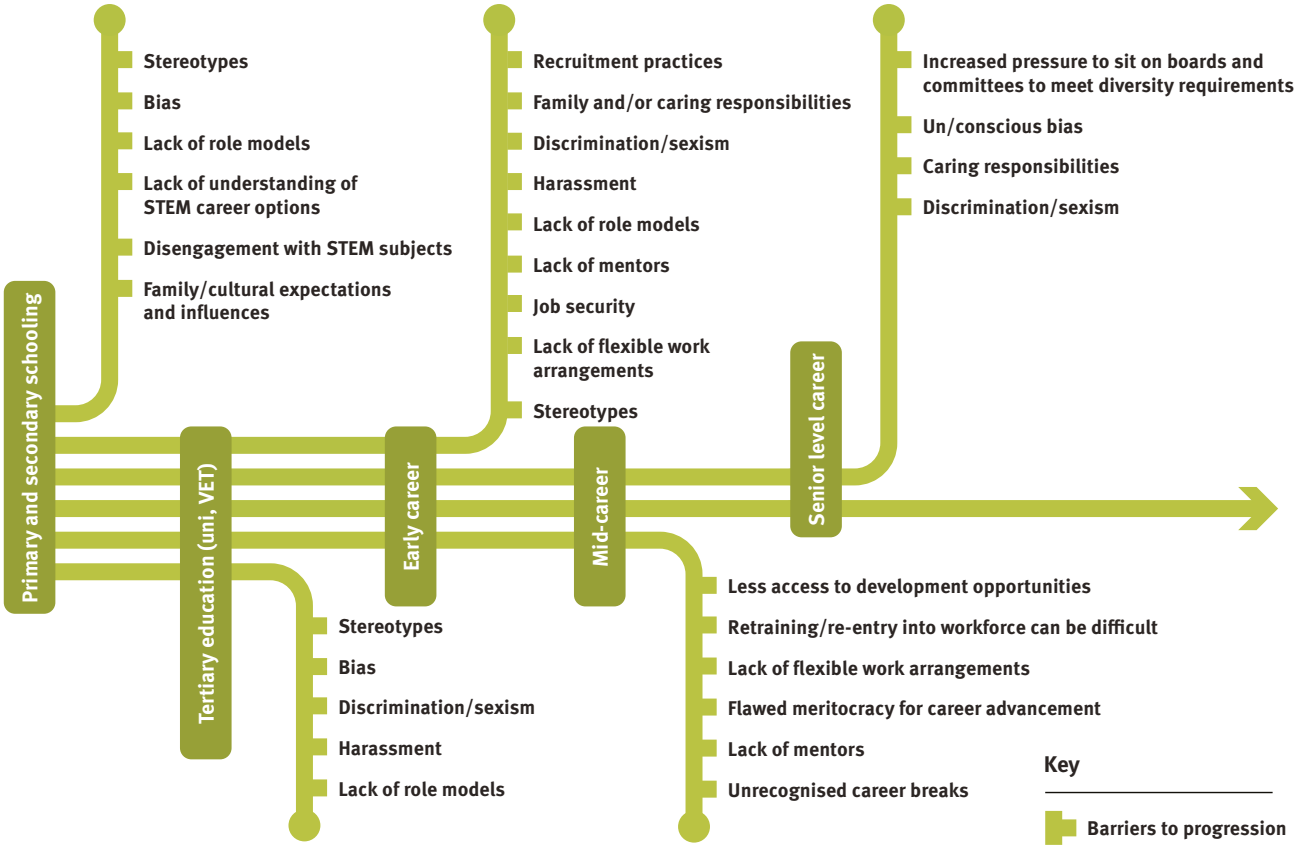
The diagram shows the current education and career paths are obstructed by barriers at every stage, resulting in lower numbers of females studying STEM at university.

Addressing this challenge starts in primary school; a problem faced in many countries and not just Australia.

Disengagement with STEM continues as students progress through the education system due to various factors such as stereotypes, lack of role models, limited understanding of STEM career options, etc.

Society and families are critical in changing stereotypes associated with subject and career choice. In addition, merit needs to be assessed more accurately from different perspectives.

During early to senior career levels, females further face challenges such as lack of flexible working arrangements, less access to development opportunities and caring responsibilities, slowing down career progression as compared to their male counterparts. Facilitating female participation in STEM requires a more cohesive and sustained approach. Positive outcomes will not result from addressing a single factor alone, but rather from the interactions between factors at the individual, family, school, workplace and societal levels.[27]



This diagram was adapted from the *Women in STEM Decadal Plan* Discussion Paper (2019) p2.

Build diverse and inclusive workplaces

Queensland cannot afford to lose the expertise and talent of diverse STEM professionals while an increase in diversity is driving innovation.[42]

Policies to promote women and minority groups joining and remaining in the STEM workforce must be accompanied by measures to address the barriers these demographics face in the labour market.

Pay gap analysis and resulting correction for like-for-like pay gaps is a significant issue for Australian women.[43]

Adopting better workplace flexibility arrangements would benefit both genders. In 2012, 79% of fathers wanted to alter their work hours, but only 41% did.[44]

Research institutions would benefit greatly with SAGE accreditation and if other employers were to adopt recommendations made by the Workplace Gender Equality Agency, OECD and Human Rights Commission.[43,45]

To tackle issues of gender inequity in STEM-based careers, the Australian Government committed to a number of new measures in the 2019–20 Budget.[46]

This includes appointment of a Women in STEM Ambassador, and creation and implementation of a Women in Science Strategy, a Decadal Plan for Women in Science, and a Girls in STEM tool kit.[27,47]

These are all positive initiatives to address the issue, but there is more to be done as evidenced by the current diversity imbalance and pay gap in STEM careers.

Recommendation 3:

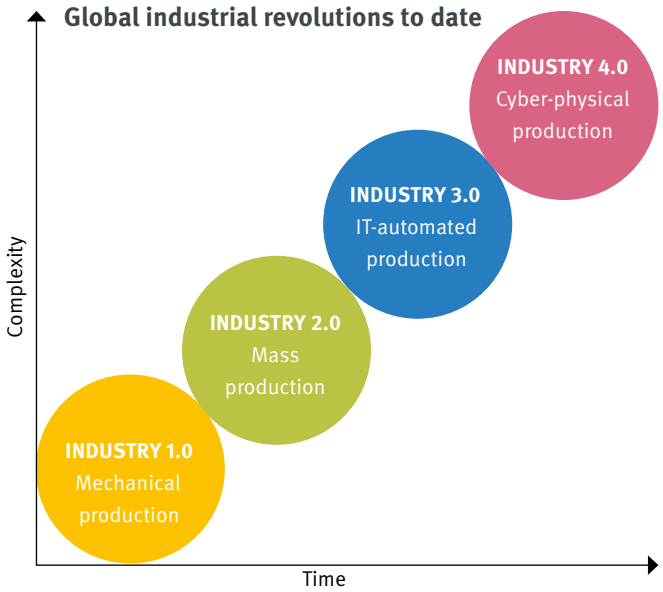
Well-prepared transition to Industry 4.0

Global industrial revolutions to date

Industry 1.0 focussed on the development of coal-, water- and steam- powered machines to aid workers in mechanical production. Industry 2.0 facilitated mass production through the use of electricity-powered machines and the development of a number of management programs that made it possible to increase the efficiency of manufacturing facilities through division of labour and increased productivity.

In the 20th century, Industry 3.0 led to the development of electronic devices and software systems which made it possible to fully automate individual machines enabling humans to plan, schedule and track product flows through the manufacturing facility giving rise to the concept of supply chain management.

In the 21st century, Industry 4.0 connects the Industrial Internet of Things (IIoT) with manufacturing techniques to enable systems to share information, analyse it and use it to guide intelligent actions. It also incorporates cutting-edge technologies, such as artificial intelligence (AI), robotics, sensors, and additive manufacturing—the primary drivers of the movement to the fourth industrial revolution.[48,49,50]



As a result, industry and business are being transformed by a new wave of digital technology lowering the cost of doing business. This poses the question: how will Industry 4.0 affect the job market?

Industry 4.0

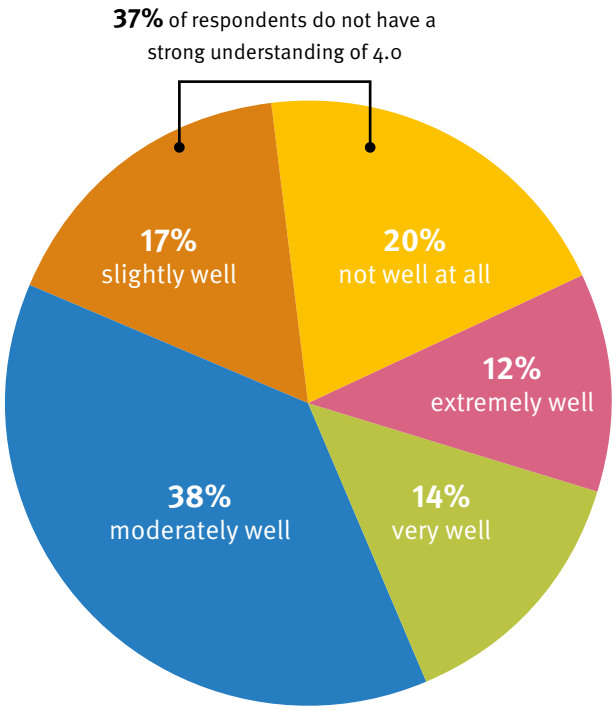
Touted as the Fourth Industrial Revolution, it enables advanced manufacturers to connect big data and analytics with automation and robotics, improving cost, productivity, profitability and operations. The Queensland Government's Advanced Manufacturing 10-year Roadmap and Action Plan and its Biofutures 10-year Roadmap and Action Plan, together contain 20 actions to position Queensland as a leader in advanced manufacturing technologies, products, systems and services:

- big data and analytics
- cybersecurity
- cloud computing
- internet of things
- biofutures.

How well do people understand Industry 4.0?

While industry and businesses are being transformed in Australia, only a quarter of survey respondents understand Industry 4.0 extremely or very well, and 38% understand it moderately well. Of the survey respondents, 20% indicated they do not understand Industry 4.0 well, and 17% only understand it slightly well, illustrating the lack of understanding around the overall concept of Industry 4.0.[50]

This type of intelligent and interconnected ecosystem is formed by a potent combination of technologies that adds accuracy, efficiency, productivity and personalised customer service to business and industry in unprecedented ways. It can include replacing physical labour type jobs, data collection and processing, traditional manufacturing, etc. However, labour demand will be in new types of occupations that have not existed before. Similar to the way the introduction of the personal computer in the 1980s transformed how and where people worked, creating new jobs at a higher rate than replacing existing ones.



These figures add to 101% due to rounding to whole numbers.

Emerging industries

Data61 identified in its Digital Megatrends 2019 report that although some jobs may disappear as a result of digital disruption, most jobs will be reshaped and new ones created. The key skills required for future work include adaptability, flexibility, people skills, as well as technical skills and an ability to learn.[51]

Synthetic biology is providing opportunities in the development of new and sustainable approaches to energy and food production, environmental protection and healthcare challenges. Synthetic biology is also creating new STEM skilled employment and business opportunities.

Brisbane has secured the establishment of a Bio-Foundry—a one-stop-shop for synthetic biology R&D.

'It's where we apply the four core steps of engineering to biology—design, build, test and learn.'

Associate Professor Claudia Vickers
AIBN, UQ

The jobs that will be in demand in the future include:

- artificial intelligence and machine learning
- big data specialists
- process automation experts
- information security analysts
- user experience and human-machine interaction designers
- robotics engineers
- blockchain specialists.[52]

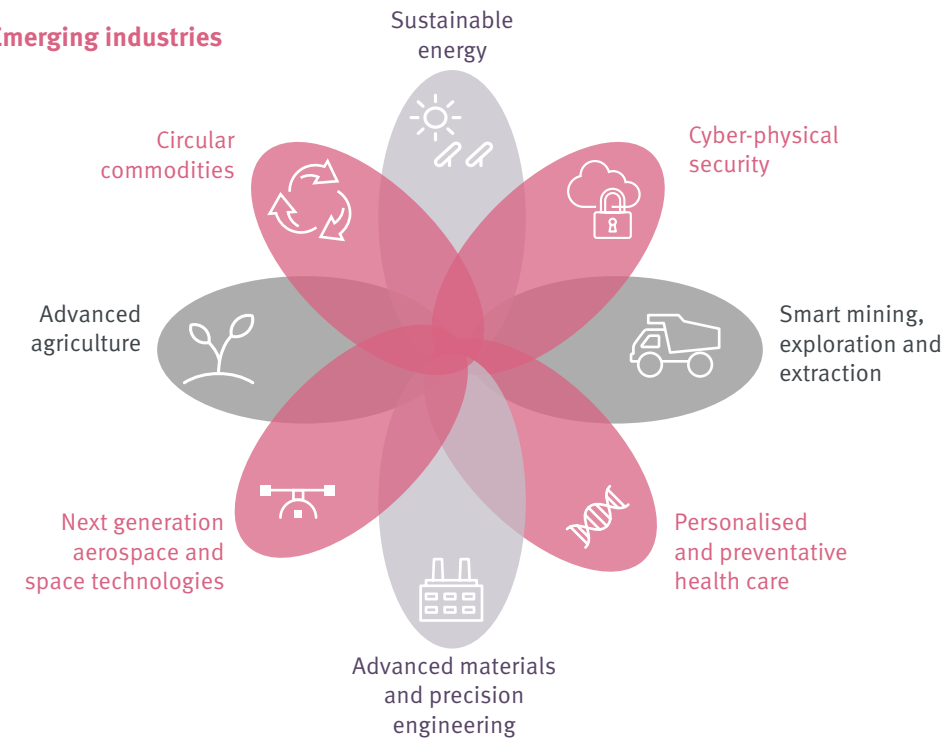
Eight emerging industries were identified by the Data61 New Smarts report in 2019.

Most align with the Queensland Government's ten-year roadmap priority sectors.[51]

The ten-year industry roadmaps to focus investment in priority sectors with global growth potential:

- advanced manufacturing
- aerospace
- biofutures
- biomedical
- defence
- mining equipment, technology and services
- screen industry
- agriculture and food.[53]

Emerging industries

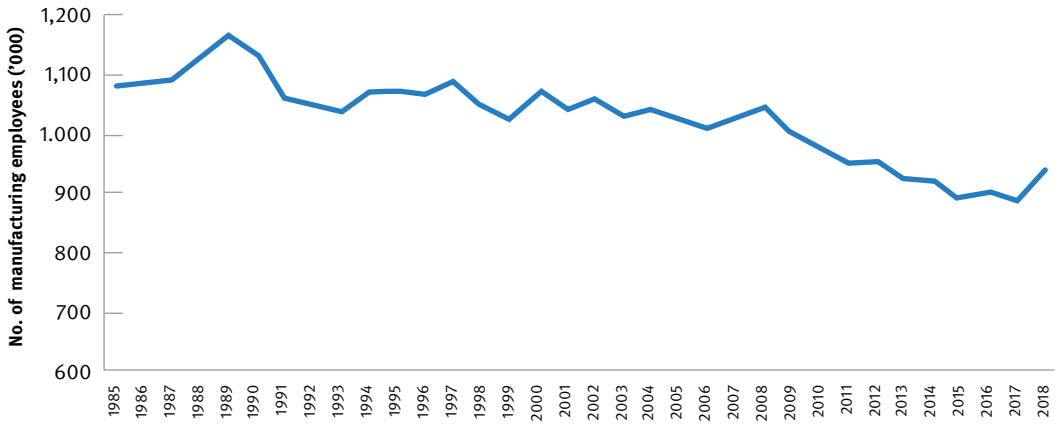


Australian manufacturing

The Australian manufacturing workforce has changed over the past 30 years. In 1988, there were nearly 1.2 million employees, but by 2018 this number had reduced to about 0.95 million. This was due to changes in Australian government policies, and some offshoring of manufacturing operations to achieve cost reductions, amongst other reasons.

It is worth noting that despite the trends in the size of the manufacturing workforce, total figures have stabilised in recent years, and the number of people employed has increased by 50,000 from 2017 to 2018.[54,50]

Size of the Australian manufacturing workforce 1986–2018



Note: employment total averaged over the year.

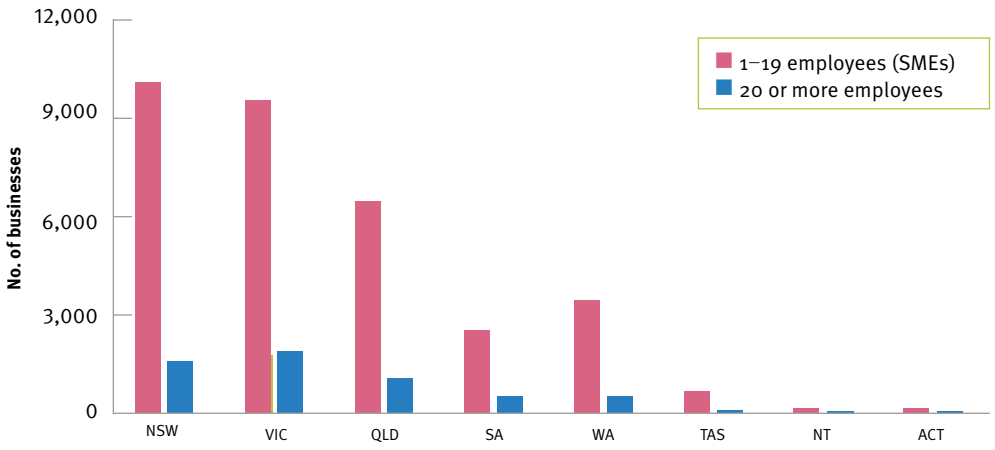
By strengthening international competitiveness and creating the jobs of the future, the manufacturing sector is vital to growing and diversifying the economy. As much as 41% of global trade is now in intermediate goods (unfinished products and components of a final product). This has resulted in a growing market for advanced manufacturers that create finished products, and has also added value at every stage of, and within, the global supply chain.[53]

Australian manufacturing

The Australian manufacturing industry has an overwhelming number of small to medium enterprises (SMEs) with fewer than 20 employees. SMEs are important contributors to job creation and productivity growth, but have less capacity than larger organisations (with 20 or more employees) to engage in research and development and incorporate Industry 4.0 technologies into their businesses. Therefore, business–business collaborations are necessary to bridge the gap enabling small businesses to see the value and relevance of Industry 4.0, including advanced biomanufacturing and how it can be implemented.[55,23]

In Queensland, 97% of all businesses are small businesses, employing 43% of Queensland's private sector workforce. Given the significance of the small business sector to Queensland's core job creation and economic growth objectives, particularly in regional Queensland, the Queensland Government is planning to release a new Queensland Small Business Strategy (2020–24) to extend the life span of SMEs by increasing global competitiveness and the ability to adapt to new technologies.

Number of businesses by size and location within the Australian manufacturing industry 2016



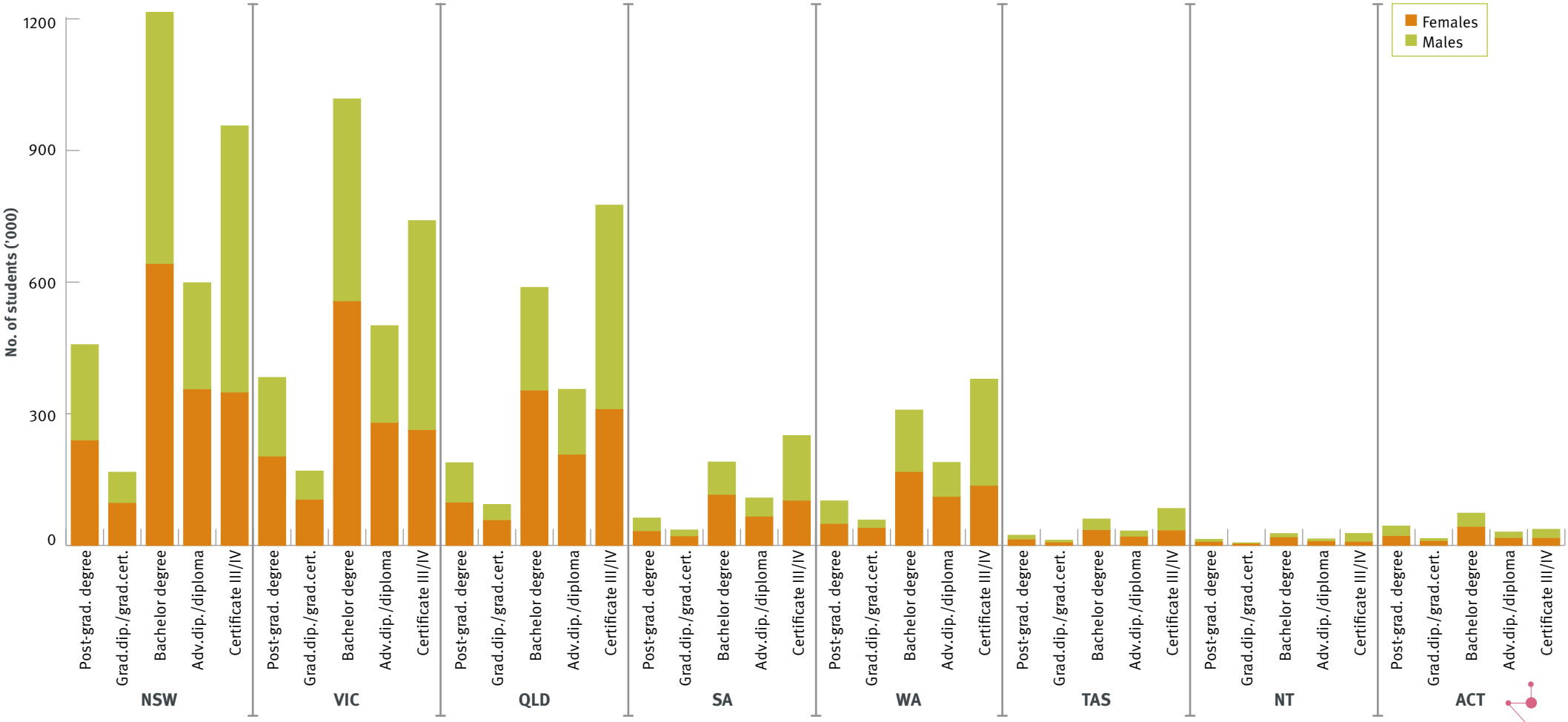
Australian education levels

QLD, WA and SA have the highest number of certificate-level qualifications as opposed to bachelor or higher university degrees. This is due to the industry strengths in those states around mining and manufacturing.

Moving to Industry 4.0 where growth will be in knowledge-based jobs and services, will require higher levels of education attainment and perhaps shift this trend.[26]

See Appendix 6 to compare by qualifications not state/territory.

Number of students with highest educational attainment by state/territory and gender



Utilisation of STEMM skills

The three commonly used measures of skills utilisation or the quality of graduate jobs are proportion of graduates:

- employed part-time/seeking more hours of work
- employed in managerial and professional occupations
- stating they believed their job did not allow them to fully utilise their skills or education.

In 2019, the highest number of graduates in part-time employment and seeking more hours were in the fields of Science and Mathematics (51.6% and 25.6%), and Agriculture and Environmental studies (31.3% and 19.4%). The main reasons for underemployment were: no more hours available in their current position; they were studying; or because there were no suitable jobs in their area of expertise.[32]

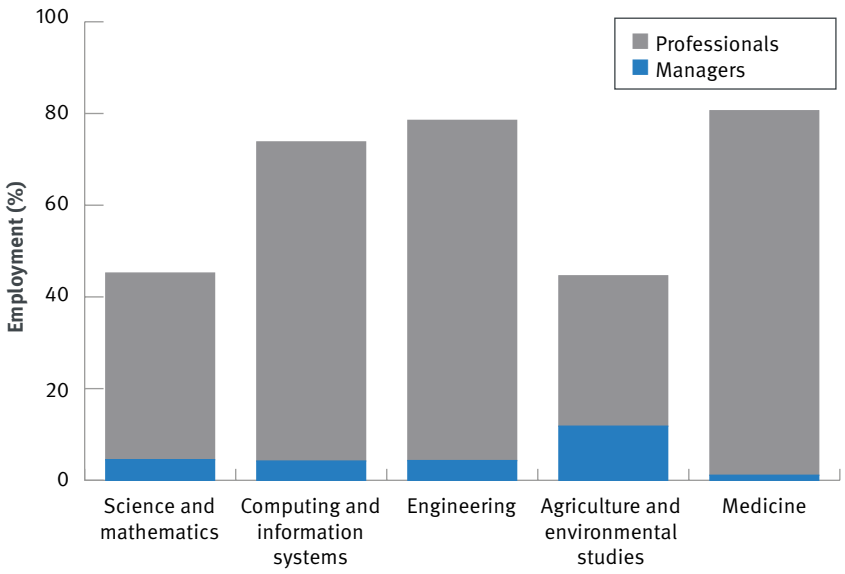
Hence, a higher percentage of undergraduates in these two subject areas are in further full-time study (39.5% and 17.3%).

Further, 38.7% of Science and Mathematics and 35.1% of Agriculture and Environmental studies undergraduates reported that their occupation did not fully utilise their skills and education. The primary reason given for this was being unable to find suitable jobs in their areas of expertise. Although the percentage of Science and Mathematics postgraduates is slightly better at 30.5% than undergraduates, almost 41% of Agriculture and Environmental studies post graduates do not have jobs in their area of expertise.[32]

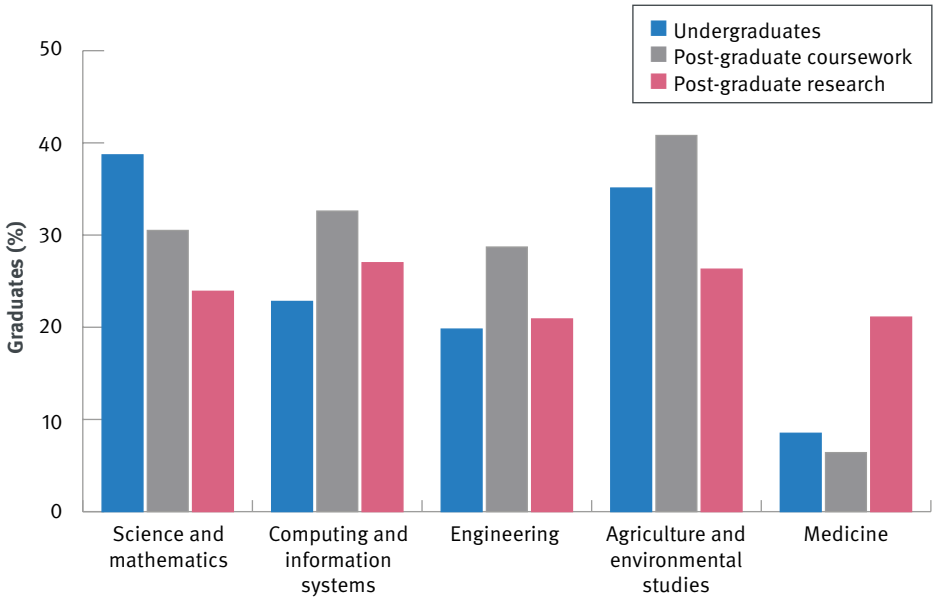
The proportion of undergraduates working in managerial and professional occupations is the highest for Engineering, and Computing and Information Systems graduates, while it is the lowest for Agriculture and Environmental studies, and Science and Mathematics graduates. Of all STEMM study areas, Agriculture and Environmental studies has the highest proportion of managers indicating that work experience as opposed to degree qualifications might be a key factor for employment in such areas of Science.[32]

Utilisation of STEMM skills

Undergraduates occupational level, total employed, by study area 2019



Graduates reporting occupation does not fully use skills and education, and main reason being no suitable jobs in their area of expertise, by study area



Workforce re-skilling

Global technology is changing at an unprecedented rate. This is creating challenges for industry and teaching institutions to forecast the required skills for these future industries.[57]

For example by 2024, Australia is predicted to need 100,000 more technology workers to meet market demand.[58]

The current graduate rate of Information Technology students is insufficient to meet the predicted demand. Re-skilling and skilled migration are anticipated to fill this gap.

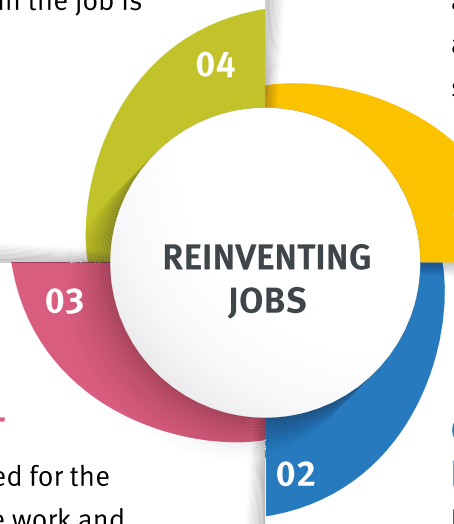
By 2030, it is predicted that all workers will spend 30% more time learning on the job to update and apply new knowledge, and analysing and interpreting information.[57]

In the US, the emergence of advanced biomanufacturing via precision fermentation to mass produce tailored food protein products is expected to disrupt 600,000 beef and dairy related jobs, while creating 700,000 biomanufacturing jobs by 2030.[59] This alternative protein technology is being developed in Australia, with CSIRO and a number of private organisations pioneering this space.[60]

Reinventing jobs

The World Economic Forum, in its Future of Jobs report, not only predicted strong employment growth in emerging sectors like AI, robotics and blockchain, but also in non-tech positions such as customer service, sales, marketing, training and skills development. Combined with employment growth in sectors like green technology (defined as being any form of scientific use of technology to help benefit and/or protect the environment), and consumer goods and services, this high level of job demand would more than offset any jobs replaced by automation.

A four-step approach to achieving the optimal combinations of humans and machines, and ensuring the continued relevance of the workforce[56]



DECONSTRUCT JOBS

Deconstruct jobs into their activities and classify the tasks so all the type of work in the job is now broken down.

REEVALUATE

Assess the best way to automate tasks and redeploy them by alternate means (technology and/or human-automation solutions).

RESKILL TALENT

Identify skills needed for the future version of the work and reskilling pathways for talent whose work is being transformed by automation.

OPTIMISE WORK AND RECONSTRUCT JOBS

Look at the activities collectively and reconstruct into (new) jobs where it makes sense, taking into account: the new means of accomplishing work, and what the new work distribution between talent and technology requires.

Current investment in STEM industry

In 2017–18 the Queensland Government invested $352.8 million into research and development, with 51% of this leveraged from non-Queensland Government organisations.[61]

During 2008 to 2012 the Queensland Government invested highly in science infrastructure such as the Translational Research Institute, QIMR Berghofer Medical Research Institute, Health and Food Sciences Precinct, and Ecosciences Precinct.[61]

These research institutes have produced world-leading scientific research and discoveries, established world-wide collaborations, orchestrated clinical trials, and participated in diverse community events, such as the World Science Festival Brisbane and National Science Week.

The Queensland Government continues to provide industry investment to develop solutions to Queensland's ongoing challenges with programs such as the Advance Queensland Industry Attraction Fund.

Boeing Australia Ltd launched its largest autonomous systems development program in 2018 with investment from the Advance Queensland Industry Attraction Fund, providing jobs and capital expenditure in the aerospace, advanced manufacturing, defence, and resources technology and services sectors.[62]

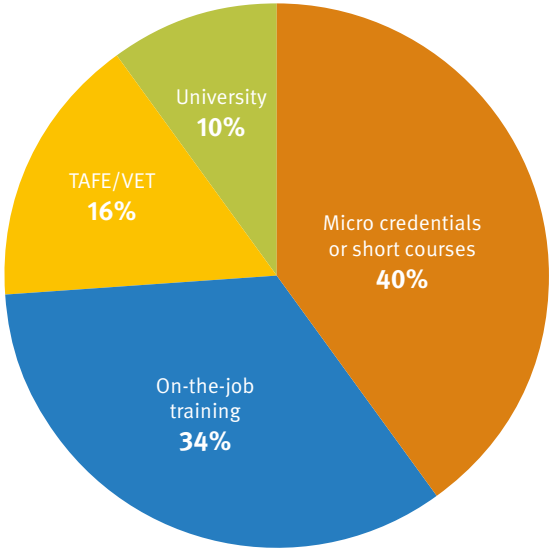
The **Advance Queensland Ignite Ideas Fund** supports Queensland-based startups and SMEs to commercialise innovative products, processes and services to strengthen key industries in Queensland; diversify the Queensland economy; compete in global markets; engage and/or benefit regional Queensland; and create new jobs.[63]

Supported by this fund, the KINDERGO platform aims to become the premier reading tool in educational facilities around Australia for children aged 2–7 years. KINDERGO provides a reader-driven experience using different modes of reading: Read to Me; Read Together; and Tap & Hear. Each book offers multiple levels of interaction, allowing children to improve their reading ability as they repeatedly read their favourite content. KINDERGO is already in the marketplace, including on Virgin Australia's inflight entertainment system.

Workforce re-skilling for Industry 4.0

Technological and societal transformation are creating new forces shaping the future of work. Integration of technology and automation is central to new business models across industries and there is greater need for companies to understand these shifts and disruptions in order to transform tasks for employees. As a result of task transformation, the skills required by the workforce will also change, requiring up-skilling and re-skilling of employees.

A recent survey showed that 34% of respondents believed that on the job training is required for up-skilling or re-skilling of the workforce to engage with Industry 4.0. While 40% believed that short courses should be used as a means of up-skilling or re-skilling, only 10% believed that employees should be up-skilled or re-skilled through traditional university qualifications. It is important that education and training is appropriately aligned to the concept of Industry 4.0 to enable smooth transitioning to the fourth industrial revolution.[50,56]



Survey responses to 'How should the workforce be upskilled to engage with Industry 4.0?'

Government's role in enabling innovation

Managing a successful transition to a new era of work will require significant and well-coordinated efforts by both the private and public sectors. It is critical that businesses take an active role in supporting their existing workforces through re-skilling and up-skilling. In addition, individuals should take a proactive approach to their own lifelong learning, and the government should assist in these efforts to enable a smooth transition and transformation. The public sector has several policy levers to help drive innovation.[64]

Provider: Create methodologies, laws and policies for private sector access to public sector data and databases that may be necessary or desirable for developing related innovations.

Funder: Increase funding for private sector experimentation and development with co-ownership or private sector proprietary access to any intellectual property rights (IPRs). Public sector support for this also includes encouraging IP development by permitting the private sector to retain the IPR.

Market creator: Push legislators to reduce barriers to entrepreneurship and calibrate regulation to the appropriate contexts. Numerous statutory and regulatory barriers discourage or prevent entrepreneurs from bringing innovations into new markets.

Facilitator: Drive governance reform and create common metrics for accountability and the adoption of common standards and assessments. Reform is needed to enable more of the public sector to experiment (for example, via accelerators).

Disseminator: Promote formal and informal networks of businesses, academia and entrepreneurs. In a more fluidly networked world, policy-makers and entrepreneurs should be able to converse in real time about what works, what doesn't work and the real challenges of implementation.

Technology supporter: Enhance technical assistance between the public and private sectors, with up-to-the-minute communication, data and feedback loops, to radically reshape innovation development.

Researcher: Public sector programs intended to promote external innovation may increase awareness and public support, but they need the right people, expertise and resources to be truly effective. Running internal programs for public sector employees can be a powerful tool for generating new ideas. It also helps ensure scrutiny for policies and practices that may no longer be relevant.

Organiser: Public sector bodies can create dedicated teams (across multiple public sector organisations) that are responsible for innovation. Such teams work to stimulate innovative thinking across government. A team works to bring user-focused innovation into the parent entities by observing the effects of their policies and programs on employees, businesses, consumers and markets. The team may also host projects that run in collaboration with universities and the private sector.

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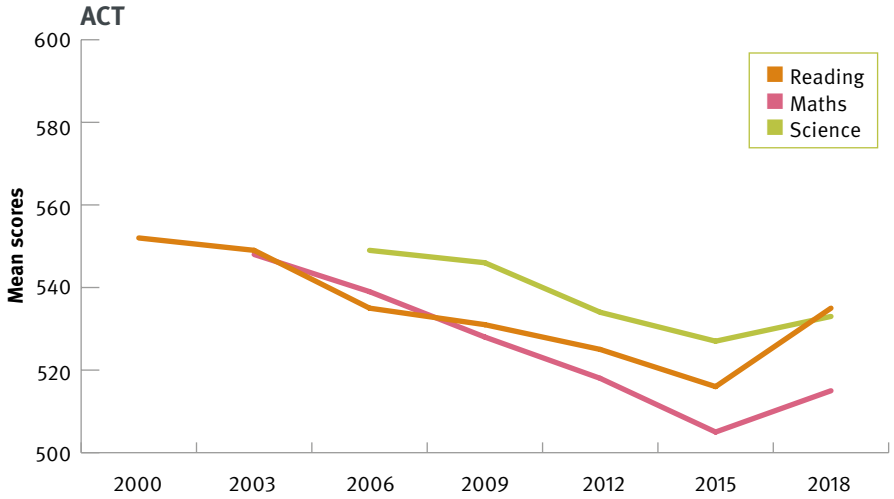
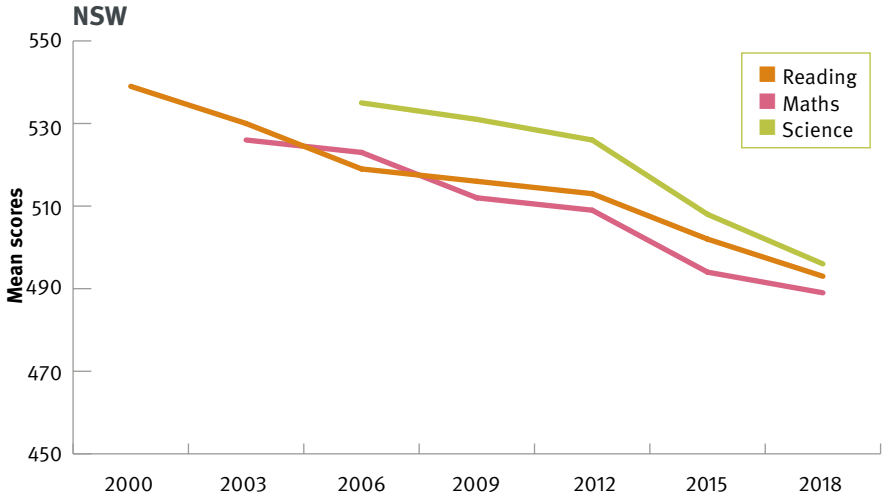
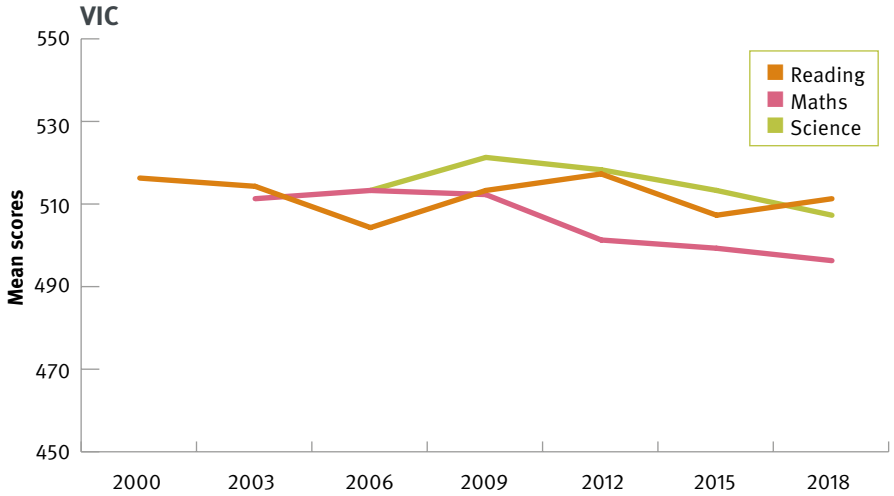
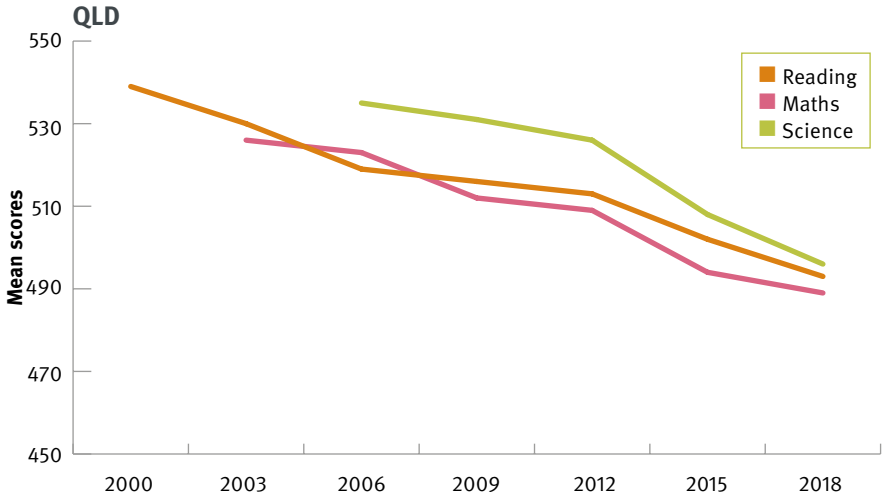
Appendix 1: Australian student performance in reading, maths and science

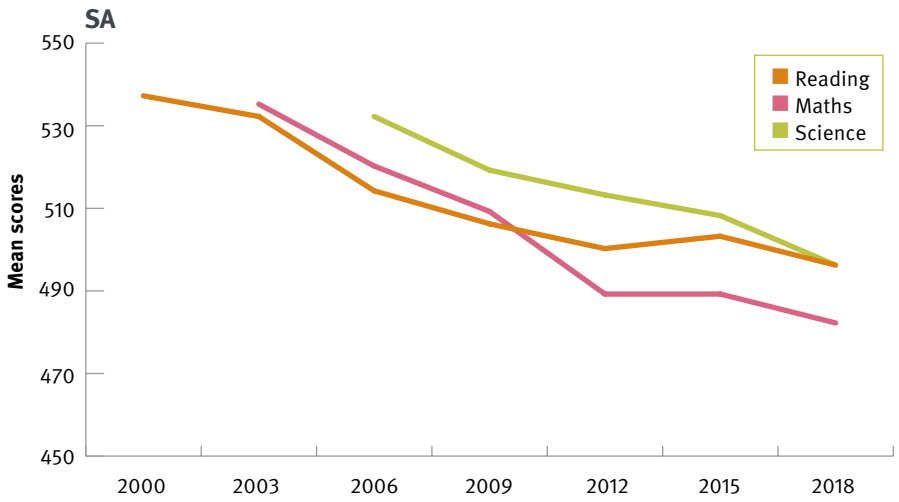


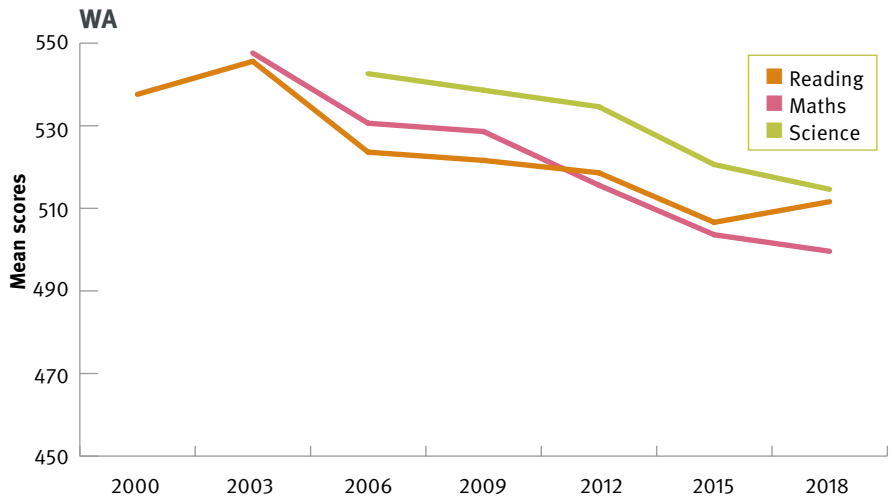


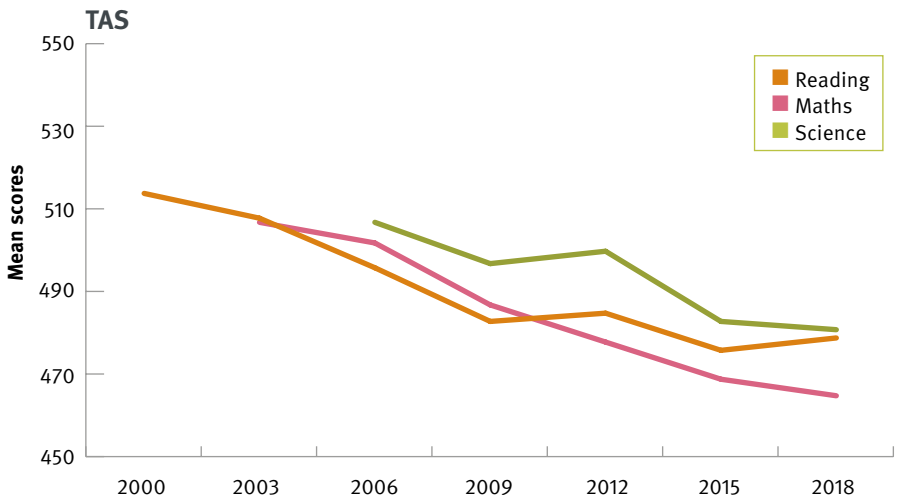




Appendix 1: Australian student performance in reading, maths and science

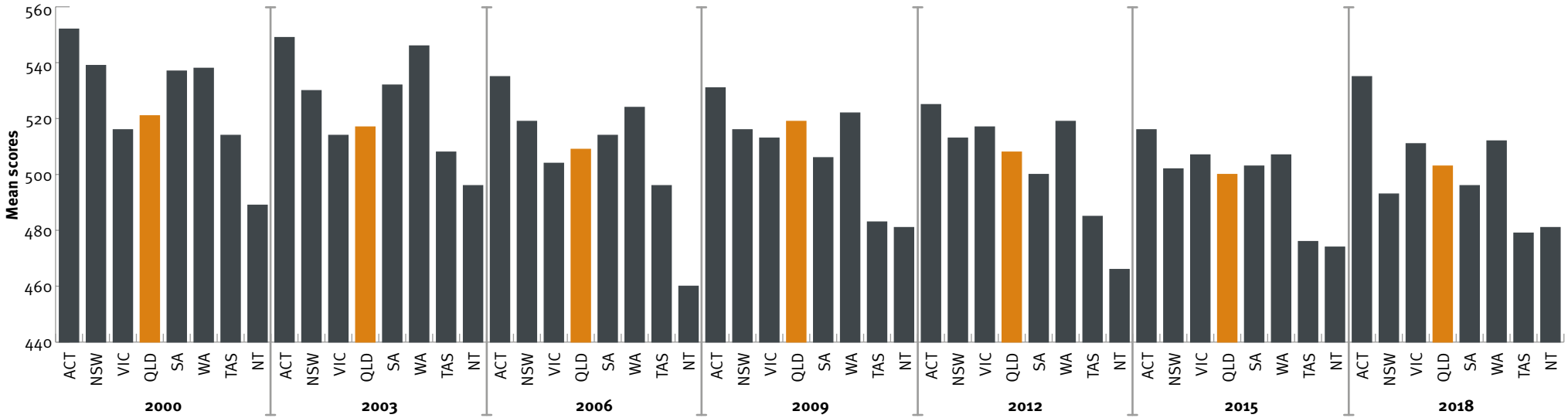




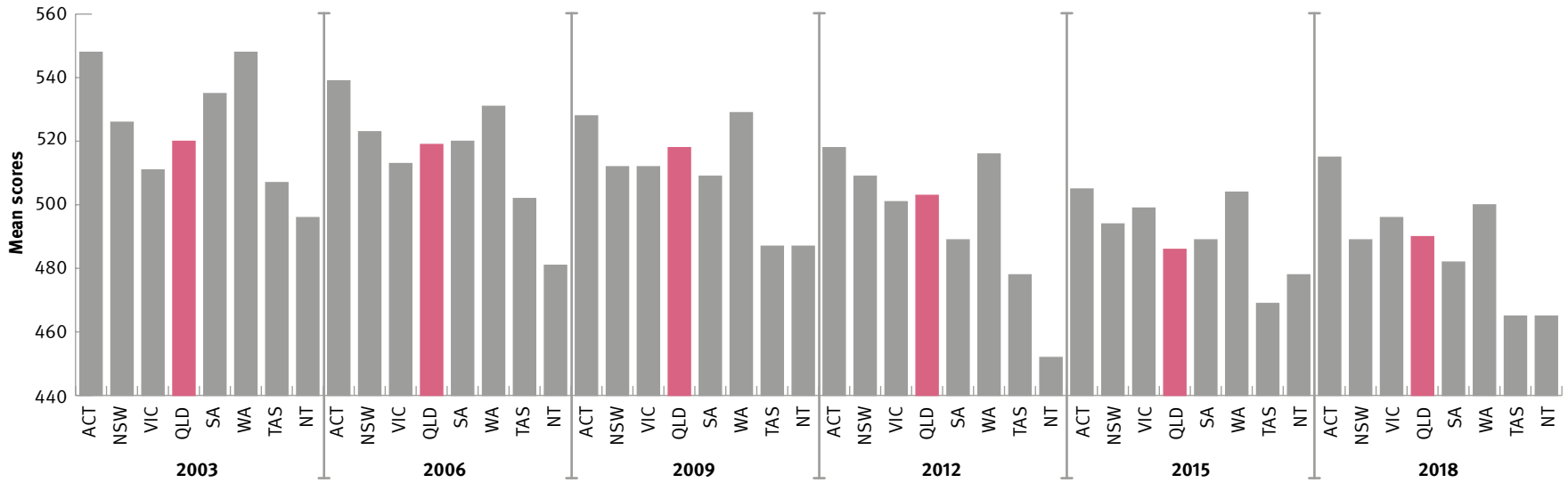


Appendix 2: Australian student performance in reading, maths and science

Reading



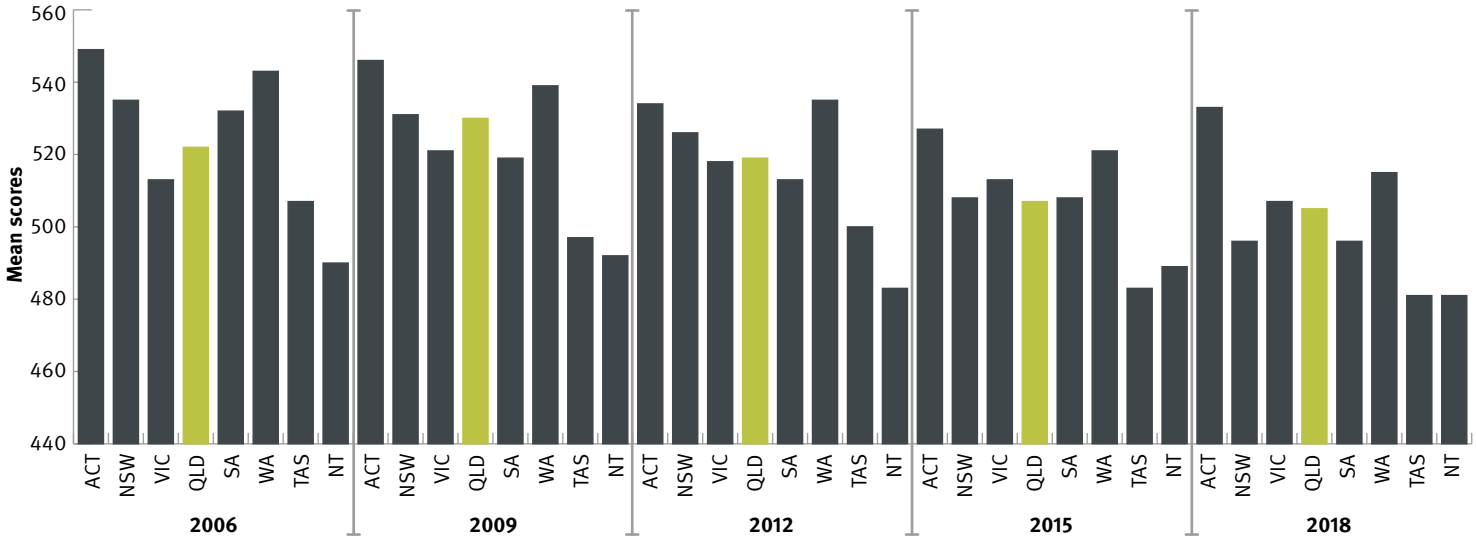
Maths*



* PISA data for maths only available from 2003.

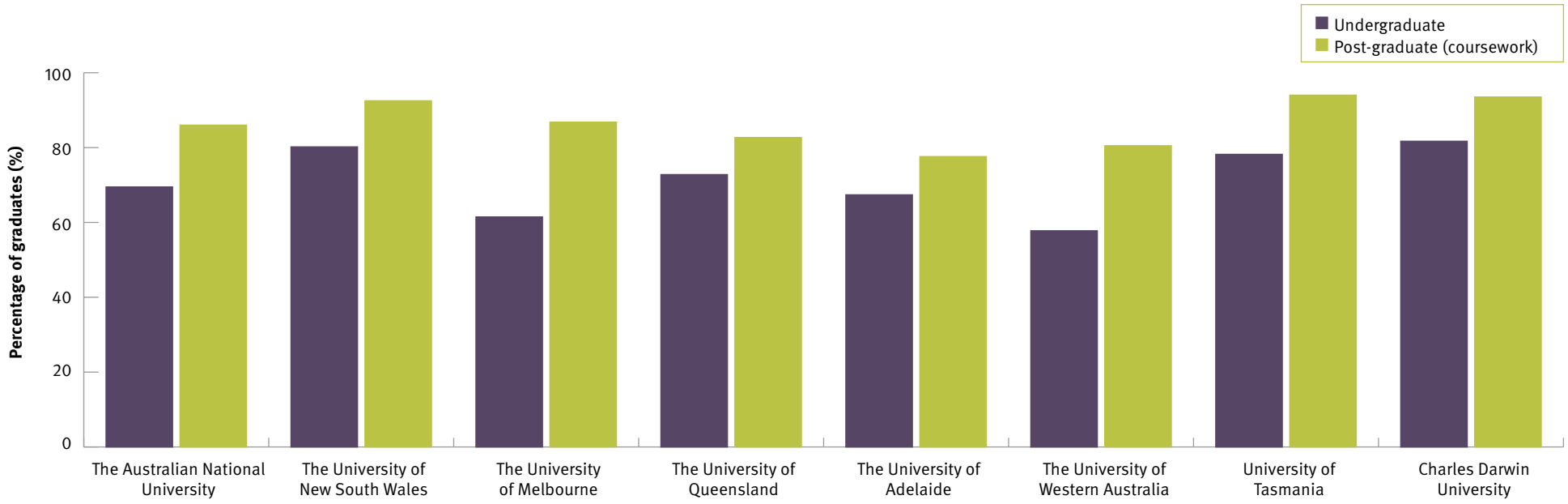
Appendix 2: Australian student performance in reading, maths and science

Science**



** PISA data for science only available from 2006.

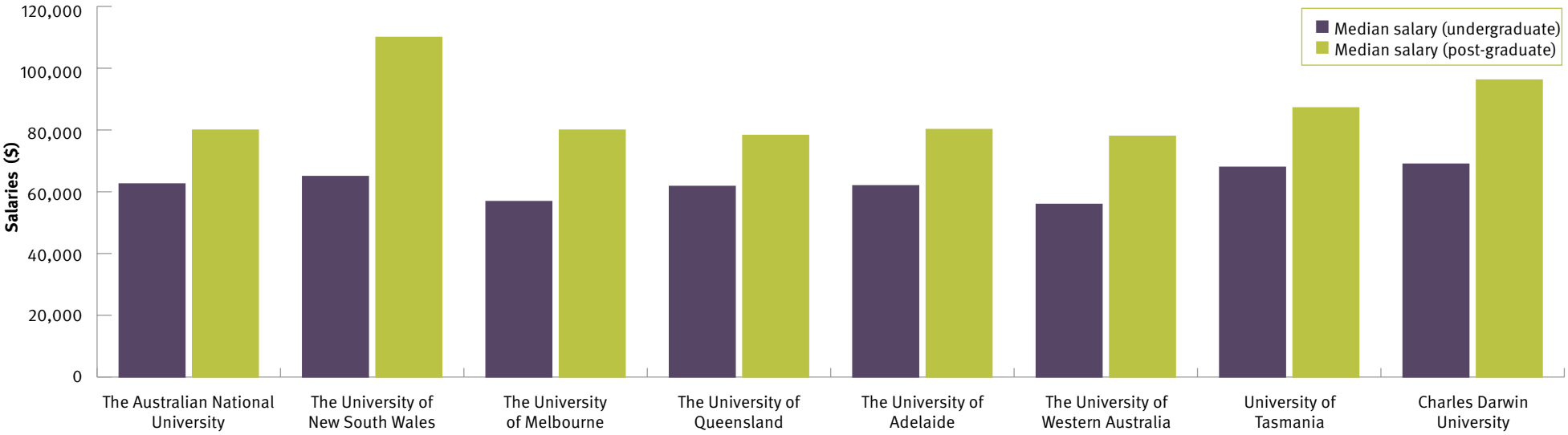
Appendix 3: Employment status of graduates from top Australian universities



Note: Top university based on criteria:

- being chartered, licensed or accredited by the appropriate Australian higher education-related organisation
- offering at least four-year undergraduate degrees (bachlor degrees) or post-graduate degrees (masters or doctoral degrees)
- delivering courses predominantly in a traditional, face-to-face, non-distance education format.

Appendix 4: Salaries by top Australian universities

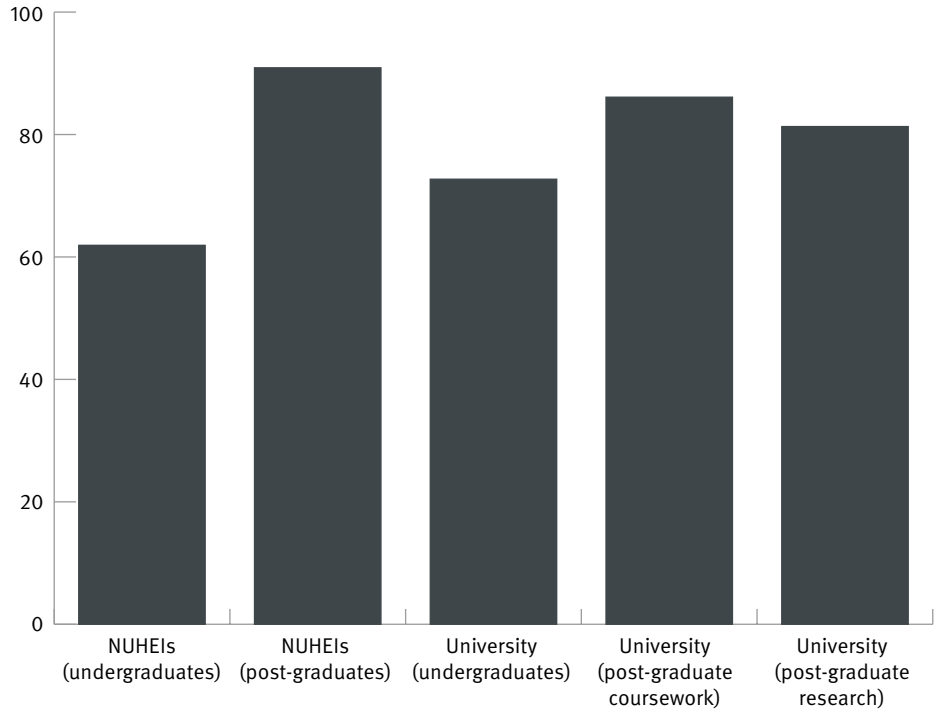


Note: Top university based on criteria:

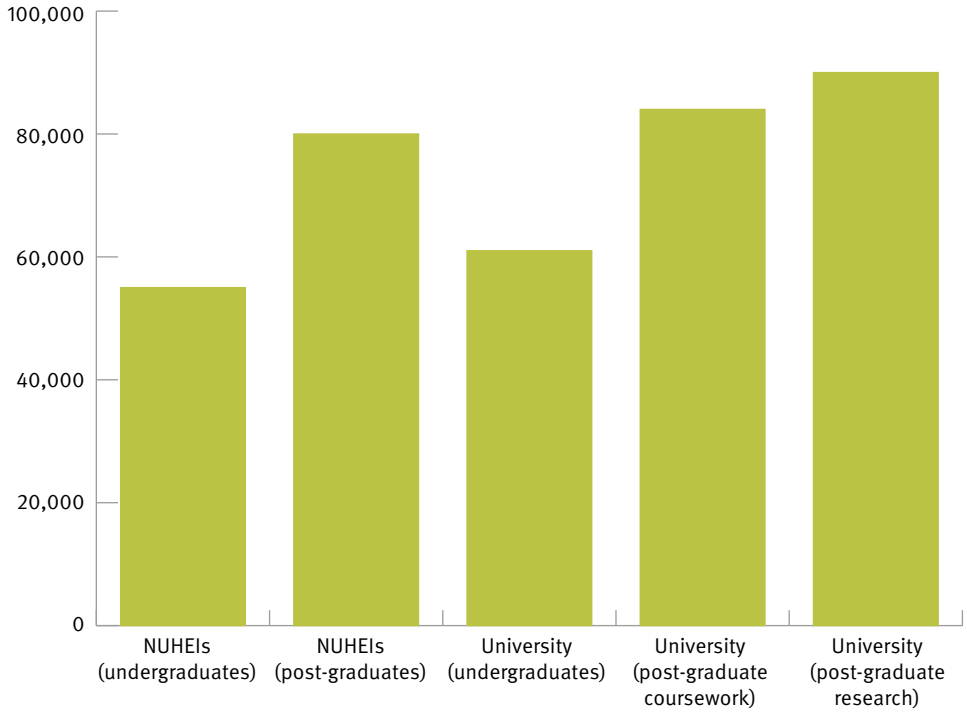
- being chartered, licensed or accredited by the appropriate Australian higher education-related organisation
- offering at least four-year undergraduate degrees (bachelor degrees) or post-graduate degrees (masters or doctoral degrees)
- delivering courses predominantly in a traditional, face-to-face, non-distance education format.

Appendix 5: Employment status and salaries of university graduates versus NUHEIs* graduates

Full-time employment (%)



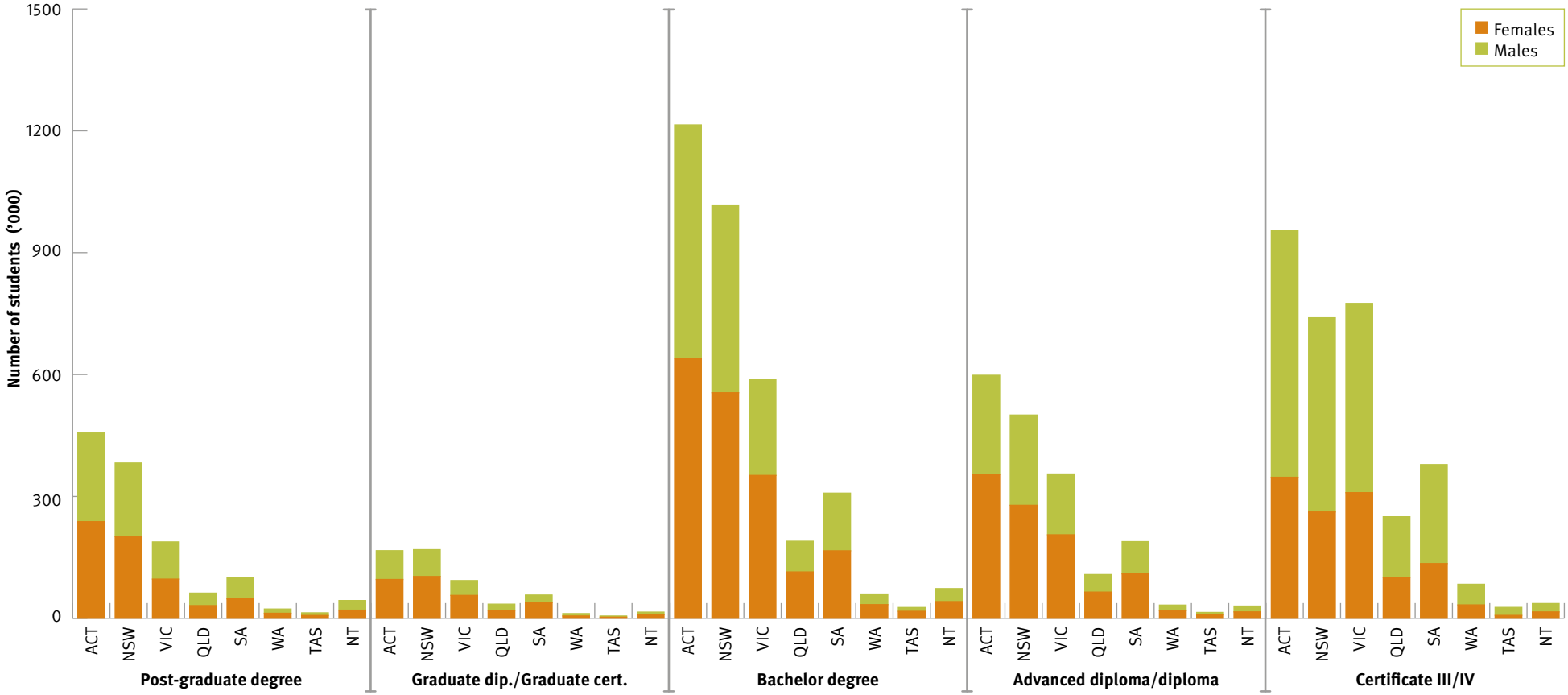
Median full-time salary ($)



* NUHEIs = Non-university higher education institutions

Appendix 6: Number of students with highest educational attainment

Highest educational attainment by state/territory and gender



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