THE STATE OF

MATHEMATICAL SCIENCES 2020

7th DISCIPLINE PROFILE OF MATHEMATICS AND STATISTICS IN AUSTRALIA

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

About **AMSI**

In high demand across all industry sectors, expertise in the mathematical sciences is central to powering Australia's STEM capability, enabling new technologies and innovation.

As Australia's only not-for-profit national voice and champion for mathematics and statistics, the Australian Mathematical Sciences Institute (AMSI) is working with schools, universities, industry, philanthropists, government and the community in shaping policy and skilling Australia for the future.

Building engagement and capability, AMSI is driving programs strengthening the mathematical disciplines—enhancing their impact and importance in Australian education, research, innovation and industry.

A collaboration of Australia's university mathematics departments, AMSI's influential and growing membership network comprises over 41 universities together with mathematics societies and government agencies.

Vision

That Australia values mathematics, and mathematical sciences propel Australia

Mission

Championing the mathematical sciences for Australia's advancement

Contents

Author: Maaike Wienk
Design: Michael Shaw

AMSI Members

Full Members

University of Adelaide
Australian National University
La Trobe University
University of Melbourne
Monash University
University of Newcastle
University of New South Wales
University of Queensland
Queensland University of Technology
RMIT University
University of Sydney
University of Western Australia

Associate Members

Curtin University
Deakin University
Edith Cowan University
Federation University Australia
Flinders University
Griffith University
James Cook University
Macquarie University
Murdoch University
University of New England
University of South Australia
University of Southern Queensland
Swinburne University of Technology
University of Tasmania
University of Technology, Sydney
Victoria University
Western Sydney University
University of Wollongong

Government Agencies

Australian Bureau of Statistics
Bureau of Meteorology
CSIRO
Defence Science and Technology Group
Reserve Bank of Australia

Societies

Australian Bioinformatics and Computational Biology Society (ABACBS)
Australian and New Zealand Industrial and Applied Mathematics (ANZIAM)
Australian Mathematical Society (AustMS)
Australian Mathematics Trust (AMT)
Mathematics Education Research Group of Australia (MERGA)
Statistical Society of Australia (SSA)

AMSI and its members acknowledge the significant contribution of the University of Melbourne as our Lead Agent and host

List of members as of March 2020.

Fundamental to social wellbeing and economic prosperity, the mathematical sciences are crucial to enhancing Australia's innovative and creative culture, global competitiveness, and the safety and health of its people.

The challenges of these historically significant times are intensifying the importance of mathematical sciences in sustaining the health and social wellbeing of the Australian people. Now, perhaps more than ever, it is evident how a thriving mathematical sciences discipline and the capability it provides is informing essential guidance to the ongoing work of government and the health sector, and enabling the nation's return to economic security and future prosperity.

This 2020 *State of Mathematical Sciences* is the seventh edition of AMSI's periodic discipline profile for mathematics and statistics, providing a detailed snapshot of the condition of the mathematical sciences at all stages of the continuum – from the classroom and higher education through to research and development, workforce utilisation and innovation by commerce and industry.

The data contained in this report is influential and highly valued in informing and validating policy, and in sustaining evidence-based analysis and debate by key stakeholders spanning academia, research, government and the business community.

For 2020, this publication brings together diverse information from many sources, complemented with AMSI research and the latest data from the 2018 PISA survey of academic performance in secondary schools. This edition also includes data on university prerequisites and the mathematical workforce sourced with the generous co-operation of the Office of Australia's Chief Scientist. We are also grateful to Australian mathematical sciences departments continuing to supply data through the annual AMSI university survey.

A key concern is the deepening of Australia's 'mathematics deficit' with the sustained decline in the proportion of the senior secondary school population pursuing calculus-based mathematics subjects. This ongoing issue is compounded by a high proportion of secondary school teachers possessing no methodology training in mathematics.

This year we have seen the brilliance of so many women in the sciences displayed in response to the global pandemic crisis. The use of mathematical modelling by epidemiologists and biomedical scientists has both informed governmental policy and societal response, and expanded exposure of this aspect of the mathematical sciences to new audiences. An undesirable paradox is that with only 7 percent of girls studying higher mathematics in Year 12 compared to a 12 percent figure for boys, gender imbalance in secondary school mathematics threatens to diminish the feasibility of a comparable contribution by future generations of female scientists in Australia. Entrenched socio-economic disadvantage also continues to hamper equitable outcomes in mathematical achievement.

With the current mathematical workforce ageing rapidly Australia needs to employ all efforts in exposing young people from all backgrounds and both genders to the power and beauty of mathematics, persuading more of them to make it their profession as teachers, researchers, or government and industry professionals.

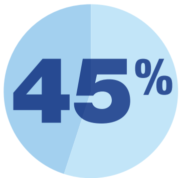
Timothy C Brown

Professor Tim Brown
Director

KEY INDICATORS

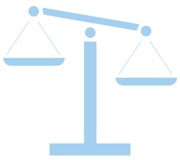
School Education

There is a shortage of qualified maths teachers in Australia's secondary schools



In 2018, 45 per cent of surveyed secondary school principals reported that there were maths and science classes taught at their school by a teacher not fully qualified in the subject area. Vacancies for maths teachers were the most difficult to fill, according to 49 per cent of school principals. **See pages 32–33**

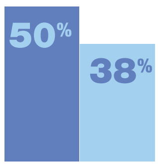
The inequality in the maths performance of school students has grown worse in the last 15 years



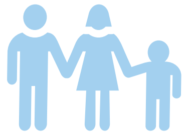
The proportion of Australian students performing poorly in maths has increased from 14 per cent to 22 per cent, while the proportion of students doing very well in maths has declined from 20 to 10 per cent. **See page 16**

Half of Australia's students in Year 8 dislike studying maths

This is significantly higher than the international average of 38 per cent of students. **See figure 1.23**



Disadvantaged students get left behind in maths



In 2018, the difference in mathematical literacy between 15-year old students from the most advantaged and most disadvantaged social, economic and cultural backgrounds was equivalent to almost three years of schooling. **See page 17**

Students prefer the basic maths subjects in Years 11 & 12 over more advanced maths subject options

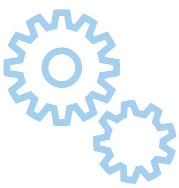
The proportion of students choosing calculus-based maths subjects in senior secondary school has declined sharply in the last twenty years. In every year of the last decade, fewer than 30 per cent of students chose intermediate or higher mathematics as their hardest maths subject in Year 12. **See pages 25–26**

Higher Education

Most universities **do not require intermediate or even basic maths** for entry into university degrees in science, IT, commerce, health professions, education or architecture

See page 30

Only 56% of engineering degrees require at least intermediate maths as a prerequisite for entry into the course

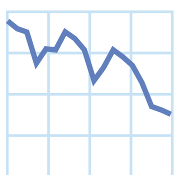


See page 30

Some universities **do not offer a major in the mathematical sciences**

See page 41

The numbers of students pursuing maths degrees are not growing in line with the substantial growth of university student numbers in other fields of education

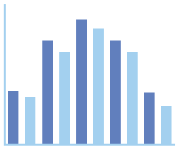


See pages 45 & 47

Workforce

In Australia, around 33,000 people have a qualification in the mathematical sciences

Most of them (66 per cent) have a bachelor degree, and around 30 per cent hold a postgraduate degree. This represents only 0.7 per cent of all people with a university degree. **See page 54**



A rapidly ageing mathematical workforce

In 2016, 17 per cent of people with a mathematical sciences qualification was 65 or older, up from 7 per cent in 2006. Labour force participation declined from 75 per cent in 2011 to 71 per cent in 2016. **See page 54**

Employment prospects for newly graduated mathematical scientists with an undergraduate degree is around the average for all new graduates

About 73 per cent of new bachelors find full time work within 4 months after completing their degree. **See page 59**

The top three occupations for mathematical scientists in 2016

- Secondary school teachers
- Software & applications programmers
- University lecturers & tutors

See page 61

But the largest employment growth for mathematical scientists can be found in other professional occupations.

There has been increased demand for actuaries, statisticians and mathematicians, management and organisational analysts and professionals in “new” jobs such as data science. **See table 3.13**

Research

Since 2011, **the mathematical sciences have had a higher average success rate for research grants** from the Australian Research Council than other STEM disciplines

See page 66

The mathematical sciences **produce between 2 and 3 per cent of Australia’s research output**

See page 71

The **mathematical research disciplines** participating in the Excellence in Research Australia (ERA) are all deemed to be at world standard, **with the vast majority above, or well above world standard**

See pages 72–73

FEMALE PARTICIPATION IN MATHS: BRIDGING THE DIVIDE

Promoting equity and diversity in the mathematical sciences, including for women and girls, remains a key AMSI priority as we seek to secure Australia's mathematical capability and capacity to support a prosperous future. Addressing the gender imbalance is critical to ensure skills supply can meet industry needs. Increased female participation is also a priority to prevent contraction of the mathematical workforce through ageing.

At the moment Australian men appear to be outperforming women at every life stage. The gap in adult numeracy is smallest in the younger age bands of 15-19 years and 20–24 years, but starts to increase in the 24–34 age band—**see figure 3.3**

This feature provides a snapshot of female participation across Australia's mathematical pipeline from the classroom and higher education to research and the workforce. Links to fuller reporting in key sections of the Discipline Profile are provided.

School Education

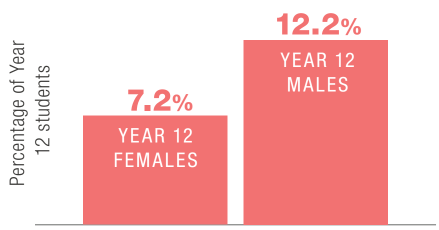
According to the 2018 NAPLAN data the percentage of Year 9 students reaching the national minimum standard in numeracy has remained largely static, with 95.9 per cent of girls at or above the minimum standard against 95.1 per cent of boys. However, in the higher achievement levels there is a persistent gender gap. **Representation at the second-highest level, band 9, was just 15.7 per cent for girls and 18 per cent for boys,** falling to **10.5 per cent for boys and just 7.2 per cent for girls in the highest achievement level,** band 10.

Further analysis of NAPLAN data confirms that girls are behind in the highest available band in every year level. That is, band 6 and above for Year 3, band 8 and above for year 5, and band 9 and above for Year 7. These figures suggest that girls do not excel in maths as often as boys. **See page 18**

These figures do not suggest there an innate difference between boys and girls. Trends in International Mathematics and Science (TIMSS) and the Programme for International Student Assessment (PISA) confirm there is a narrow gap between the mathematical achievement of boys and girls. However, comparatively girls outperform boys in literacy by a much larger margin. Other factors related to socio-economic circumstances substantially outweigh gender in their impact on numeracy performance. **See pages 16–17**

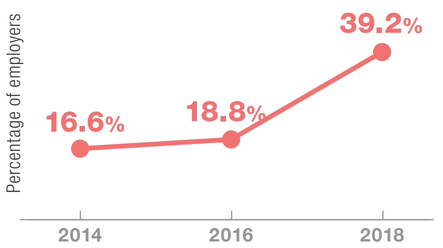
However, girls are less invested in choosing mathematics. Perhaps most concerning is the report card for Year 12 participation in mathematics, which threatens capacity to build the STEM workforce for the future. In 2018, only 7.2 per cent of female Year 12 students took higher maths compared to 12.2 per cent of male students. **See pages 26 & 28**

Year 12 *higher* mathematics students in 2018



Figures reproduced from figure 1.27, Percentage of students studying higher mathematics by gender

Difficulty recruiting STEM skilled empolyees



Figures reproduced from figure 3.11, Employers reporting difficulties recruiting employees with STEM skills

Higher Education

The gender imbalance is continued at university level. In 2018, female students accounted for an estimated 38 per cent of undergraduate mathematics students, consisting of about 26 per cent domestic and 12 per cent international female students. **See page 43**

Annual enrolment percentages for domestic female students in the mathematical sciences have not increased since 2012. **See Page 43**

The proportion of women completing Bachelor (Honours) degrees in the mathematical sciences has declined to below 25 per cent on average in the last decade, compared to over 30 per cent in the 1990s. **See page 44**

In the 2018 Bachelor (Honours) student cohort, 28 per cent of enrolled students were female, with 16 per cent domestic, and 12 per cent international students. **See page 45**

The news is not all bad, with growth in the number of PhDs in mathematical sciences completed by women over the past 15 years. Since the beginning of this century the proportion of female students completing a PhD has increased from approximately 25 per cent to around 35 per cent. This is largely attributable to a rising influx of international students — domestic female participation in PhD programs in the mathematical sciences has remained largely stagnant. **See pages 46–47**

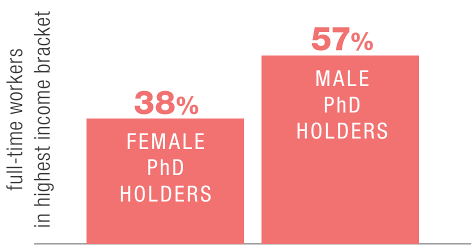
Workforce

Women accounted for 43 per cent of the population between 20 and 64 with a mathematical sciences qualification, up from 39 per cent in 2006. Among the youngest cohorts the gender balance tends to be more even. **See page 56**.

Gender distribution across the mathematical sciences differs between employment divisions and occupations. Female mathematical scientists outnumber men within the Healthcare and Social Assistance sectors. The proportion of women in the Education and Training sector was 46 per cent, and in Finance and Insurance Services around 36 per cent. The proportion in Professional, Scientific and Technical services drops to approximately 30 per cent. While gender balance is even for secondary school teachers, female representation among university lecturers and tutors is significantly lower. **See pages 56–57**.

The academic mathematical workforce remains predominantly male, with only 20 per cent of reported academic research staff (excluding casuals) female. This is one of the lowest percentages of women in any academic discipline. However, some universities have made concerted efforts to increase female staff levels in the mathematical sciences over the last few years. **See pages 37–38**.

Incomes of Mathematical Sciences graduates



Figures reproduced from figure 3.10, Personal annual income of Mathematical Sciences graduates working full-time and part-time, by field, gender and level of qualification

Employment structure also differs with approximately 37 per cent of women with a bachelor degree working part time compared to 21 per cent of men. At the doctorate level, 27 per cent of women with a PhD work part time compared to 19 per cent of men with a PhD. The lower and middle-income brackets have the highest representation of part time employment. Of full-time employees, 37 per cent of men versus 19 per cent of women earn an income in the highest income bracket. Of the doctorate degree holders 57 per cent of men and 38 per cent of women are represented in the highest income brackets. **See page 57**

INDIGENOUS AND REGIONAL ENGAGEMENT: TACKLING SOCIO-ECONOMIC DISADVANTAGE

Addressing entrenched inequality across Australia's education system is critical to securing Australia's future mathematical capability and capacity. This requires a coordinated approach to lift standards and close the gap for disadvantaged, regional and indigenous students. Importantly, with many industries in regional areas dependent on STEM, the achievement gap threatens future economic stability and skills supply across regional growth areas.

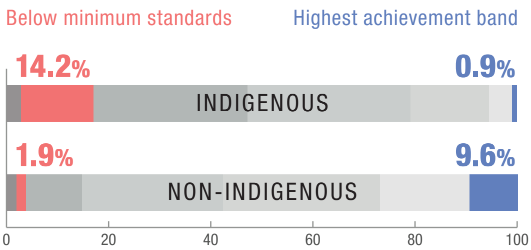
To enhance the mathematical skills of the future workforce, Australia cannot rely on a small minority of well-resourced, high-performing metropolitan schools. Critically, addressing educational disadvantage across the board should enable the creation of a much broader pool of mathematically highly capable students—which Australia will need to, for example, battle current teacher shortages and decrease out-of-field teaching.

The following provides a snapshot of mathematics participation from the classroom to higher education and beyond across regional Australia, low SES schools and Australia's indigenous population.

School Education

The mathematical capability gap between Australia's indigenous and non-indigenous population remains wide. The 2018 NAPLAN data reveal that 17 per cent of Year 9 indigenous students failed to achieve minimum numeracy standards (with results below band 6), compared to only 3.7 per cent of non-indigenous students. While indigenous students in major cities and inner-regional areas tend to perform better than those in remote communities, the gap is still significant. In the highest achievement bands percentages of indigenous students are very low with only 0.9 per cent of indigenous students reaching the highest achievement band 10 compared to 9.4 per cent of non-indigenous students. **See page 17**

Year 9 numeracy 2018 by Indigenous status



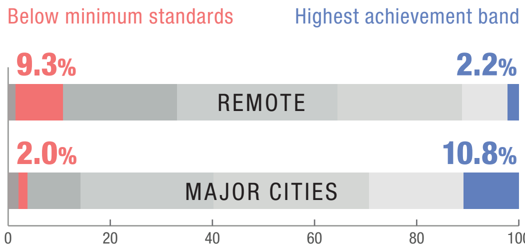
Figures reproduced from table 1.9, Year 9 numeracy in 2018 by Indigenous status, page 17

Nevertheless, some progress has been made in the period 2008–2017. Compared to 2008, the proportions of Indigenous students reaching the minimum standard or above for numeracy were slightly higher in 2017 for Years 5 and 9. In the period 2006 to 2016, Year 12 attainment among Indigenous 20-24-year-olds has also increased, from 47 per cent in 2006 to 65 per cent in 2016, including in remote and very remote areas. **See figure 1.10, page 18**

Students in metropolitan areas are achieving better results in mathematics than their counterparts in provincial and remote areas. The 2018 NAPLAN results revealed that 10.7 per cent of students in remote regions were below minimum standards (with results below band 6). This figure soared to nearly 35 per cent in very remote areas. The number of students in the highest achievement bands is vastly lower in remote and very remote areas than in major cities and inner regional schools. Only 1 per cent of students in very remote areas achieved the highest achievement band 10, climbing to 2.2 per cent in remote areas. This compares to 10.8 per cent of students in major cities. **See pages 20-21**

Students with similar capabilities might have different learning outcomes depending on where they go to school

Year 9 numeracy 2018 by geolocation



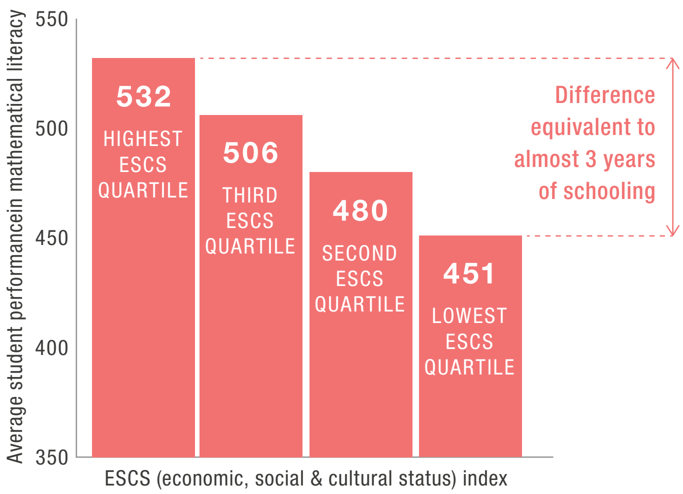
Figures reproduced from table 1.17, Year 9 numeracy in 2018 by geolocation, page 21

In Australia, there are significant differences in mathematical literacy performance between students from the four quartiles on the economic, social and cultural status index (ESCS). In 2018, the difference between students from the highest and lowest quartiles was 81 points, which is equivalent to almost three years of schooling. **See page 17**

Students with similar capabilities might have different learning outcomes depending on where they go to school: Students who go to socio-economically disadvantaged schools tend to make less progress than students in advantaged schools. Students in disadvantaged schools who score high on numeracy in Year 3 end up making on average two years and five months less progress by Year 9 than similarly capable students in high advantage schools. **See page 19-20**

Generally speaking, students in moderately advantaged schools tend to make more than 2 years' worth of learning progress in the two-year periods between NAPLAN tests, while students in moderately disadvantaged schools are likely to make far less. Students should be making one year's worth of learning progress every year, but only students in more advantaged schools tend to reach that goal. **See page 19-20**

Differences in mathematical performance by socio-economic background



Figures reproduced from figure 1.7, Average student performance in mathematical literacy, by socio-economic background, page 17

Teacher supply

Regional and remote schools are the most likely to experience substantial out-of-field teaching. In 2018, 45 per cent of Australian secondary school principals surveyed reported that there were maths and science classes taught by not fully qualified teachers at their school. The differences between states were very substantial, with no less than 63 per cent of principals surveyed from Western Australia, and 68 per cent of principals from Queensland reporting maths and science classes taught by not fully qualified teachers. Secondary school principals also reported that vacancies in the curriculum areas of maths (49 per cent), technology (42 per cent) and science (31 per cent) were the most difficult to fill. **See figure 1.36, page 33**

There is a shortage of qualified maths teachers in Australia's secondary schools

In 2018, **45%** of surveyed secondary school principals reported that there were maths and science classes taught at their school by a teacher not fully qualified in the subject area. Vacancies for maths teachers were the most difficult to fill, according to **49%** of school principals. **See pages 32–33**

The inequality in the maths performance of school students has grown worse in the last 15 years

The proportion of Australian students performing poorly in maths has increased from **14%** to **22%**, while the proportion of students doing very well in maths has declined from **20%** to **10%**. **See page 16**

Half of Australia's students in Year 8 dislike studying maths

This is significantly higher than the international average of **38%** of students. **See figure 1.23**

Disadvantaged students get left behind in maths

In 2018, the difference in mathematical literacy between 15-year old students from the most advantaged and most disadvantaged social, economic and cultural backgrounds was equivalent to almost **3 years** of schooling. **See page 17**

Students prefer the basic maths subjects in Years 11 & 12 over more advanced maths subject options

The proportion of students choosing calculus-based maths subjects in senior secondary school has declined sharply in the last twenty years. In every year of the last decade, fewer than **30%** of students chose intermediate or higher mathematics as their hardest maths subject in Year 12. **See pages 25–26**

1 SCHOOL EDUCATION

STUDENT PERFORMANCE, PARTICIPATION RATES AND THE TEACHING OF MATHS IN SCHOOLS

In Australia, the mathematical performance of students, measured by NAPLAN, has remained stable for some time. However, mathematical literacy, measured by the international PISA survey, has declined. According to both the PISA and TIMMS international surveys other countries have overtaken Australia and its international ranking has been in decline.

Moreover, within the school population the difference between low performing and high performing students has increased. Some students starting off at a disadvantage may never catch up, falling further behind during their schooling years.

Like some other Western democracies, Australia experiences a shortage of specifically trained mathematics teachers. A high proportion of secondary school teachers, particularly in Years 7–10, have no methodology training in mathematics, and vacancies for mathematics teachers are difficult to fill, making out-of-field-teaching a necessity for many schools.

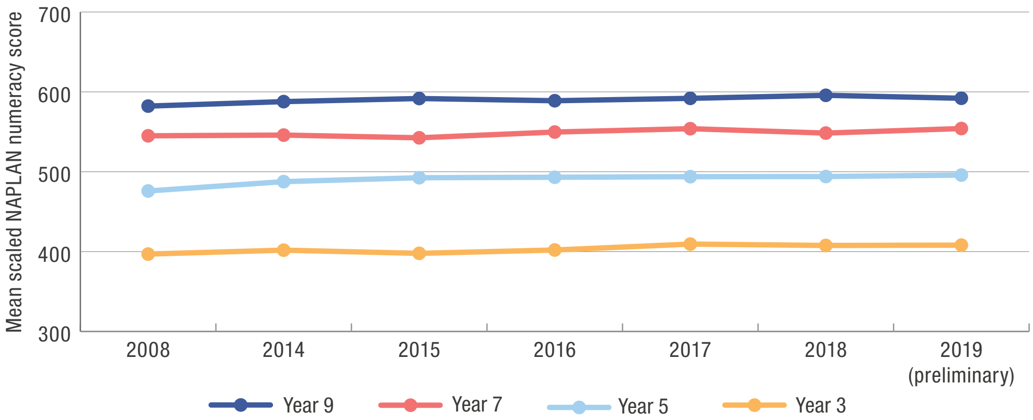
Nevertheless, the vast majority of students choose to take mathematics in senior secondary school, albeit that the proportions of students choosing higher or intermediate mathematics as their most advanced mathematics subject have declined in the last two decades.

Many universities do not require intermediate or higher mathematics to enter science, business or engineering degrees. The proportion of girls taking higher mathematics in Year 12 is about 7 per cent, against 12 per cent of boys.

1.1 Student performance in numeracy and mathematics

NAPLAN national reports show overall student performance in numeracy has not changed over the past twelve years. Figure 1.1 shows the NAPLAN numeracy achievement by year; the mean numeracy score is in the upper band and the percentage of students scoring at, or above, the national minimum standard is in the lower band of the table. Between 2018 and 2019 the scores show no statistically significant difference (note for 2019 only preliminary results were available at time of writing). The Year 5 results indicate a modest increase in the mean numeracy achievement in 2019 compared to 2008, but otherwise there has been no meaningful movement either up or down.

Figure 1.1 NAPLAN: Achievement of students in numeracy, 2008, 2014–2019 (preliminary)



Students		2008	2014	2015	2016	2017	2018	2019 (preliminary)	Nature of difference 2008 vs 2019	Nature of difference 2018 vs 2019
Year 9	Mean	582.2	587.8	591.7	588.9	591.9	595.7	592	■	■
	(S.D)	(70.2)	(70.9)	(67.8)	(66.8)	(63.5)	(66.3)	(64.1)		
	% at or above NMS	93.6	94.1	95.7	95.2	95.8	95.5	96.3	n/a	n/a
Year 7	Mean	545.0	545.9	542.5	549.7	553.9	548.4	554.1	■	■
	(S.D)	(73.2)	(73.0)	(68.6)	(70.4)	(71.1)	(69.1)	(75.7)		
	% at or above NMS	95.4	95.1	95.9	95.5	95.4	95.6	94.7	n/a	n/a
Year 5	Mean	475.9	487.6	492.5	493.1	493.8	494.0	495.8	△	■
	(S.D)	(68.8)	(69.0)	(68.0)	(70.6)	(65.5)	(65.4)	(67.1)		
	% at or above NMS	92.7	93.5	95.1	94.3	95.4	95.7	95.6	n/a	n/a
Year 3	Mean	396.9	401.8	397.8	402.0	409.4	407.7	408.1	■	■
	(S.D)	(70.4)	(73.0)	(74.3)	(73.4)	(73.9)	(71.6)	(74.1)		
	% at or above NMS	95.0	94.6	94.4	95.5	95.4	95.8	95.7	n/a	n/a

Notes: *NMS: national minimum standard.*
△ indicates statistically significant increase when compared to the base year or previous year.
■ indicates no statistically significant difference when compared to the base year or previous year.
Mean scaled score: Average score on a common scale (for NAPLAN this scale ranges from 0-1,000).

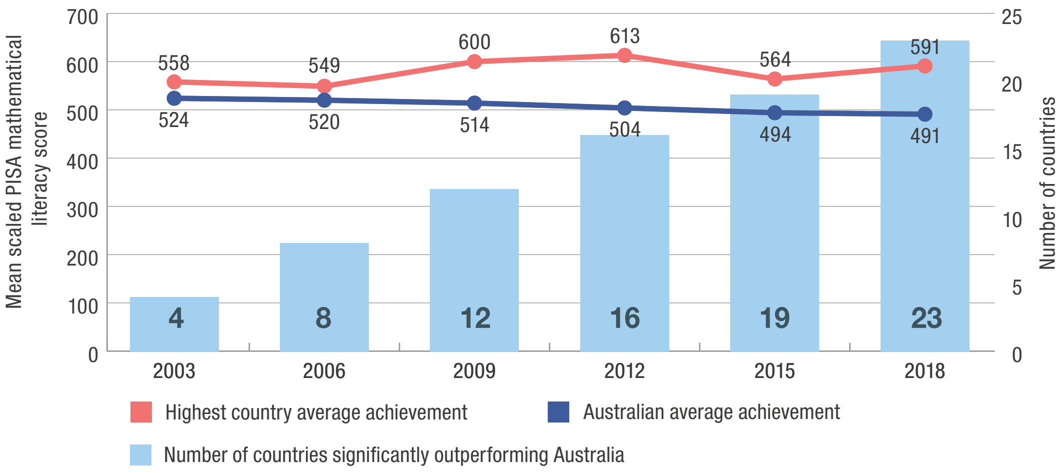
Source: *ACARA (2018), Table and Figure TS.N1, page 279; ACARA (2019), NAPLAN 2019 preliminary results.*

This trend is echoed in the results of international surveys of student performance in mathematics. PISA, the most recent major international survey administered in 2018, assesses mathematical literacy with a focus on application of the essential skills and knowledge of 15-year-old students to participate in society. The PISA results of Australian students in the period 2003–2018 indicate that:

- the Australian average mathematical literacy performance has declined in absolute terms over this period
- a gap has opened between the Australian mean score and the highest mean country score since 2009
- the number of countries that significantly outperform Australia has steadily increased between 2003 and 2018 (Figure 1.2)

In total, the average performance by Australian students in the PISA survey declined by 33 percentage points (or about one year of schooling) since 2003, the biggest decline after Finland. In the most recent PISA survey an additional four countries—the United Kingdom, Austria, the Czech Republic and Sweden—surpassed Australia. For the first time since PISA testing of mathematical literacy began Australia did not score higher than the OECD average.

Figure 1.2 PISA: comparative mathematical literacy of Australian 15-year-old students 2003–2018

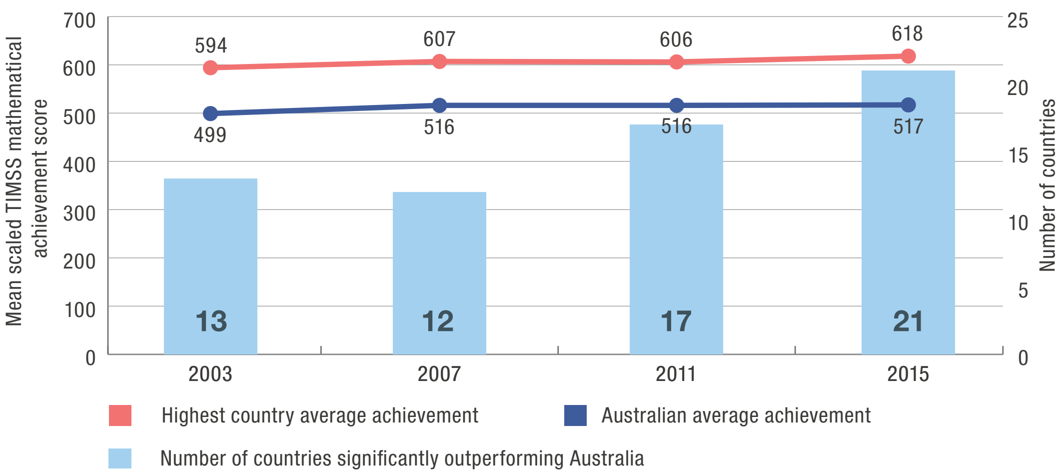


Source: *OECD (2019), Selected data from PISA 2003, 2006, 2009, 2012, 2015, and 2018.*

The 2015 TIMSS results showed that between 2003 and 2015, the educational achievement of Australian students in Year 4 remained steady after a slight increase in 2007. For Year 8 students, the achievement in 2015 was the same as in 2003 (despite a dip in 2007). The average achievement of Australian students did not move closer to the highest country average achievement. In fact, while Australian achievement remained stable, the number of countries surpassing Australia increased (Figure 1.3 and 1.4).

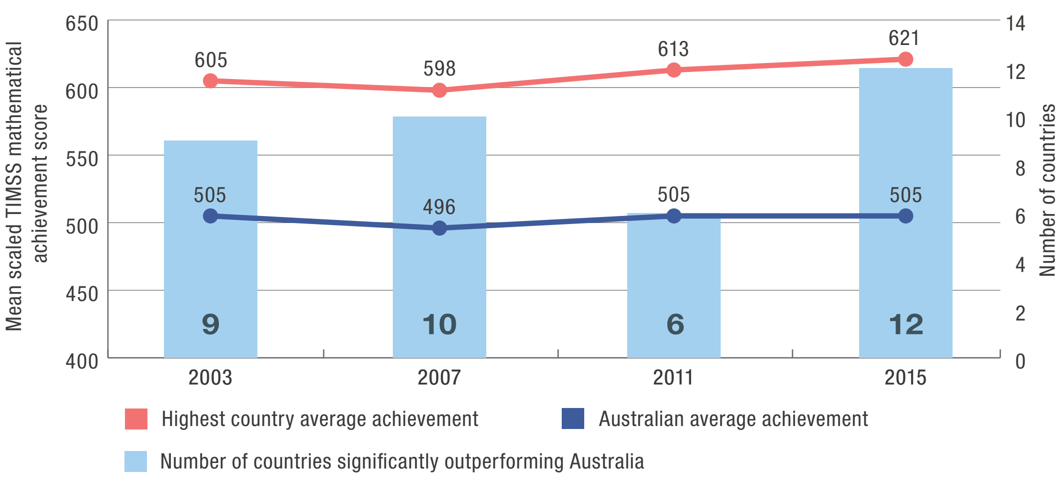
In both the TIMSS and PISA surveys, countries in South-East Asia (Republic of Korea, parts of China, Singapore and Japan) are the consistent top performers. Other countries out-performing Australia in the most recent TIMSS and PISA surveys include Canada, Ireland, and Slovenia.

Figure 1.3 TIMSS: comparative achievement of Australian students in maths in Year 4 2003–2015



Source: *TIMSS (2015), Selected data from TIMSS 2003, 2007, 2011 and 2015. Note: Countries are free to choose if they participate in either the Year 4, Year 8, or both surveys. In 2015, 49 countries participated in the Year 4 survey and 39 in the Year 8 survey. Of the 21 countries ranking higher than Australia for Year 4, ten did not participate in the Year 8 survey—it would therefore be incorrect to conclude that the higher ranking for Year 8 is an indication of a relatively better performance than for Year 4.*

Figure 1.4 TIMSS: comparative achievement of Australian students in maths in Year 8 2003–2015



1.2 Distribution of mathematical achievement

The persistent, and in some aspects deepening performance inequality amongst Australian students is of great concern, both socially and economically.

There are large gaps between high and low performers when comparing students from different socio-economic backgrounds.

Australia cannot successfully compete in a world increasingly reliant on skill in mathematical sciences if a considerable proportion of its population lacks the necessary basics.

The Australian PISA survey results in the period 2003–2018 showed a decrease in students performing very well in mathematical literacy, and an increase of students performing poorly. While in 2003 Australia was doing significantly better than the OECD average on both counts, low performance rose, and high performance declined in the period to 2018. In 2018, both high and low performance were very close to the OECD average (Figures 1.5 and 1.6). The OECD average also saw an increase in low performance and a decrease in high performance, albeit not as pronounced.

The NAPLAN, PISA and TIMSS surveys contain a wealth of information about the factors influencing mathematical achievement, and it is outside of the scope of this publication to discuss them all in detail.

What follows is a very brief discussion of some factors that might be linked—to varying degrees—on how well students perform in mathematics.

Figure 1.5 Australian 15-year-olds performing poorly (at or below proficiency level 1) in mathematics

Source: *OECD (2019), Selected data from PISA 2003, 2006, 2009, 2012, 2015, and 2018.*

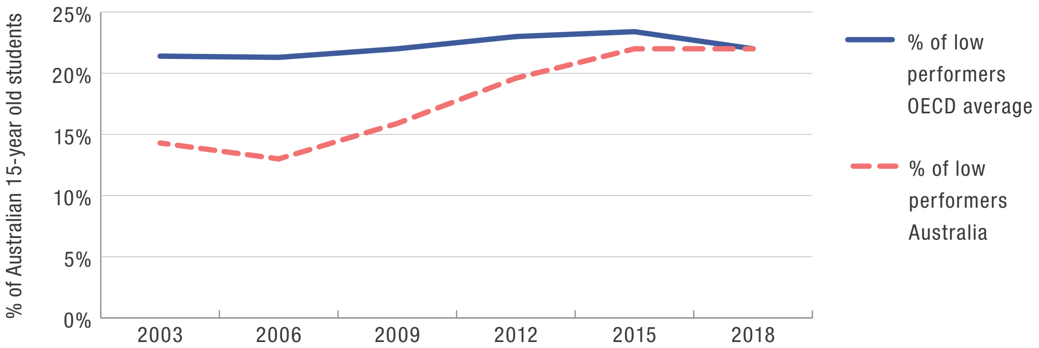
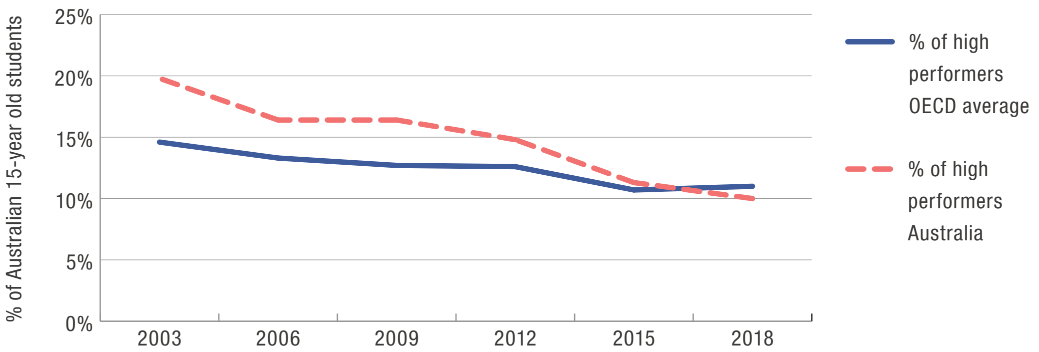


Figure 1.6 Australian 15-year-olds performing very well (at proficiency level 5 or above) in mathematics

Source: *OECD (2019), Selected data from PISA 2003, 2006, 2009, 2012, 2015, and 2018.*

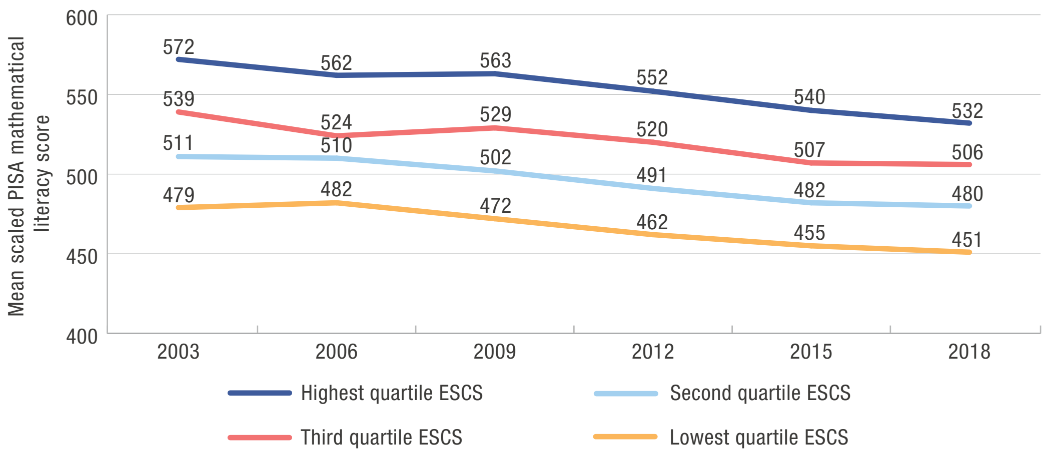


Student-related factors—*Socio-economic background*

All studies—NAPLAN, PISA and TIMSS—indicate that the socio-economic background of students may determine how well they perform in mathematics. Factors such as parental education and occupation, as well as other proxy indicators like the number of books and other learning resources in the home, can have a substantial influence, as illustrated in Figure 1.7.

This graph shows the correlation of socio-economic background and mathematical performance over time. In Australia, there are significant differences in mathematical literacy performance between students from the four quartiles on the economic, social and cultural status index (ESCS), which persist over the whole period to 2018. Note that the performance for mathematical literacy in the PISA survey declined for students of all socio-economic backgrounds since 2003. In 2018, the difference between students from the highest and lowest quartiles was 81 points, which is equivalent to almost three years of schooling. The difference between each quartile represents about one year of schooling.

Figure 1.7 Average student performance for mathematical literacy, by socio-economic background



Source: *Thomson, de Bortoli, Underwood & Schmid (2019), extract Figure 5.34, page 163.*

Other factors indicating the importance of home background to students include the resources available to them. For instance, even having an average number of books in the house, as opposed to a few books, is related to a higher achievement in mathematics, as the 2015 TIMSS survey results show (Table 1.8).

Table 1.8 Mathematics achievement in Year 8 according to the number of books in the home

	Mean achievement score (TIMSS)	< Low achievement	Low achievement	Intermediate achievement	High achievement	Advanced achievement
Many books	541	5%	15%	31%	35%	14%
Average no. of books	515	6%	22%	39%	26%	6%
A few books	468	21%	34%	29%	12%	3%

Source: *Thomson, Wernert, O'Grady & Rodrigues (2017), extract Figures 3.19 and 3.20, page 67.*

Student-related factors—*Indigenous background*

The disadvantage endured by students from Aboriginal and/or Torres Strait Islander background has repercussions for school performance, including in mathematics.

The 2018 NAPLAN data illustrates the achievement gap between indigenous and non-indigenous students in Year 9. Of indigenous students, 83 per cent reach the national minimum standard in numeracy compared to 96.3 per cent of non-indigenous students (Table 1.9). Indigenous students located in major cities and inner regional areas tend to do quite a bit better than indigenous students in outer regional and remote areas; however even in major cities only 88.5 per cent of Indigenous students reach the national minimum standard. In the highest achievement bands, percentages of Indigenous students are extremely low.

Table 1.9 Year 9 numeracy in 2018 by Indigenous status

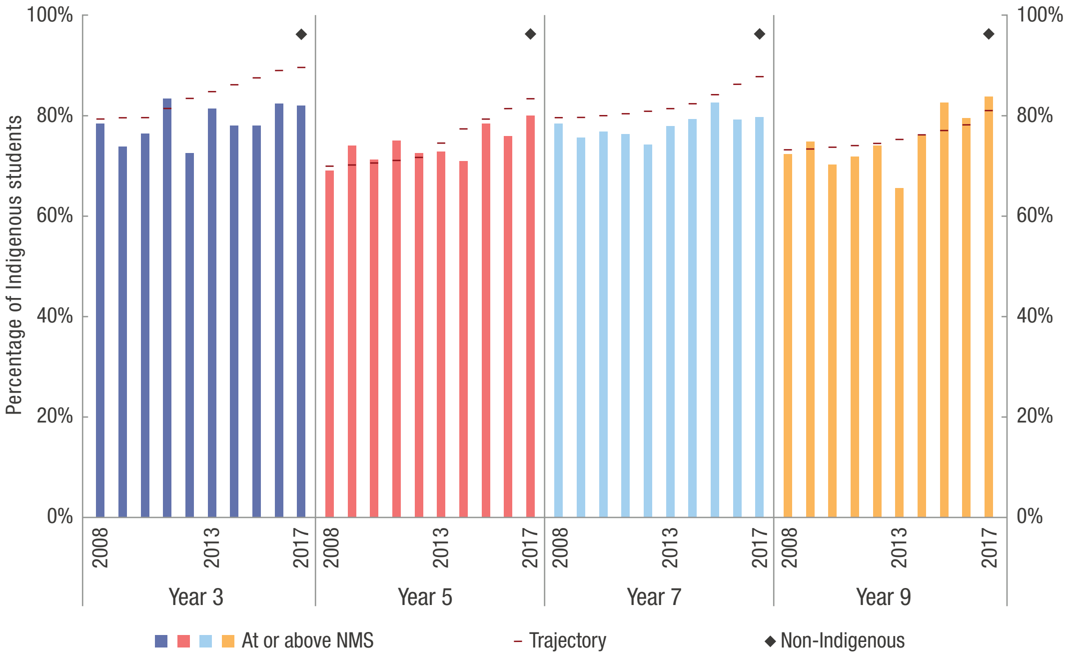
	Below national minimum standard (%)		At national minimum standard (%)	Above national minimum standard (%)				At or above national minimum standard (%)
NAPLAN Year 9 Numeracy in 2018	Exempt	Band 5 & below	Band 6	Band 7	Band 8	Band 9	Band 10	
Achievement of Year 9 Students by Indigenous Status, 2018								
Indigenous	2.8	14.2	30.2	31.9	15.4	4.5	0.9	83.0
Non-Indigenous	1.9	1.9	11.0	27.6	30.7	17.6	9.4	96.3
Achievement of Year 9 Indigenous Students by Geolocation, 2018								
Major cities	3.1	8.4	26.4	35.1	19.3	6.3	1.5	88.5
Inner regional	3.2	10.4	30.5	33.7	16.8	4.5	0.9	86.4
Outer regional	2.7	13.8	35.3	32.1	12.6	3.1	0.4	83.5
Remote	2.0	24.0	34.9	26.5	9.8	2.4	0.4	74.0
Very Remote	1.1	46.6	30.7	15.7	4.7	1.0	0.2	52.4

Source: *ACARA (2018), extracts from Table 9.N3, page 240 and 9.N6, page 243. Note that 2019 NAPLAN analysis was not yet available at time of writing.*

However, despite the persistence of the large gap in achievement, some gains have been made in the period 2008–2017. Compared to 2008, the proportions of Indigenous students reaching the minimum standard or above for numeracy were slightly higher in 2017 for Years 5 and 9 (Figure 1.10). In the period 2006 to 2016, Year 12 attainment among Indigenous 20–24-year-olds has also increased, from 47 per cent in 2006 to 65 per cent in 2016, including in remote and very remote areas (Department of Prime Minister and Cabinet (2019), pages 83 and 86).

Figure 1.10 Indigenous students at or above national standards for numeracy

Source: *Department of the Prime Minister and Cabinet (2019), Figure 3.7, page 78.*



Student-related factors—*Gender*

All three studies—PISA, TIMSS and NAPLAN—show that in Australia boys tend to have somewhat higher scores than girls in mathematics. However, in the TIMSS surveys the difference in achievement between boys and girls was only statistically significant for Year 8 in 2007, and in 2015 for Year 4 students.

The PISA results showed small statistically significant differences in 2006, 2009, 2012, and 2018 but not in 2003 and 2015. The NAPLAN results generally show no real difference between female and male students when it comes to reaching the national minimum standard.

However, male students tend to be represented more in the highest achievement bands 9 and 10, and girls in the “middle of the range” achievement bands 7 and 8.

Table 1.11 Year 9 Numeracy in 2018

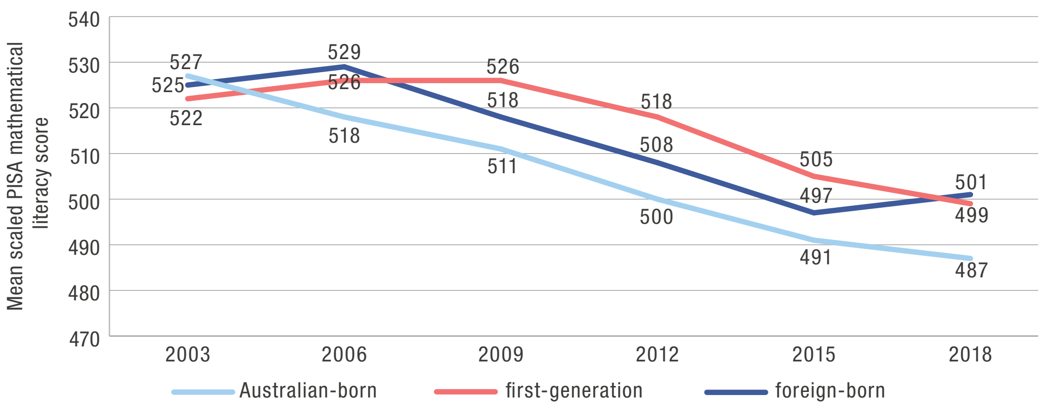
Source: *ACARA (2018), extract from Table 9.N2, page 239. Note that 2019 NAPLAN analysis was not yet available at time of writing.*

	Below national minimum standard (%)		At national minimum standard (%)	Above national minimum standard (%)				At or above national minimum standard (%)
NAPLAN Year 9 Numeracy in 2018	Exempt	Band 5 & below	Band 6	Band 7	Band 8	Band 9	Band 10	
Achievement of Year 9 Students by Sex, 2018								
Male	2.4	2.4	11.4	26.1	29.2	18.0	10.5	95.1
Female	1.4	2.8	12.9	29.6	30.4	15.7	7.2	95.9

Student-related factors—*Immigrant and non-English-speaking background*

With regard to immigrant background, from figure 1.12 it is clear that first-generation and foreign-born students did not escape the general decline in mathematical literacy evident from the 2018 PISA results. However, foreign-born and first-generation students seem to have a slight but consistent positive difference relative to others. The difference in PISA performance in 2018 between first-generation students and Australian-born students was equivalent to about half a year of schooling.

Figure 1.12 Average student performance for mathematical literacy over time, by immigrant background



Source: *Thomson, de Bortoli, Underwood & Schmid (2019), extract Figure 5.42, page 170.*

The potential influence of being from a non-English speaking or immigrant background seems to work both ways.

In the 2015 TIMSS study, students from a non-English-speaking background more often performed in the highest mathematical achievement bands (17 per cent versus 6 per cent of students who speak English at home). However, they were also represented more in the lower achievement bands, albeit to a lesser extent (15 per cent versus 10 per cent of students who speak English at home).

In all three studies (TIMSS, PISA and NAPLAN), the average achievement of students who speak a language other than English at home is not significantly different from students with an English-speaking background. Table 1.13 with data from the latest TIMSS survey illustrates this.

Table 1.13 Mathematics achievement in Year 8 according to whether a language other than English is spoken at home

	Mean Achievement score (TIMSS)	< Low achievement	Low achievement	Intermediate achievement	High achievement	Advanced achievement
English	505	10%	25%	35%	24%	6%
Other	518	**15%**	21%	24%	24%	**17%**

Source: *Thomson, Wernert, O'Grady & Rodrigues (2017) extract Figures 3.28 and 3.29, page 72.*

School and teaching—*Inequality and learning progress in (dis)advantaged schools*

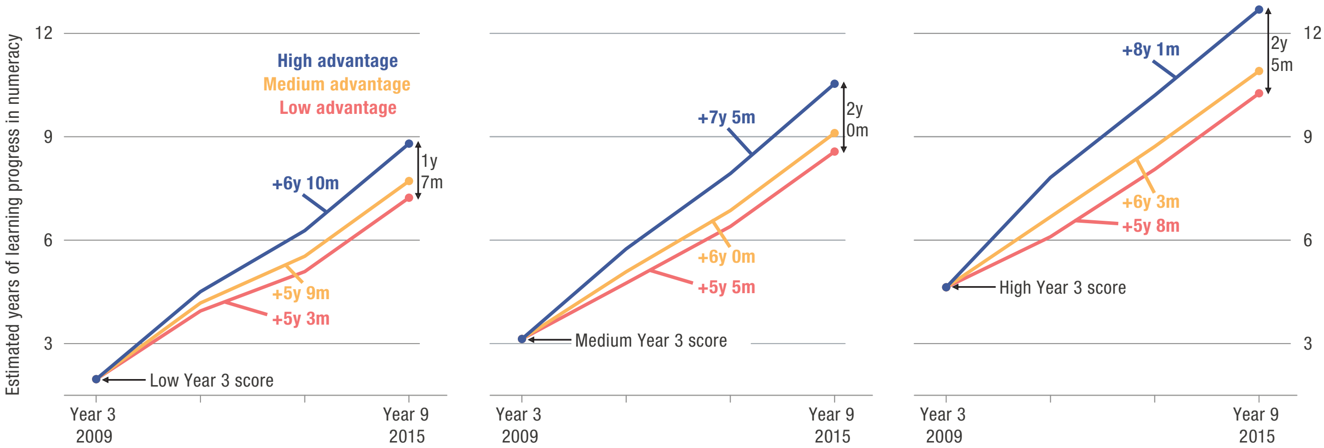
To measure whether a school is advantaged or disadvantaged, factors such as the education and occupations of parents in the school community are used to produce the Index of Community Socio-Educational Advantage (ICSEA).

To measure actual progress of students at schools with different levels of advantage, the Grattan Institute has proposed a time-based measure entitled "equivalent year levels" to interpret NAPLAN data.

The conversion of NAPLAN scores into "years of learning progress" allows comparison of different groups of students within the same cohort. For instance, analysis of the NAPLAN numeracy data from the 2009–2015 cohort in the state of Victoria showed that students with similar capabilities might have different learning outcomes depending on where they go to school: Students who go to disadvantaged schools (as measured by the ICSEA value) tend to make less progress than students in advantaged schools.

Figure 1.14 compares the progress of students with similar capabilities. The figure shows that students in disadvantaged schools who score high on numeracy in Year 3, end up making on average two years and five months less progress by Year 9 than similarly capable students in high advantage schools.

Figure 1.14 Estimated numeracy progress of low, median and high achievers grouped by their school ICSEA

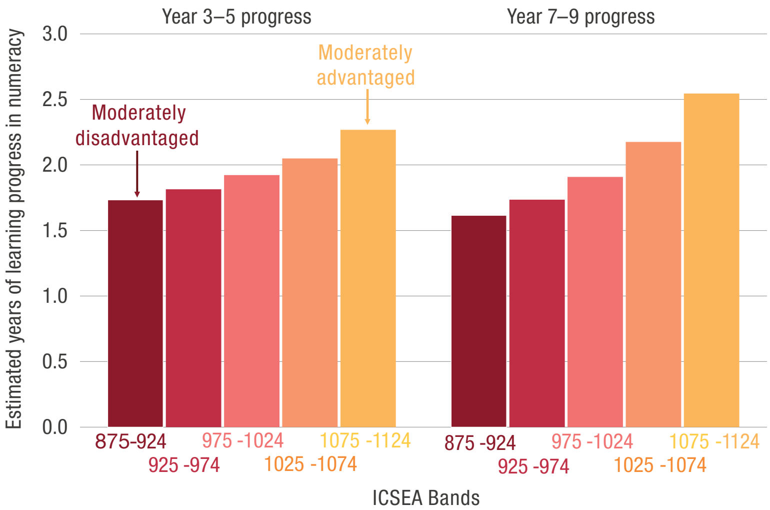


Notes: *Equivalent year level, numeracy, median, Victoria, 2009–15. Results show the estimated progress of low, median and high achievers (students who scored at the 20th, 50th and 80th percentiles in Year 3) grouped by their school ICSEA (referred to as low, medium and high advantage schools).*

Source: *Goss & Sonnemann, (2016), Figure 11, page 27.*

Comparison of NAPLAN data from all states confirms this pattern: figure 1.15 sets out the progress (in years) in numeracy for Years 3–5 and 7–9 across schools in five ICSEA bands ranging from moderately disadvantaged to moderately advantaged. Students in moderately advantaged schools tend to make more than 2 years' worth of learning progress in the two-year period between NAPLAN tests, while students in moderately disadvantaged schools are likely to make far less. Students should be making one year's worth of learning progress every year, but only students in schools in the highest two ICSEA bands represented in this graph tend to reach that goal.

Figure 1.15 Numeracy progress in years by school ICSEA level



Source: *Goss & Sonnemann (2018), Figure 1.4, page 11.*

Note: *ICSEA band 975–1024 is the average level of advantage. ICSEA band 1075–1124 is moderately advantaged; around one standard deviation above the mean. ICSEA band 875–924 is moderately disadvantaged; around one standard deviation below the mean.*

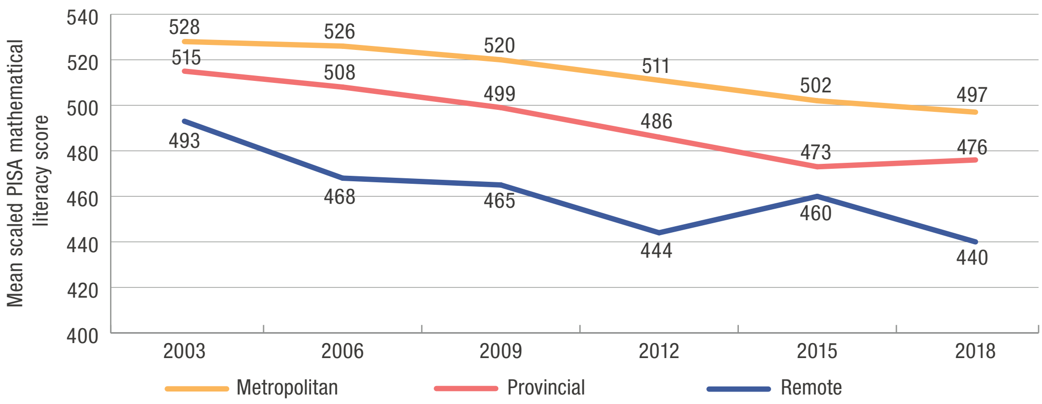
However, school advantage alone does not explain all the difference in student learning progress: Student progress is likely to be even more influenced by other school level factors, such as how much value schools add through their teaching and learning practices (Goss and Sonnemann 2018, 12 and 39), an area that would deserve further exploration.

School and teaching—*Geographic location*

The mathematical achievement of Australian students varies significantly depending on the location of the school.

NAPLAN, PISA and TIMSS consistently show that students in metropolitan areas are achieving better results in mathematics than their counterparts in provincial and remote areas. Figure 1.16 shows the differences in PISA results over time. The difference in performance between metropolitan and provincial areas increased from 13 points in 2003 to 21 points in 2018—which equates to around three-quarters of a year of schooling. For students from remote schools the performance gap in 2018 with students in metropolitan schools amounted to about two years of schooling.

Figure 1.16 Average student performance for mathematical literacy over time, by geographic location



Source: *Thomson, de Bortoli, Underwood & Schmid (2019), extract Figure 5.30, page 160.*

NAPLAN (see Table 1.17) uses a slightly more fine-grained distinction of locations—between major cities, inner regional, outer regional, remote and very remote locations.

There are substantial differences in the performance of students in the various regions.

However, if we compare non-Indigenous students in the various regions, the difference in mathematical performance between students in different locations becomes much smaller, at least where reaching the national minimum standard is concerned. In the high achievement bands 9 and 10, the gap between major cities and all other regions remains substantial.

Table 1.17 Year 9 numeracy in 2018 by geolocation

NAPLAN Year 9 Numeracy in 2018	Below national minimum standard (%)		At national minimum standard (%)	Above national minimum standard (%)				At or above national minimum standard (%)
	Exempt	Band 5 & below	Band 6	Band 7	Band 8	Band 9	Band 10	
Achievement of Year 9 Students by Geolocation, 2018								
Major cities	2.0	1.8	10.3	26.1	30.4	18.6	10.8	96.2
Inner regional	1.9	3.4	15.4	32.1	29.3	13.4	4.5	94.7
Outer regional	1.7	4.3	18.5	33.1	27.1	11.7	3.6	93.9
Remote	1.4	9.3	22.4	31.4	24.3	9.0	2.2	89.3
Very Remote	0.8	34.0	27.5	20.6	11.8	4.2	1.0	65.1
Achievement of Year 9 Non-Indigenous students by Geolocation, 2018								
Major cities	1.9	1.5	9.7	25.8	30.8	19.0	11.2	96.5
Inner regional	1.8	2.8	14	32.1	30.4	14.2	4.7	95.5
Outer regional	1.5	2.7	15.6	33.3	29.6	13.2	4.1	95.7
Remote	1.3	2.2	16.1	33.8	31.4	12.1	3.1	96.5
Very Remote	0.4	2.9	17.9	31.9	30.3	13.4	3.3	96.7

Source: *ACARA (2018), extracts from Table 9.N5, page 242, and Table 9.N7, page 244. Note that 2019 NAPLAN analysis was not yet available at time of writing.*

However, when measuring student *progress* rather than achievement, there are two points to be made when comparing student progress in various geographic locations, and taking the school advantage (measured by ICSEA) into account:

- According to analysis by the Grattan Institute, student progress varies more by State than between city and country locations. Once school advantage is taken out of the equation, some states do better or worse in progressing their students in certain learning areas at primary or secondary level. However, no one state excels in all subjects at all levels (Goss & Sonnemann, 2018, page 18).
- Adjusted for school advantage, students in country schools make similar progress to students in city schools (Goss & Sonnemann, 2018, page 17). This confirms that differences in achievement between geographic locations are much more likely to be the result of differences in socio-economic advantage than other factors.

School and teaching—*School sector*

Taken at face value, the average mathematical literacy performance across the government, independent and Catholic school sectors shows significant differences.

According to the 2018 PISA results, the difference in average performance between independent schools (with the highest average score) and government schools (with the lowest average score) amounted to the equivalent of two years of schooling. However, once these scores were adjusted for student and school socio-economic background, most of the remaining differences in achievement were no longer statistically relevant (see Table 1.18).

Similarly, student learning progress in numeracy is very similar across the government, Catholic and independent school sectors once school advantage is taken into account (Goss & Sonnemann, 2018, page 16).

Notes: **denotes difference not statistically significant.*

Source: *Thomson, de Bortoli, Underwood & Schmid (2019), extract Figure 5.10, page 135 and extract Table 5.6, page 136.*

Table 1.18 Average mathematical literacy performance 2018 by school sector

	Average mathematical literacy performance 2018 (PISA)		Difference in raw score	Difference in scores after student and school level socio-economic background is accounted for
Independent	524	Independent-Catholic	25	7*
Catholic	499	Independent-government	47	-5*
Government	477	Catholic-government	22	-11

School and teaching—*Culture and attitudes to learning mathematics*

The TIMSS survey traditionally includes a number of questions to teachers, principals and students in Year 8 about the school environment, instructional time, time spent on homework, absenteeism and so forth.

As an illustration of the importance of school environment, the emphasis a school places on academic success has an influence on mathematical achievement. Table 1.19 sets out the mathematical achievement of students by school emphasis on academic success, as reported by teachers. The difference in average achievement between a school with medium and high emphasis on academic success is a significant 39 points. In Australia 56 per cent of schools place a high to very high emphasis on academic success against 51 per cent internationally.

Source: *TIMSS (2015), Exhibit 6.5.*

Table 1.19 Mathematics achievement in Year 8 according to school emphasis on academic success (according to teachers)

	Average mathematical achievement (Australia)	Proportion of students	International average mathematical achievement	Proportion of students
Very high emphasis	543	8%	515	5%
High emphasis	523	48%	495	46%
Medium emphasis	484	44%	464	49%

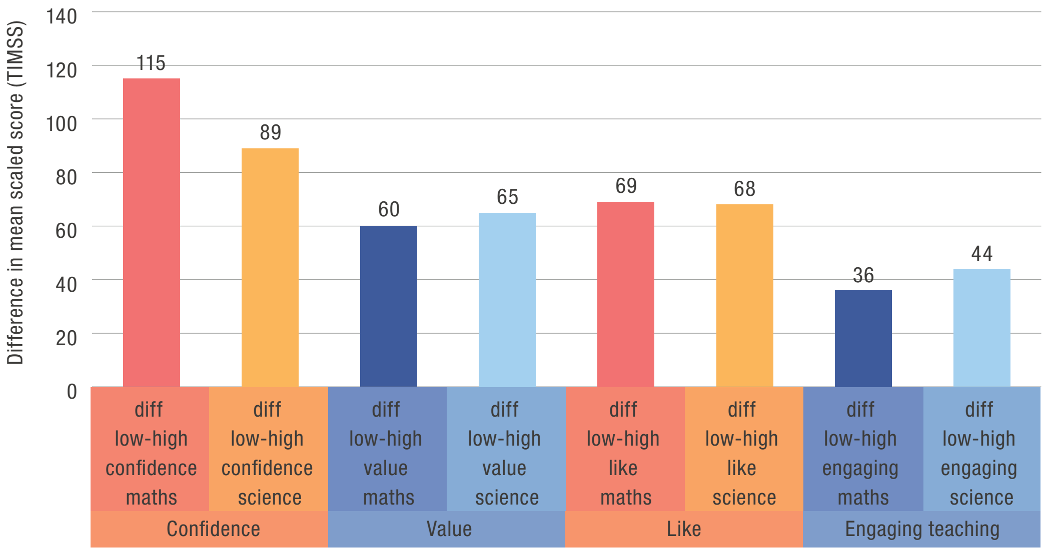
The TIMSS survey also yields important information on student attitudes towards mathematics.

Within Australia, enjoyment of and engagement with mathematics matters, as mathematical achievement improves with students' satisfaction with the subject.

Figure 1.20 displays the difference in 2015 in mean achievement between students with low confidence, low value, low enjoyment and low engagement with maths and science, versus students who rate these subjects very highly. From this figure it is clear that self-confidence in mathematics is especially important—in Australia the difference in average achievement between students with low confidence in their mathematical ability and those with very high confidence was 115 points.

Figure 1.20 Difference in mean achievement in mathematics and science by student attitudes and experiences in Year 8

Source: TIMSS (2015), extracts from Exhibits 10.2, 10.4, 10.6 and 10.7.



The 2015 TIMSS results for Year 8 showed that Australian students do not place less value on mathematics than the international average (see figure 1.21). By comparison, Australian Year 8 students placed a lot less value on science, both compared to the international average and to mathematics. The confidence Australian students had in their own mathematical ability was very close to the international average as well (Figure 1.22).

Figure 1.21 Value placed on mathematics and science in Year 8 compared to international average

Source: TIMSS (2015), Extracts Exhibit 10.7. 10.4, 10.6 and 10.7.

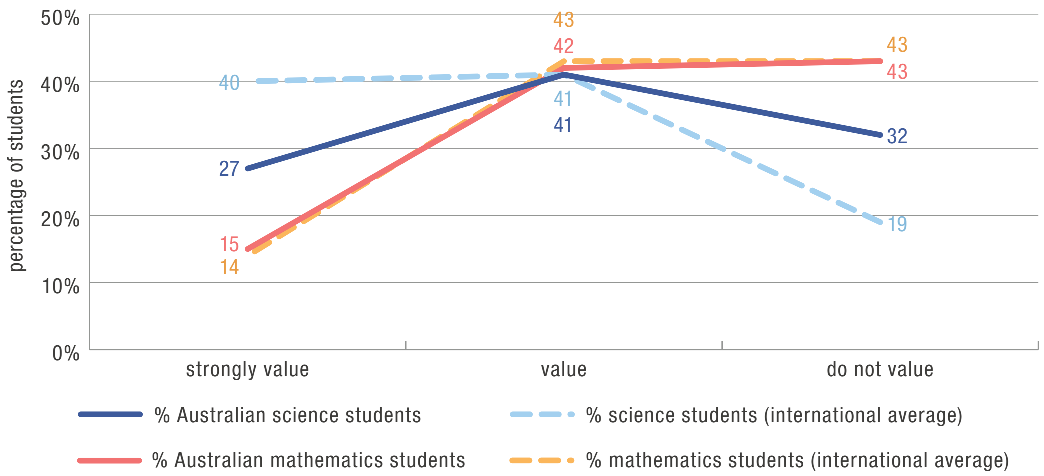
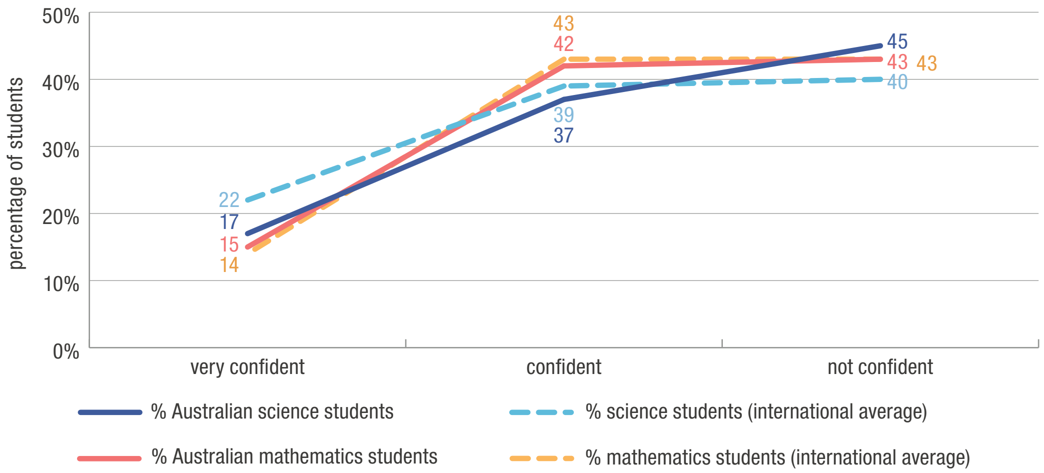


Figure 1.22 Student confidence in mathematics and science in Year 8 compared to international average

Source: TIMSS (2015), Extracts Exhibit 10.6.



When it comes to enjoying the pursuit of mathematics and being engaged by it, however, we see a different result. In Year 8, at least 50 per cent of students did not like mathematics, significantly higher than the international average of 38 per cent — see figure 1.23. Science did a bit better, with 29 per cent admitting they did not like the subject (compared to 19 per cent internationally). According to the 2015 TIMSS study, 24 per cent of students in Year 8 found mathematics teaching less than engaging (see figure 1.24).

Figure 1.23 Enjoyment of mathematics and science in Year 8 compared to international average

Source: *TIMSS (2015), extracts Exhibit 10.4.*

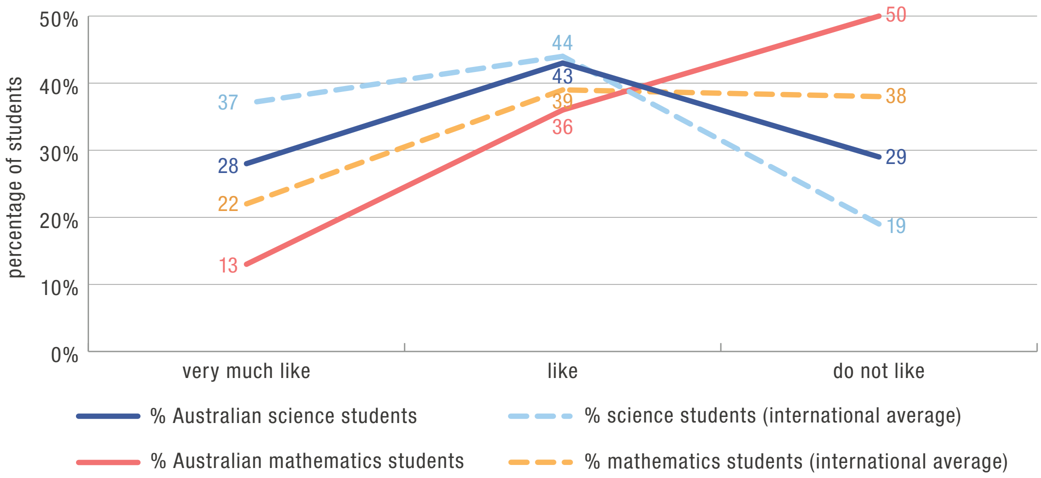
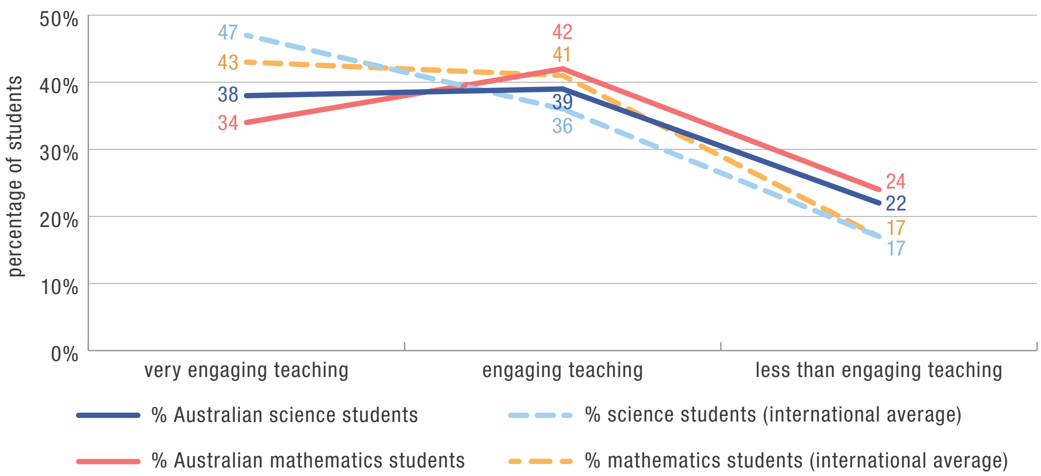


Figure 1.24 Students' view of engaging teaching in mathematics and science in Year 8 compared to international average

Source: *TIMSS (2015), extracts Exhibit 10.2.*



1.3 Student numbers and participation rates

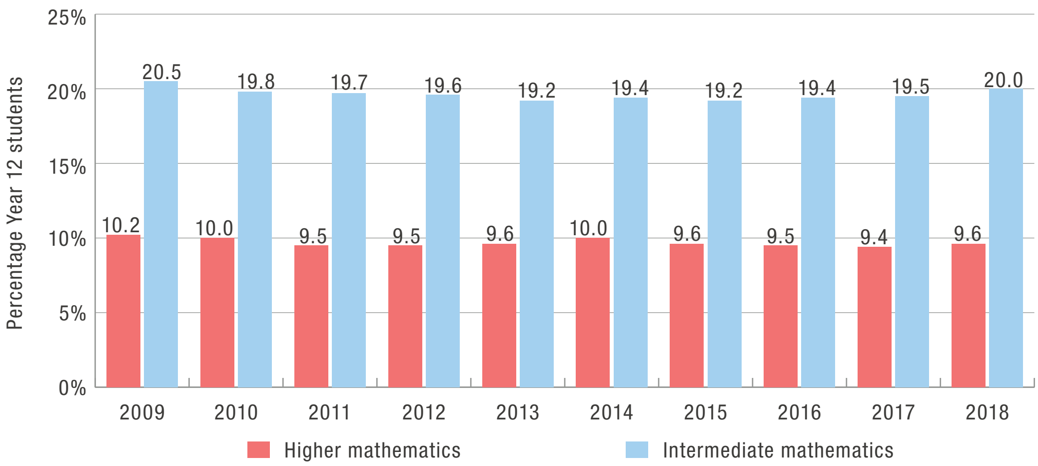
The number of students completing Year 12 has been steadily increasing in Australia. Over the last ten years, the Year 12 population has grown by 15 percent, from approximately 200,000 in 2007 to around 230,000 in 2018. The proportion of Australian students studying mathematics in Year 12 in some form has remained steady at an estimated 80 per cent over the past two decades. However, when we examine what mathematics subjects these students are choosing to take, the proportion of students taking more advanced, calculus-based levels of mathematics as their "highest" maths subject has declined in favour of "easier" maths subjects.

Previous AMSI reports have classified the various mathematical studies offered in Australian as *advanced*, *intermediate* and *elementary*. To avoid any confusion between these categories and the new 'Advanced Mathematics' study offered in New South Wales, we now refer to *higher*, *intermediate* and *elementary* levels of mathematics. The *higher* level is representative of the Australian Curriculum Level Specialist Mathematics, *intermediate* represents Mathematical Methods and *elementary* combines both Essential and General Mathematics (ACARA 2020).

Figure 1.25 includes data for all Year 12 mathematics students enrolled through the secondary boards of studies and the Australian International Baccalaureate (IB) in all states and territories, for the years 2009 to 2018. Keeping in mind that students often enrol in mathematics subjects at more than one level—for example in both an *elementary* and *intermediate* maths subject—Figure 1.25 displays the most advanced level of mathematics students have chosen, with overlapping enrolments in lower level maths subjects taken out. The figure below therefore gives the best indication of the level of preparedness of students to enter university degrees—especially degrees with a mathematical component such as science, engineering and commerce.

The number of Australian Year 12 students studying *higher* mathematics increased slightly from 21,831 in 2017 to 22,037 in 2018. Given the growth of the Year 12 population, the proportional increase was just 0.2 per cent, with the percentage of students undertaking mathematics at the *higher* level being 9.4 per cent in 2017 and 9.6 per cent in 2018. The number of students with *intermediate* maths as their highest level maths subject also increased, from 45,132 in 2017 to 45,815 in 2018. The percentage of students studying at the *intermediate* level increased slightly from 19.5 per cent in 2017 to 20 per cent in 2018. Both participation in *intermediate* and *higher* mathematics was slightly better in 2018 than in previous years. Altogether, only 29.6 per cent of the population studied mathematics to at least *intermediate* level in 2018. The last time this percentage topped 30 per cent was in 2009.

Figure 1.25 Higher and intermediate mathematics students in Australia



Source: *James (2019).*

Note: *The following (non-exhaustive) key for intermediate and higher level mathematics:*

Intermediate *- VIC/TAS/ACT Math Methods, NSW Advanced Mathematics (previously NSW Mathematics or 2-unit), SA/NT Mathematical studies, QLD Maths B, WA Mathematics 3CD.*

Higher *- VIC/ACT/SA/NT Specialist maths, NSW Ext 1+2, TAS Specialised maths, QLD Maths C, WA Specialist 3CD. With the introduction of the National Curriculum, new mathematics subjects are being introduced. Level D is considered higher, while Level C is considered intermediate mathematics.*

The proportion of students taking *elementary* mathematics as their most advanced level maths subject (those enrolled in an *elementary* mathematics subject but NOT enrolled in either an *intermediate* or *higher* mathematics subject) is estimated to have remained steady at 52 per cent in 2018.

Over the past twenty years, we have seen a steady decline in the proportion of Year 12 students taking the "harder" mathematics subjects — see figure 1.26. The proportion of Year 12 students taking higher mathematics dropped from 13.6 per cent in 1997 to 9.6 per cent in 2018. The proportion of students taking *intermediate* mathematics as their most advanced maths subject has similarly dropped, from 27.2 per cent in 1997 to 20 per cent in 2018. The steepest decline in participation in *intermediate* or *higher* maths took place before 2010, after which participation seems to have stabilised.

Furthermore, there is a persistent gender gap in Year 12 mathematics participation in *higher* mathematics (see figure 1.27), with only 7.2 per cent of girls taking *higher* mathematics in 2018, compared with 12.2 per cent of boys.

Figure 1.26 Percentage decline in Year 12 participation in *intermediate* or *higher* mathematics 1997–2018

Source: *James (2018), AMSI Year 12 participation data collection 1997–2018.*

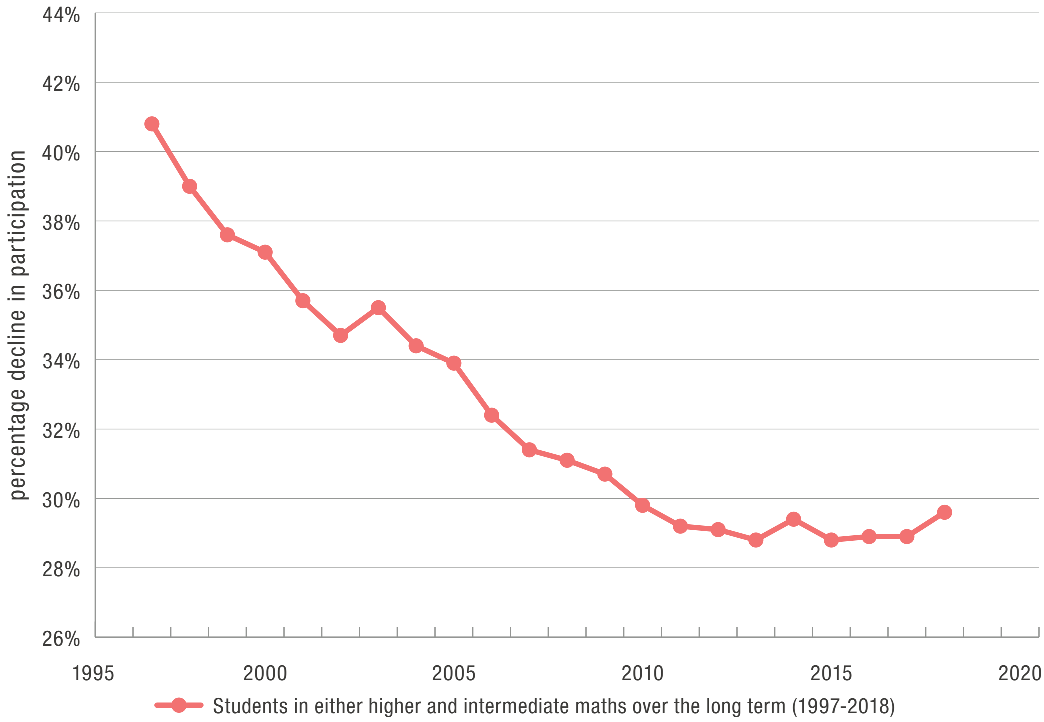
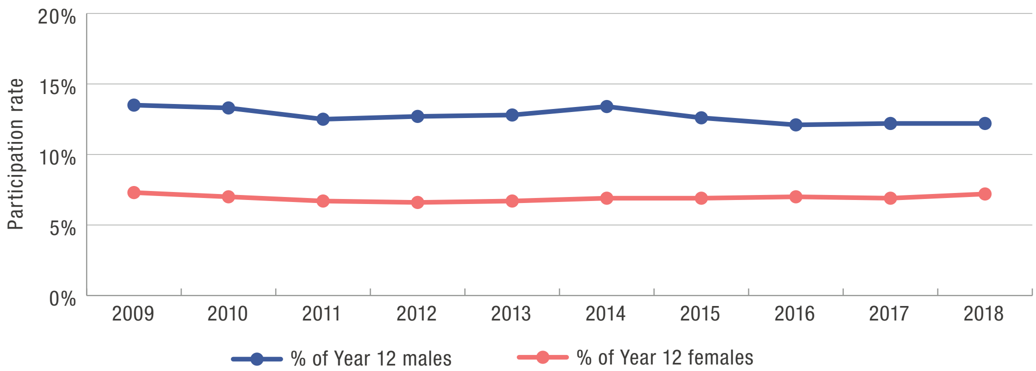


Figure 1.27 Percentage of students studying *higher* mathematics by gender

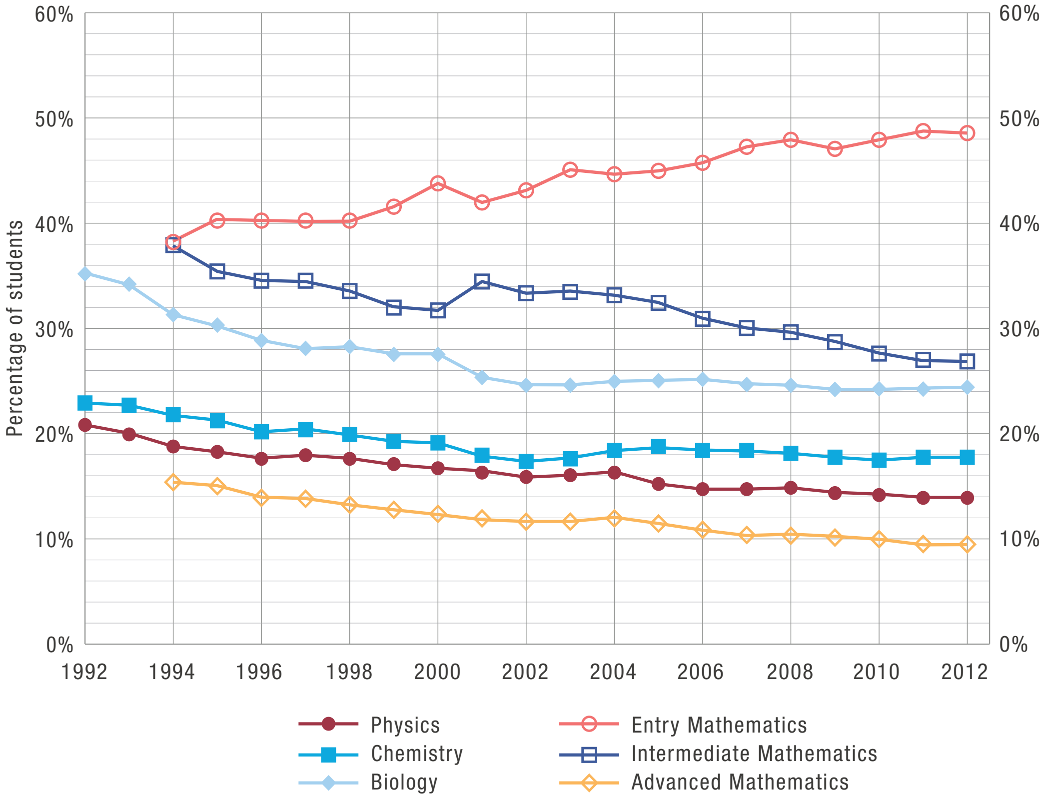
Source: *James (2018), AMSI Year 12 participation data collection 1997–2018.*



The field of mathematics is not the only field in the Science, Technology, Engineering and Mathematics (STEM) area affected by declining participation (Kennedy et al., 2014). Figure 1.28 shows that other STEM subjects such as chemistry, biology and physics have also suffered a long-standing decline in participation. In the case of biology and chemistry, the most significant decline took place in the period 1992–2002, and participation stabilised after that. Unfortunately, we do not have a more recent analysis of the participation in other STEM subjects.

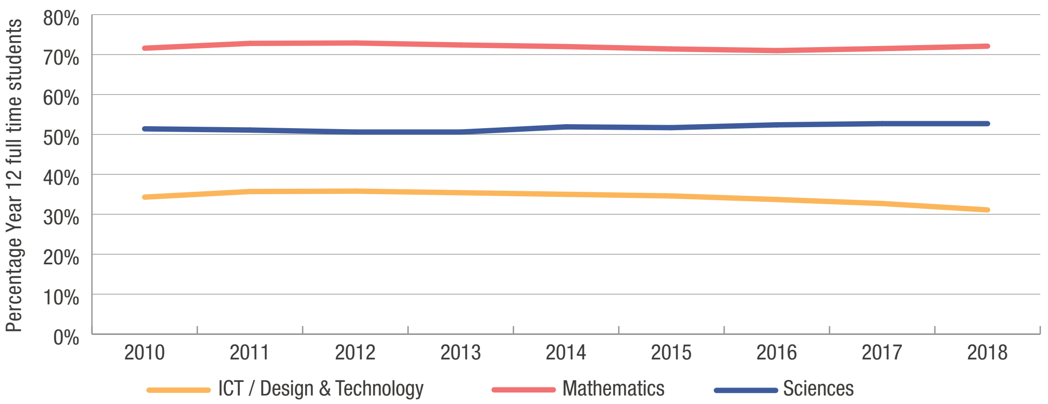
The ACARA Year 12 enrolment numbers by learning area (see figure 1.29) show that the proportion of students taking at least one science subject has been fairly stable, as has the proportion of students taking at least one mathematics subject. However, this provides no information on which specific mathematics or science subjects individual students are undertaking, therefore masking any changes in how many subjects are taken and at what level.

Figure 1.28 Participation rates in science and mathematics subjects 1992–2012



***Source:** Kennedy, Lyons & Quinn (2014), extract of figure 2, page 39.*

Figure 1.29 Year 12 participation in the science, mathematics and ICT technology learning areas

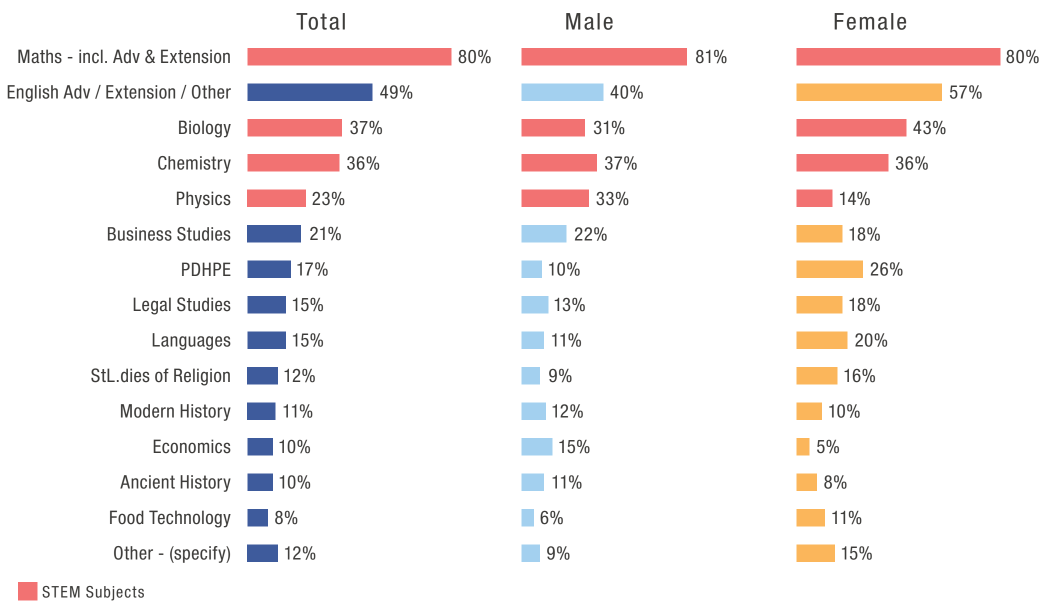


***Source:** ACARA (2019b) The graph represents the proportion of students taking at least one subject in the areas of Science, Mathematics, and ICT / Design & Technology.*

The importance of healthy participation in STEM subjects in high school has been widely recognised for some time now. A survey among 2,000 people aged 12–25, commissioned by the Department of Industry, Innovation and Science, into students' attitudes and behaviours towards STEM education and careers (YouthInsight, 2019) revealed the following on study preferences among Year 11 and 12 students:

- 80 per cent of Year 11 and 12 students surveyed were enrolled in at least one mathematics subject (Figure 1.30). This percentage was the same for male and female students.
- 95 per cent of students in Year 11 and 12 in the survey participated in at least one STEM subject (YouthInsight, 2019, page 24). Apart from mathematics, other STEM subjects such as physics, biology and chemistry were among the most popular subjects — more popular than business, economics, languages, or humanities subjects (Figure 1.30).

Figure 1.30 Year 11 and 12 current elective subject selections – Top 15



Notes: *Question: "Which of the following elective subjects best describes the subjects you have chosen to do in Year 11 and 12? Please select a maximum of 6 subjects and minimum of 3".*
Base: Total - 375, Males - 201, Females - 162.
Standard English is mandatory at this stage of school, hence it is not included in this question.

Source: *YouthInsight (2019), page 22.*

Without a proper analysis of the Year 12 enrolment numbers in physics, biology and chemistry it is not possible to tell if participation in these subjects has turned a corner and is on the rise again. However, the same survey outcomes predict a likely increase in STEM subject selection based on the intentions of Year 9 and 10 students (YouthInsight, 2019, page 31). Despite all this, engagement with STEM subjects will require continued attention.

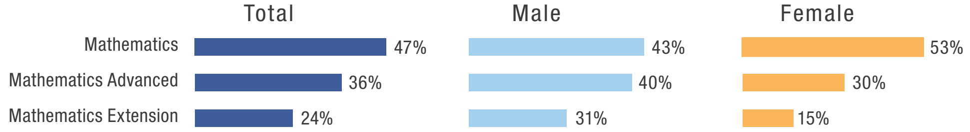
According to the YouthInsight (2019) survey results the take-up of STEM subjects by male students is higher than by female students as figure 1.30 shows; however, there are differences between subjects. Male students are overrepresented in physics, and female students are overrepresented in biology. The take-up of chemistry is evenly balanced.

While the same proportion of male and female students choose at least one maths subject, the gender distribution over the three levels of mathematics is uneven (Figure 1.31). Among the three different levels, female survey respondents were overrepresented in mathematics (53 per cent against 43 per cent for male students), underrepresented in advanced mathematics (30 per cent against 40 per cent for male students) and severely underrepresented in mathematics extension (15 per cent against 31 per cent for male students). This likely aligns with AMSI findings that the gender distribution is skewed towards boys in the more advanced levels of maths (see paragraph 1.3 of this Chapter).

Note that due to differences in terminology and methodology we cannot make a direct comparison between these figures and the AMSI Year 12 data collection.

While presumably the term "advanced mathematics" refers to "intermediate mathematics' in the AMSI terminology, and "mathematics extension" to "higher mathematics", the survey report does not clarify which subjects fall under which category in which state, and it is also unclear whether the survey only includes Year 11 and 12 subjects that lead to an ATAR.

Table 1.31 Year 11 and 12 current elective subject selections – Maths subjects only



Notes: Question: "Which of the following elective subjects best describes the subjects you have chosen to do in Year 11 and 12? Please select a maximum of 6 subjects and minimum of 3".
Base: Total - 375, Males - 201, Females - 162.
Standard English is mandatory at this stage of school, hence it is not included in this question.

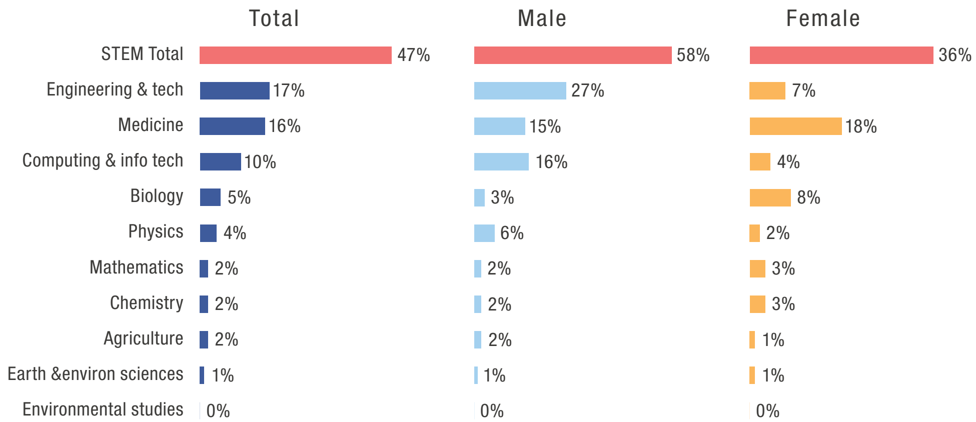
Source: YouthInsight (2019), page 23, extract.

The second issue which justifies continued concern is that the high take-up of STEM subjects in high school is not translated into a preference to study STEM subjects after secondary school in anywhere near the same proportions.

About 47 per cent of surveyed students in Year 11 and 12 (58 per cent of male students and 36 per cent of female students) considered studying a STEM-related subject in tertiary education (see figure 1.32). Most popular course preferences were engineering and technology, and medicine. However, the most popular subject surveyed students ended up studying at university was business and management (YouthInsight, 2019, page 26).

Also worth noting is the extremely low uptake of university mathematics as a separate degree or major (Figure 1.32). Only two per cent of surveyed students aspired to study, or actually studied, mathematics after high school (YouthInsight, 2019, pages 27 and 37). This indicates that while the vast majority of students accept mathematics as a skill or tool that they need to understand to enable study in other subjects, there is minimal engagement with mathematics as a subject of study in its own right.

Figure 1.32 Courses considered for higher education – STEM only subjects



Notes: Question: "Please select from the below list which course(s) you are considering after high school. Please select up to 2 courses.
Base: Total - 375, Males - 201, Females - 162.

Source: YouthInsight (2019), page 39.

The causes for the decline in engagement with 'harder' mathematics subjects in school, and the extremely low interest among young people to pursue mathematical sciences as a career are likely multi-faceted and complex.

The underlying causes could include dissatisfaction with the subject as it is taught in school, and lack of external incentives to undertake intermediate and higher mathematics subjects.

Perceptions on the best strategies to maximise ATAR scores (whether these perceptions are correct or not since ATAR is based on scaled results) may also have a detrimental effect (Murray, 2011; MANSW, 2014; Pitt, 2015; Hine, 2018, 2019).

Many students may prefer to follow the short-term goal of getting into university (where many universities do not require mathematics for entry into most degrees), without having sufficient insight in the importance of having studied mathematics to be successful at university.

Previous studies have shown that having studied mathematics at a higher level in secondary school can have a positive cross-disciplinary effect on performance in several science subjects at university (Sadler & Tai, 2007; Poladian & Nicholas, 2013; Nicholas, Poladian & Wilson, 2015; Joyce, Hine & Anderton, 2017).

According to the key findings of the most recent and most comprehensive Australian analysis to date (McMillan & Edwards, 2019), both the level and performance in Year 12 mathematics subjects is relevant for passing science and mathematics subjects in the first year of university.

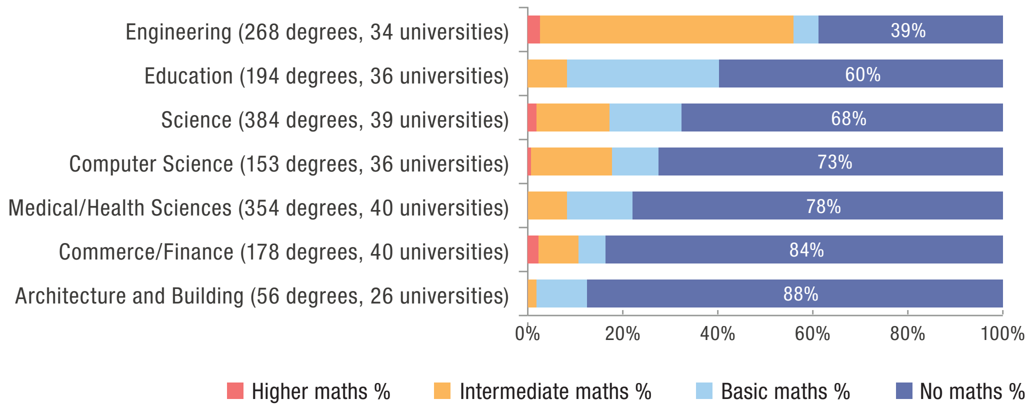
Broadly speaking, students who had undertaken Mathematical Methods or Specialist Mathematics in secondary school had higher first year subject pass rates than those who had studied General Mathematics. However, students with strong academic results in General Mathematics achieved similar or higher pass rates than students who performed poorly in the more advanced secondary school maths subjects.

Mathematics and statistics are basic subjects in the university study of science, engineering and computer science — but also of commerce, education, and health sciences. However, universities are not necessarily sending clear messages to secondary school students about what prior content knowledge they should have to successfully study certain degrees (King & Cattlin, 2015).

As is clear from Figure 1.33, in only a minority of degree streams universities require completion of mathematics subjects in senior secondary school.

To study science, computer science, health and medical sciences, architecture, finance and commerce, most universities do not require completion of any mathematics, let alone completion of intermediate or higher mathematics. The entry requirements for engineering are generally the strictest, with most engineering degrees requiring at least intermediate mathematics.

Figure 1.33 Mathematics prerequisites by area of study



Source: *Data collection by AMSI and the Office of the Chief Scientist (OCS), March 2020.*

1.4. Teacher profiles and qualifications

Research consistently shows there are not enough mathematically qualified teachers in Australian secondary schools.

As mathematics is taught at all secondary schools up to and including Year 10 and is studied by the majority of students up to Year 12, Australia needs large numbers of teachers able to teach this subject and teach it well.

The first teacher survey, held in 2016, as part of the AMSI Choose Maths program, indicated that teachers who consider themselves to be teaching mathematics "out-of-field" (because of a perceived lack of content knowledge or methodology training—or both), also report that they feel considerably less confident and competent in terms of mathematics content, teaching and curriculum documentation than their "in-field" colleagues (Koch & Li, 2017).

AMSI's definition of being qualified in a discipline is to have completed both content and methodology training in the area, as being a good maths teacher requires deep mathematical as well as pedagogical knowledge (Hinz, Walker & Witter, 2019, page 3).

The most recent comprehensive data—gathered in 2013 in the survey "Staff in Australia's Schools (ACER 2014a)"—on qualifications of mathematics teachers in secondary education indicated the following (see Table 1.34):

- 26.1 per cent of Years 7–10 teachers teaching mathematics had not completed methodology training in the area, suggesting they were teaching out-of-field. This was an improvement on the 2010 data, which indicated nearly 40 per cent of Years 7–10 teachers teaching mathematics had not completed methodology training. In addition, over 60 per cent of Years 7–10 mathematics teachers had at least three years tertiary education in the mathematical sciences, up from 54.8 per cent in 2010 and 53 per cent in 2007;

- In Years 11–12, 86.1 per cent of mathematics teachers had completed appropriate methodology training, up from 76.3 per cent in 2010. More than 72 per cent of Years 11 and 12 mathematics teachers had at least three years tertiary education in mathematics, up from 64.1 per cent in 2010 and 68 per cent in 2007.

Table 1.34 Teachers teaching in selected areas: qualifications, experience and professional learning

	Years of tertiary education in the area (%)				Total with at least 1 year	Methodology training in the area?	≥5 years teaching experience in the area?	Professional learning in past 12 months in the area?
	1 Sem	2 Sem						
Area currently teaching	Yr 1	Yr 1	2	3+	%	Yes (%)	Yes (%)	Yes (%)
Secondary								
LOTE 7/8–10	1.3	3.1	5.1	78.9	87.0	73.9	61.0	70.3
LOTE 11–12	0.3	2.1	1.8	89.0	92.9	82.5	72.6	76.1
Chemistry 11–12	2.6	7.7	20.5	68.6	96.7	79.7	72.7	63.5
IT 7/8–10	13.5	12.7	6.0	42.3	61.0	45.6	50.3	61.9
IT 11–12	6.2	13.0	10.3	58.4	81.7	62.5	66.3	83.4
Maths 7/8–10	5.6	11.5	11.0	60.1	82.6	73.9	69.9	74.8
Maths 11–12	4.2	7.9	10.7	72.5	91.0	86.1	79.6	84.5
Physics 11–12	3.6	19.9	21.8	52.1	93.9	72.1	76.3	66.0
General Science 7/8–10	6.9	11.5	6.4	61.3	79.2	79.6	68.9	56.7

Note: *The "Total with at least 1 year" column does not include those who indicated that they had only studied one semester in Year 1 of tertiary education.*

Source: *ACER (2014a), page 67.*

Table 1.35 Teachers in Year 8 majored in education and mathematics 2011–2015

	Major in Mathematics and Mathematics Education		Major in Mathematics but No Major in Mathematics Education		Major in Mathematics Education but No Major in Mathematics		All Other Majors	
	Proportion of students	Average achievement	Proportion of students	Average achievement	Proportion of students	Average achievement	Proportion of students	Average achievement
2011 Australia	37%	505	21%	519	9%	522	34%	500
2011 int. avg.	32%	471	41%	468	12%	470	12%	462
2015 Australia	46%	513	18%	507	14%	498	22%	503
2015 int. avg.	36%	483	36%	482	13%	481	13%	477

Source: *TIMSS (2015), Exhibit 8.4.*

The differences in teaching qualifications between teachers in Years 7–10 and Years 11–12 are an indication that out-of-field teaching occurs most frequently in the junior years of secondary school, as schools reserve their most mathematically qualified teachers for the senior years (Weldon, 2015, 2016).

The extent of out-of-field teaching also varies in other ways: It is more frequent in provincial and remote areas than metropolitan areas, and more frequent in schools with low socio-economic status than with high socio-economic status (Weldon, 2016).

The data from 2013 suggested a slight improvement in training levels of mathematics teachers between 2010 and 2013. This seems to be corroborated by the 2015 TIMSS study which also suggested a possible improvement, compared to the previous TIMMS study in 2011. Whereas in 2011 34 per cent of Year 8 students were taught mathematics by teachers without any major in mathematics, this percentage dropped to 22 per cent in the 2015 study, see Table 1.35. Despite a possible improvement in these years, the shortage of qualified mathematics teachers is far from resolved and likely to deepen in the future. There are several reasons for this projected deficit.

In the first place, the 2013 survey indicated that mathematics teachers were older than the average secondary teacher (ACER, 2014b, pages 15 and 17). In 2013, more than 40 per cent of mathematics teachers were 51 years or older (against 36 per cent of secondary teachers overall). The ageing of male mathematics teachers was especially stark, with 47 per cent of male maths teachers 51 years or older (against 39 per cent of male secondary teachers overall). The average age of a male maths teacher in 2013 was 47, with the average age of female teachers slightly lower at 44 years. In the years since, this ageing trend is likely to have progressed further.

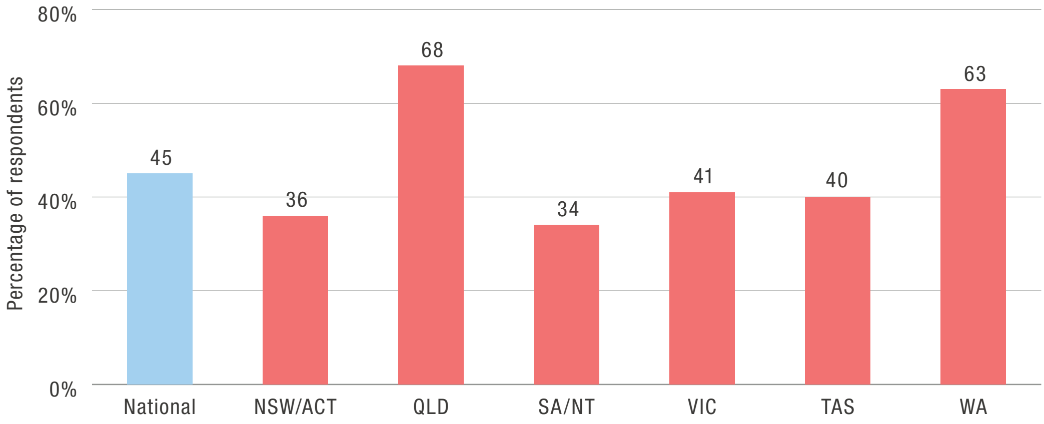
In addition, the number of school students is on the rise and is expected to keep growing for some years to come (Weldon, 2015; O'Connor & Thomas, 2019), and without a substantial influx of new teachers in combination with retraining of existing teachers currently teaching out-of-field, the shortage of qualified maths teachers will remain unresolved (Prince & O'Connor, 2018).

The results of the annual "State of our Schools" survey by the Australian Education Union (AEU) in 2018 showed that 45 per cent of secondary school principals reported maths and science classes were being taught by not fully qualified teachers (note that the term "not fully qualified" was not further defined).

The differences between states were very substantial, with no less than 63 per cent of principals from Western Australia, and 68 per cent of principals from Queensland reporting maths and science classes taught by not fully qualified teachers (Figure 1.36).

Secondary school principals also reported that vacancies in the curriculum areas of maths (49 per cent), technology (42 per cent) and science (31 per cent) were the most difficult to fill (AEU 2019). Furthermore, 32 per cent of teachers indicated they had taught outside their area of qualifications or expertise in 2018 (see figure 1.37—note this includes primary school teachers), with mathematics reported as the most frequent out-of-field subject (AEU 2019).

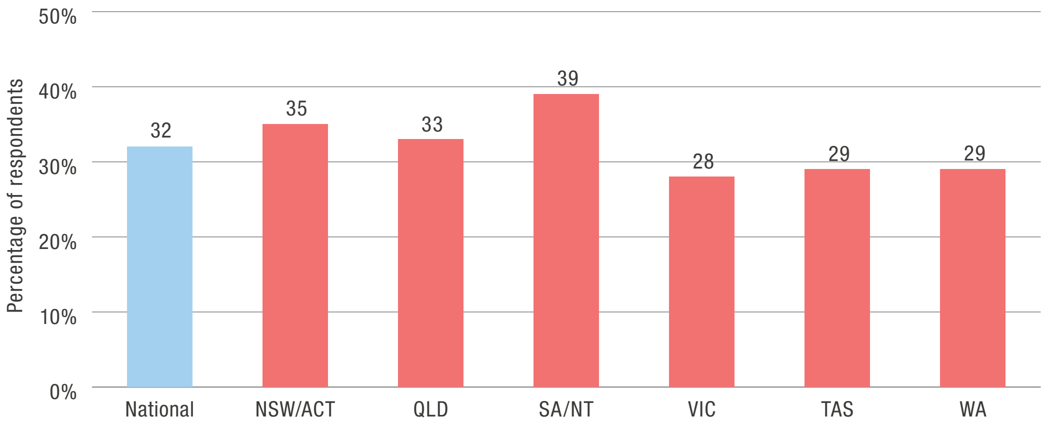
Figure 1.36 Principals reporting maths and science classes not taught by fully qualified teachers



Source: *AEU (2019).*

Note: *answers to the question "Are there maths and science classes at your school taught by a teacher who is not fully qualified in the subject area?" (All principals other than Primary or Special School principals n=233).*

Figure 1.37 Teachers reporting having taught a subject outside their area of qualifications/expertise in 2018



Source: *AEU (2019).*

Note: *answers to the question "Have you taught subjects outside your area(s) of qualifications/ expertise this year?" (Base: Teachers n=6,120).*

Most universities **do not require intermediate or even basic maths** for entry into university degrees in science, IT, commerce, health professions, education or architecture

See page 30

Only 56% of engineering degrees require at least intermediate maths as a prerequisite for entry into the course

See page 30

Some universities **do not offer a major in the mathematical sciences**

See page 41

The numbers of students pursuing maths degrees are not growing in line with the substantial growth of university student numbers in other fields of education

See pages 45 & 47

2 HIGHER EDUCATION

UNIVERSITY STAFFING, TEACHING OF MATHEMATICAL SCIENCES, STUDENT NUMBERS AND PROFILES

The mathematical sciences are a small discipline in the research and higher education sector. After a period of significant staff reductions at the end of last century, academic staff numbers are increasing again, mostly at Group of Eight (Go8) universities. A relatively high proportion of staff in the mathematical sciences is employed at level D (Associate Professor) and level E (Professor). The academic workforce is predominantly male, with women making up approximately 20 per cent (excluding casual employees).

The mathematical sciences play a central role in university teaching. Many university degrees include mathematical and statistical training in their courses, which is typically delivered by mathematical sciences departments and schools. The teaching load in mathematical sciences subjects has increased considerably since 2005, particularly at Go8 universities. Between 2012 and 2018, the proportion of international students participating in mathematical sciences subjects has also increased from an estimated 18 per cent in 2012 to 29 per cent in 2018.

Not all universities offer a mathematical sciences degree or major. Of those that do, the numbers of students completing a bachelor's degree or major in the mathematical sciences usually represent a minor part of the overall teaching load. The number of students completing honours has increased modestly in the last few years, however nowhere near to the same degree as in other fields of education. Female participation in honours degrees has not increased in this century. An increase in PhD degree completions in mathematics or statistics has been partly due to international student enrolments, which is also the main reason for the increase in female participation in PhD degrees. Despite the increases, degree completions are not keeping pace with the steep rise in degree completions in other fields of education.

Mathematical sciences students and former students are usually satisfied with their educational experience and the quality of teaching they received, with the exception of the development of generic skills such as teamwork, communication and other work-related skills which consistently receives slightly lower satisfaction rates than from students in other disciplines.

2.1 Staffing at mathematical sciences departments

Table 2.1 Staff employed in participating mathematical sciences departments in FTE (excluding casuals) in 2018

	Teaching only	Research only	Teaching & research	All staff	Avg. per university
Total Go8 universities (7/8)	66	159	256	480	69
Total ATN universities (1/4)	1	1	32	34	34
Total IRU universities (5/7)	11	3	45	60	12
Total RUN universities (4/6)	2	4	39	45	11
Total unaligned universities (7/14)	13	56	88	157	22
Total all participating universities (24)	93	222	459	775	32

__Note:__ See glossary for an explanation of acronyms Go8, ATN, IRU and RUN. Numbers in brackets indicate the number of respondents out of the total number of members in each university alignment (e.g. 7 out of 8 Go8 universities responded to this question in the survey).

Charles Sturt University has newly joined RUN in 2019 and has not been included as a RUN university in this publication.

__Source:__ AMSI University Survey 2018.

In 2018, the 24 mathematical sciences departments delivering data on staff numbers to the annual AMSI University Survey (AMSI members as well as non-members) reported employing 775 staff (in FTE) (See Table 2.1).

The average number of staff members in all participating mathematics and statistics departments in 2018 was 32—but the average number of staff members varies considerably between Go8 universities and other universities. Note that casual staff members have not been included here. Among research-only staff many are employed on fixed-term contracts at levels A and B (see Chapter 4).

In the last decade, staff numbers in the mathematical sciences discipline at Australian universities have slowly started to increase again after major staffing losses during the decade between 1995 and 2005, when mathematical sciences departments at the Go8 universities alone lost about 30 per cent of their staff (Australian Academy of Science (AAS), 2006). Staff numbers reported in the Excellence in Research for Australia (ERA) data collection increased by 7 per cent (Table 2.2) from 2010 to 2018. However, the modest growth is uneven in a couple of ways.

Table 2.2 Staff numbers reported to ERA 2010–2018 in mathematical sciences by employment level at all universities (FTE)

	level A (associate lecturer)	level B (lecturer)	level C (senior lecturer)	level D (associate professor)	level E (professor)	total levels A-E
ERA 2010	155	252	196	128	126	857
ERA 2012	134	263	192	131	137	857
ERA 2015	131	280	192	142	152	896
ERA 2018	151	238	200	149	180	918
change 2010–2018	-4	-14	4	21	54	61
% change 2010–2018	-2%	-6%	2%	17%	43%	7%

__Note:__ "Other FTE staff" and "non-academic staff" as reported in ERA have not been included here. Note also that the difference in staff numbers reported in Table 2.2 relative to Table 2.1 is due to the lower response rate of the AMSI Survey from 24 mathematical sciences departments out of 40 universities. The ERA data also include mathematical sciences researchers located in departments other than mathematical sciences.

__Source:__ ARC (2010, 2012, 2015, 2018).

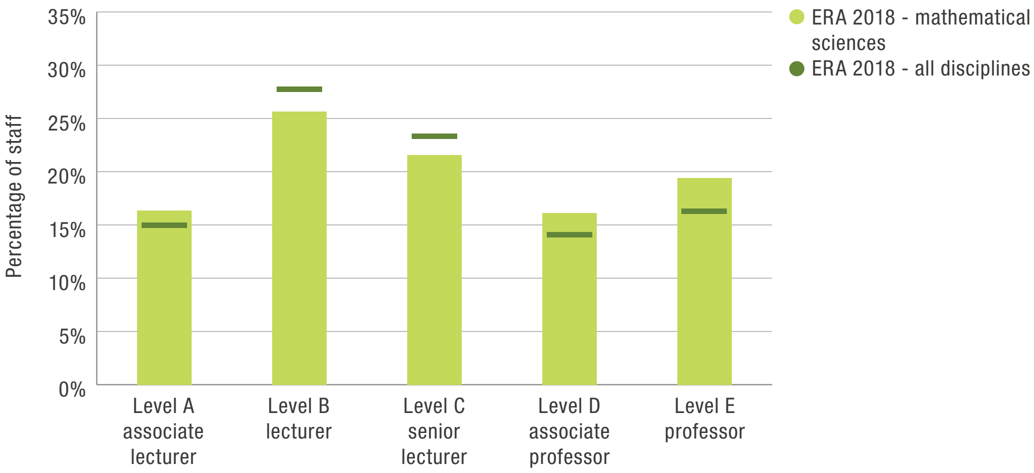
Firstly, the steady increase between 2010 and 2018 is concentrated almost exclusively at the senior levels D and E, while levels A and B fluctuated in the intervening years but ended up lower in 2018 than they were in 2010. Figure 2.3 indicates a top-heavy staffing profile, with a relatively large number of academic staff members employed at level E (professorial level). While the staffing profile is top heavy in all research disciplines, the staff levels at D and E in the mathematical sciences are even higher than in other disciplines.

The emphasis of employment at the most senior levels may be the result of the academic population ageing—if that is the case the mathematical sciences could be more deeply impacted than other disciplines if impending retirements are not offset by new appointments at more junior levels.

Second, the growth that is present is unevenly distributed across universities. Table 2.4 sets out the average academic staff numbers in the period 2011–2018 by university alignment, as reported in the annual AMSI University Survey.

Keeping in mind annual differences in number and composition of survey respondents, the average number of staff members at mathematical sciences departments has not changed greatly. Growth in average staff numbers has mostly been restricted to Go8 universities. The average staff numbers for all universities combined for 2017 and 2018 are relatively high compared to earlier years, however this is mostly a function of lower survey participation by non-Go8 universities in these two years. The differences in staff levels between Go8 universities on the one hand, and other universities, have been considerable throughout the whole period between 2011 and 2018, and the gap has likely increased.

Figure 2.3 ERA 2018 staffing profile in FTE - percentage distribution by employment level



Source: *ARC (2018).*

Table 2.4 Average staff numbers in FTE 2011–2018 by university alignment

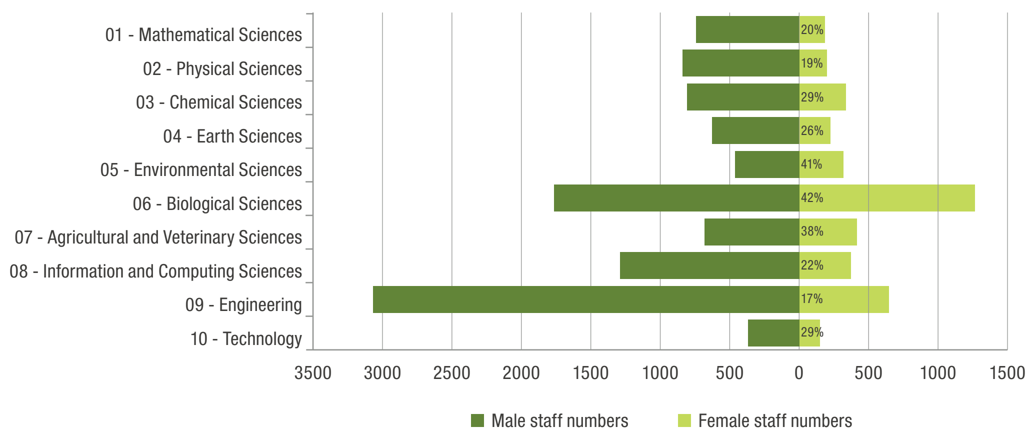
	2011	2012	2013	2014	2015	2016	2017	2018
Go8	52	53	61	60	57	62	72	69
ATN	27	27	26	24	25	31	34	34
IRU	14	15	10	11	13	12	11	12
RUN	13	12	9	11	10	10	13	11
Unaligned	20	22	14	21	27	19	26	22
All universities	29	30	24	30	29	30	35	32
number of university responses	*25*	*25*	*32*	*24*	*26*	*27*	*20*	*24*

Source: *AMSI University Survey 2011–2018. Note: Moves in alignment by the University of Newcastle, QUT and Western Sydney University have been backdated to 2011 to allow for comparison. For the purposes of this publication Charles Sturt University has not been included as a member of RUN. Staff members are reported by per university, not by department. Survey respondence by ATN universities has been very low so averages are not representative for every year.*

Figure 2.5 sets out the size and gender balance of the STEM research disciplines in Australia as reported to the ERA 2018. It shows the following:

- The size of the academic mathematical sciences workforce (level A-E) is relatively small compared to other STEM disciplines. While the research disciplines of technology, environmental sciences and earth sciences are smaller, mathematical sciences departments (as can be seen further in this chapter) carry a heavy additional teaching load helping many other fields of education with mathematical and statistical training.
- The mathematical research workforce has some of the lowest female participation of all STEM disciplines. Only engineering (with 17 per cent female participation) and physical sciences (with 19 per cent female participation) have a lower proportion of female academic staff than the mathematical sciences.

Figure 2.5 ERA 2018 - Size and gender distribution of academic staff (levels A-E) in STEM disciplines

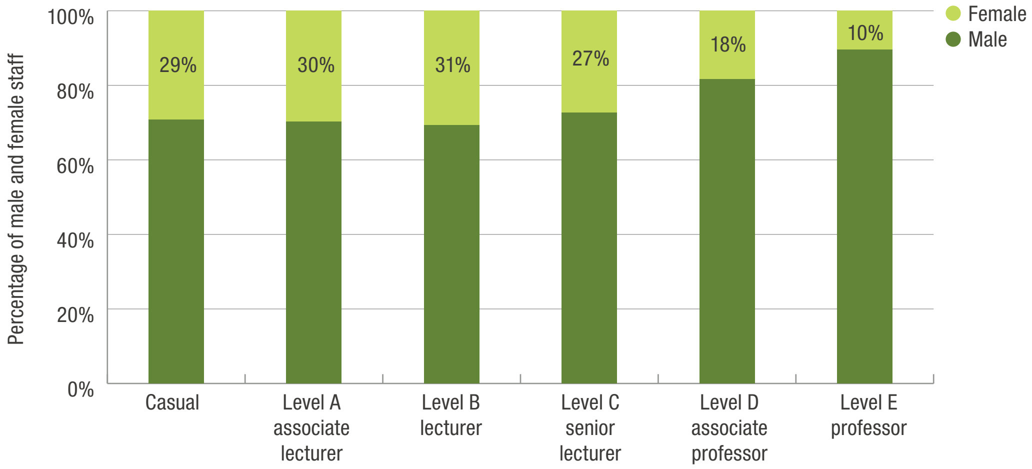


Note: *"Other FTE staff" as reported in ERA have not been included here.*

Source: *ARC (2018).*

Source: AMSI University Survey 2018. Data from 24 universities.

Figure 2.6 Staff in participating mathematical sciences departments by gender and employment level in 2018



Data from the 2018 AMSI University Survey (Figure 2.6) confirm that the academic workforce at the participating universities is predominantly male. The proportion of female academic staff reduces with the level of seniority. In 2018, about 29 per cent of reported casuals were female and 30 per cent of level A, 31 per cent at level B, and 27 per cent at level C. The female proportion of the academic workforce dropped significantly to 18 per cent at level D and 10 per cent at level E. Overall, in 2018 only 27 per cent of the academic workforce in mathematics and statistics was female. Leaving aside casual employees, the overall proportion was just 25 per cent at the universities which responded to the AMSI University Survey.

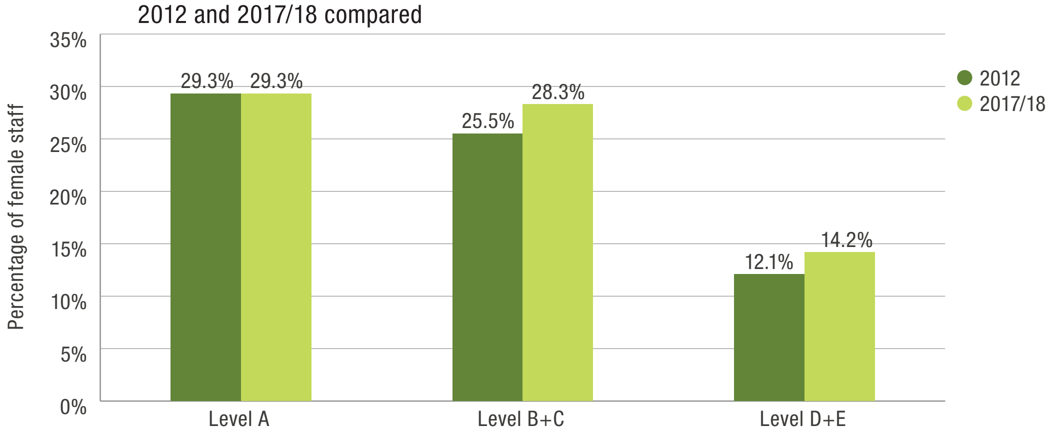
Figures 2.5 and 2.6 are only snapshots of the current gender balance. They do not provide any understanding of possible differences in the career trajectory of men and women in academia. Nor do they give a clear picture of changes to gender balance over time. In the short-term, the year-to-year differences in gender balance tracked by AMSI are heavily influenced by the mix and number of respondents captured by each survey.

Figure 2.7 below therefore compares the proportion of female academic staff from the same 20 mathematical sciences departments at 19 universities in the years 2012 and 2018 (or 2017 if 2018 numbers were unavailable). In the past few years, there has been a concerted effort at some mathematical sciences departments to attract more female academic staff, and it is heartening to see a positive change in B/C and D/E levels at the 20 departments included here. However, the increase in female participation at some universities is partially canceled out by universities where female participation has gone backwards. In addition, female participation at the junior level A is stagnant.

Further insight into patterns of hiring of academic staff at levels A and B (the entry levels for academic careers) and promotion to higher levels would be very useful to understand what is happening.

Source: AMSI University Survey 2012–2018. Note that this graph includes data from 20 mathematical sciences departments at 19 universities as one university used to have separate statistics & mathematics departments.

Figure 2.7 Proportion of female academic staff at the same 20 mathematical sciences departments in 2012 and 2017/18 compared



2.2 Mathematics and statistics teaching at universities

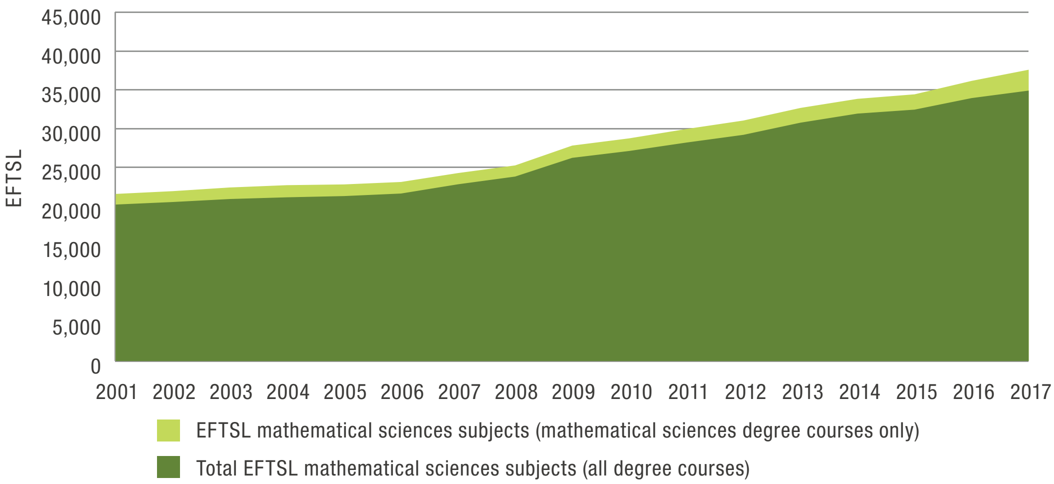
Mathematical and statistical skills and knowledge are an essential element of many university disciplines, and mathematics and statistics departments and schools supply cross-disciplinary teaching (commonly described as service teaching) to most other departments and faculties.

In fact, the vast majority of the teaching load in mathematical sciences aims to educate students who are not undertaking a mathematical sciences major but enrol in mathematics and statistics subjects as part of another major or degree.

Figure 2.8 illustrates the growth of student load of mathematical sciences subjects from 2001 to 2018. Together with Biological Sciences, Mathematical Sciences have been the specific subdisciplines within the Natural and Physical Sciences that have seen the largest increase in student load (Dobson, 2018, pages 44 & 46). The figure below underscores the large contribution of cross-disciplinary teaching to the overall student load — between 2001 and 2018, the proportion of mathematics teaching to students who are enrolled in a mathematical sciences course tended to fluctuate between an estimated 6 and 7 per cent of the total student load in the mathematical sciences in most years. In 2017 and 2018, this estimated percentage increased to nearly 8 per cent, the highest it has been in this century.

Note that this might underestimate the proportion of students studying mathematics or statistics as their main study due to differences in how universities report course participation in maths and science subjects. Nevertheless, it illustrates the importance of cross-disciplinary teaching for the mathematical sciences discipline.

Figure 2.8 Equivalent Full Time Student Load (EFTSL) in mathematical sciences 2001–2018 (all degrees)



Note: *the student load data provides no indication which Faculty, Department or School is providing the teaching in mathematical sciences subjects as universities deliver data to the Commonwealth Government centrally.*

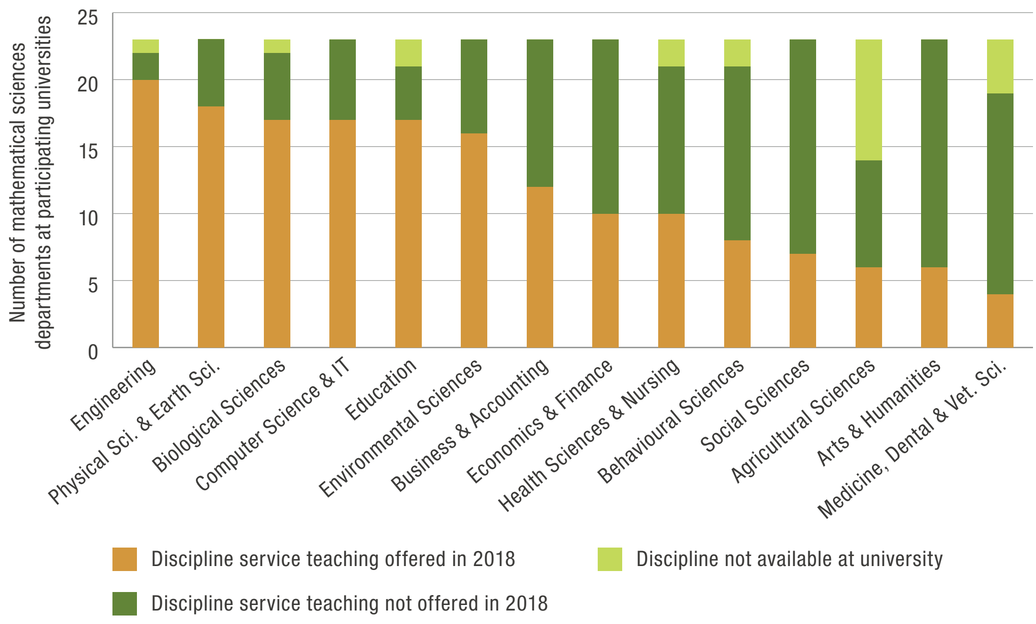
Source: *Department of Education, Skills & Employment (2019), data provided to AMSI.*

Mathematical sciences departments supply teaching to a variety of disciplines including information technology (IT), engineering, agriculture and environment, society and culture, and health and management (see figure 2.9). All university departments that responded to the AMSI University Survey supplied teaching to other disciplines in 2018. Most departments supplied teaching to at least three or four other areas, some even offering teaching to all disciplines available at their university. On average, mathematical sciences departments supported around seven other subject areas in 2018. Engineering, physical and earth sciences, biological sciences and computer science and IT are the most common disciplines to include mathematical and statistical teaching provided by mathematical sciences departments.

Note: *Data from 23 departments at 22 universities.*

Source: *AMSI University Survey 2018.*

Figure 2.9 Areas of service teaching in 2018 at participating universities



The AMSI University Survey results illustrate the breadth of disciplines supplied by mathematical sciences teaching. Figure 2.10 shows how the student load (measured in EFTSL) of all teaching in mathematical sciences subjects at the Bachelor level was divided over the several fields of education in 2018.

Mathematical sciences are a subdiscipline of the natural and physical sciences. However, teaching of mathematical sciences subjects within the natural and physical sciences only represented 30 per cent of all mathematical sciences teaching.

Almost 70 per cent of teaching in mathematical sciences occurred outside of the natural and physical sciences. Nearly a quarter of teaching is supplied to Engineering students, and over one fifth of teaching to students in Management and Commerce. Society and Culture, Education and other disciplines account for the remainder (see also Dobson 2018).

Source: *Department of Education, Skills & Employment (2019), data provided to AMSI.*

Figure 2.10 Teaching in mathematical sciences subjects in 2018 - Bachelor Pass and Honours degree course level

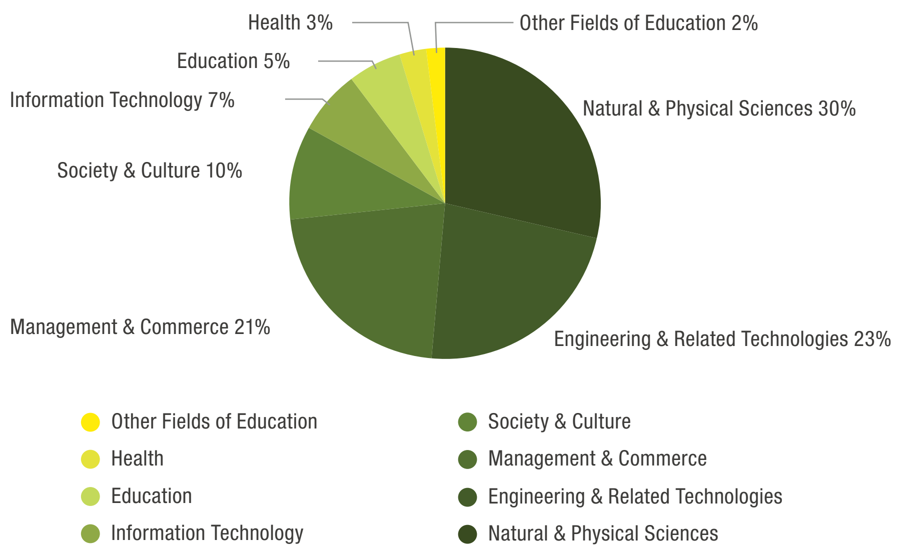


Table 2.11 Teaching by academic and casual staff at participating universities in 2018: average number of teaching hours per week

	Lecture hours all staff	% of total taught by casuals	Tutorial hours all staff	% of total taught by casuals
Go8 universities (6/8)	178	5%	323	71%
ATN/RUN universities (5/10)	48	10%	58	39%
IRU and unaligned universities (10/22)	40	22%	87	71%
All universities (21)	82	10%	148	68%

Note: *Numbers in brackets indicate the number of respondents out of the total number of members of the university alignment (e.g. 6 out of 8 Go8 universities responded to this question in the survey).*

Source: *AMSI Survey 2018. Data from 22 departments at 21 universities.*

Given the substantial teaching load, and the fact that the academic workforce on permanent and fixed-term contracts is relatively small, a large part of the teaching is performed by casual staff.

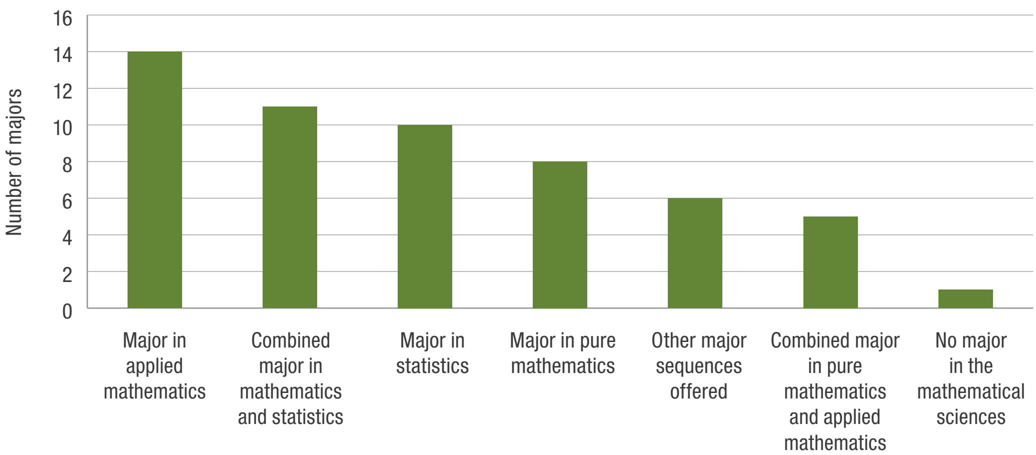
According to the data in Table 2.11, casual staff perform most of the tutorial teaching. In 2018, around 68 per cent of tutorials were taught by casual staff at the 21 universities who answered this question in the AMSI Survey. The proportion of lecture teaching by casuals was much lower, 10 per cent on average for all universities. The large share of teaching performed by casual staff members follows the insecure employment patterns commonplace at universities (Kniest 2018).

For those students who choose mathematics or statistics as their main degree study, most universities offer a choice of majors as part of (usually) a Bachelor of Science rather than a separate degree in the mathematical sciences. Majors offerings in mathematics and statistics have been stable since 2012.

Applied mathematics has consistently remained the most prevalent major offered to mathematics and statistics students in all AMSI University Surveys to date. Combined major streams in mathematics and statistics, and majors in statistics have alternated second and third place in the years since 2012.

Of the 22 departments from 21 universities that have provided data for this question in the 2018 survey, all except one reported offering at least one major in the mathematical sciences (see figure 2.12). Most participating departments offered one to three majors. There are a number of “other” majors reported, for instance in operations research, analytics, data science, data analytics, mathematical physics and oceanography. One department responding to the 2018 AMSI survey reported not offering a major in the mathematical sciences at all.

Figure 2.12 Majors offered in the mathematical and statistical sciences in 2018



Source: *AMSI Survey 2018. Data from 22 departments at 21 universities.*

2.3 Student numbers

Bachelors degrees

Figure 2.13 Average student load (EFTSL) in mathematical sciences subjects by university alignment—bachelor pass and honours degrees

__Source:__ Department of Education, Skills & Employment (2019), data provided to AMSI.

__Note:__ This graph represents alignments as of 2018. Changes in alignments of ATN and IRU have been backdated to 2005 to allow for comparison.

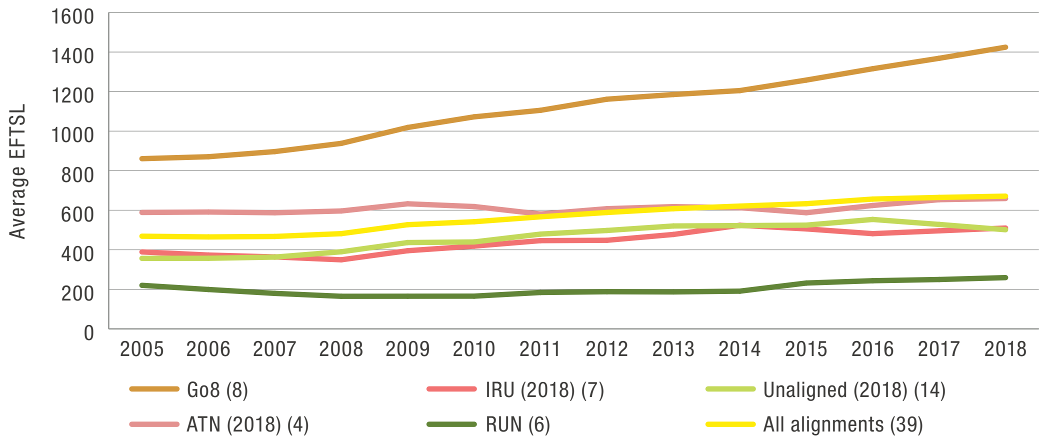


Figure 2.13 illustrates the average student load in mathematical sciences subjects per university, by university alignment.

While the average student load per university has grown 43 per cent since 2005 (from 469 EFTSL to 671 EFTSL), this increase has been unevenly distributed. Most of the growth has been concentrated in the Go8 universities (with an increase of 66 per cent, from 861 to 1424 EFTSL on average), followed by the unaligned universities (with a growth of average student load of 41 per cent from 357 to 501 EFTSL). The gap between the Go8 and other universities has grown significantly in the period since 2005.

More than half of all mathematics teaching occurs in the first year, as this is where most cross-disciplinary teaching of mathematics is concentrated. As figure 2.14 shows, the emphasis lies on teaching "commencing" students, while the student load for continuing (second year, third year and honours) students taken together covers less than half of the student load. Many students will drop mathematics after their first year (Dobson 2018, page 67).

Figure 2.14 Mathematical sciences subject student load (EFTSL) in bachelor pass and honours degrees—commencing and continuing students

__Source:__ Department of Education, Skills & Employment (2019), data provided to AMSI.

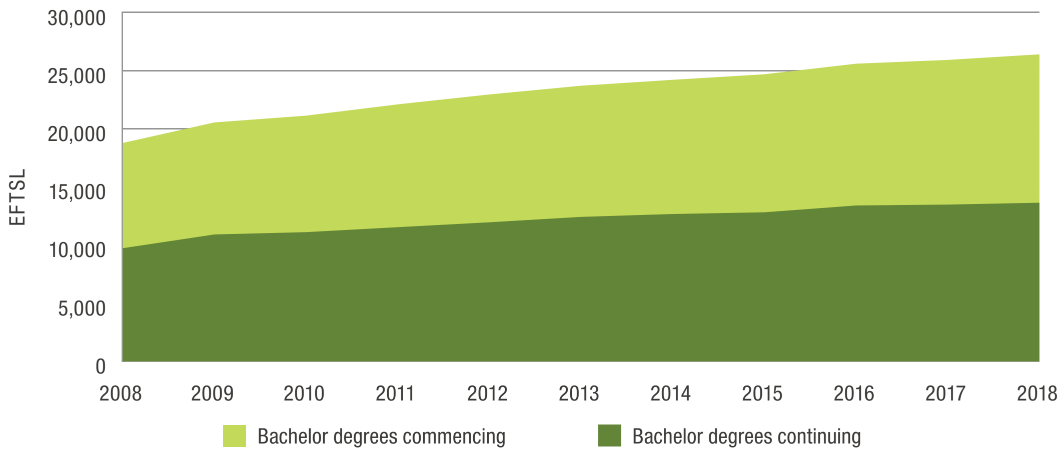
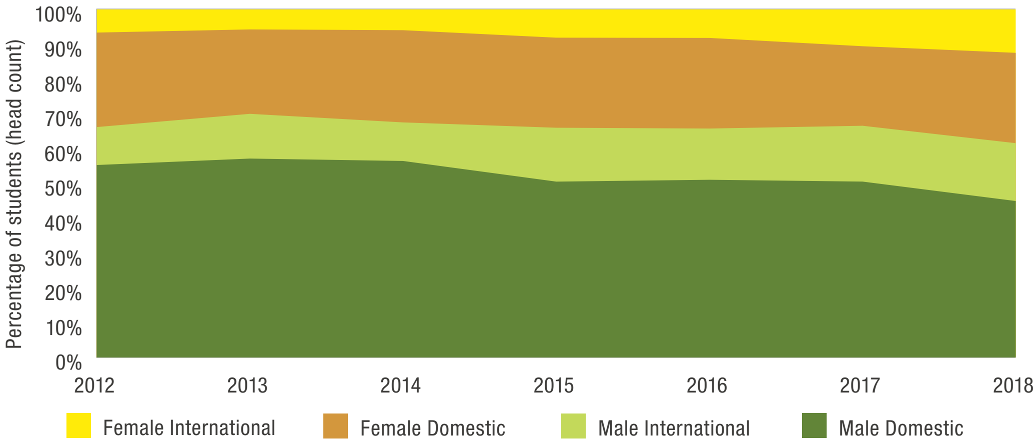


Figure 2.15 Undergraduate student profile by gender and domestic/international status 2012–2018



Source: AMSI Survey 2012–2018. This profile does not include Honours students, who are reported elsewhere.

Figure 2.15 illustrates the undergraduate student profile (excluding honours students) of students enrolled in mathematical sciences subjects according to the AMSI University Survey.

Between 2012 and 2018, the estimated proportion of international students increased from 18 per cent in 2012 to 29 per cent in 2018.

In the same period the proportion of female students increased slightly from 34 per cent to 38 per cent in 2018 (see also Dobson 2018, page 52).

Most of the growth in female participation is owed to the increase in the number of female international students; participation by female domestic students has fluctuated but there has been no overall or sustained increase.

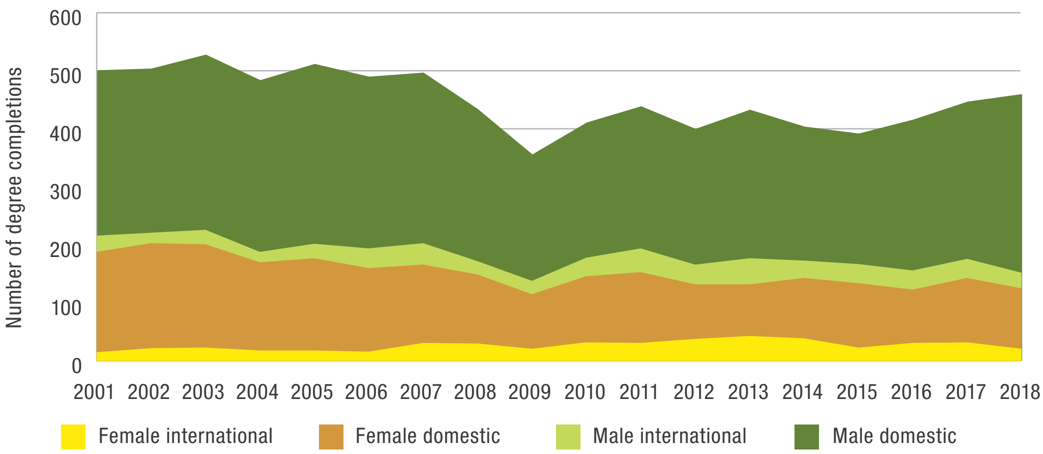
Primarily due to the growth in international student numbers, male domestic students now make up a smaller portion of the student body than previously: 45 per cent in 2018, against 55 per cent in 2012.

While the teaching load in the mathematical sciences has undoubtedly increased in recent years, it is much harder to get a sense of how many students eventually graduate as a "mathematician" or "statistician" and if these numbers have increased as well.

Many universities classify mathematical sciences degree completions as Bachelor of Science graduations, and therefore a part of the degree completions relevant to the mathematical sciences remain hidden.

According to data from the Department of Education, Skills and Employment, the number of domestic bachelors degree completions in the field of mathematical sciences has declined since 2001, see figure 2.16.

Figure 2.16 Bachelor Pass and Honours degree completions in the mathematical sciences 2001–2018 by gender and domestic/international status



Source: Department of Education, Skills & Employment (2019), data provided to AMSI.

If we were to accept the Department's higher education statistics, in the first years of this century the number of bachelors degree completions in the mathematical sciences (including honours) fluctuated around 500 every year, while the years 2007 to 2009 registered a sharp decline (mostly located in New South Wales) followed by a stabilisation around 400 completions.

However, given the manner in which universities report degree completions in science, these numbers are probably too low and the decline could be the result of changes in reporting by universities.

Given the slight increase in bachelors degree with honours completions according to the data collection on behalf of the Australian Mathematical Society (AustMS) (see Table 2.19 below), an overall decline in bachelors degree completions at least to this extent seems unlikely.

Bachelors (Honours) degrees

Peter Johnston at Griffith University, on behalf of the AustMS, assembles longitudinal data provided by mathematical sciences departments on honours and higher degree completions in the mathematical sciences in Australia.

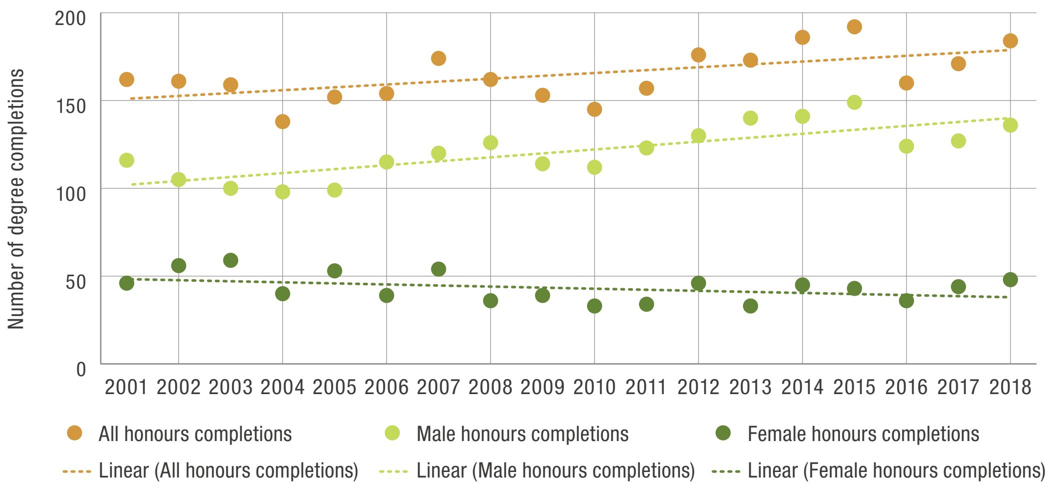
According to this data collection (summarised in figure 2.17), completions of bachelors degrees with honours in mathematics and statistics have been slowly increasing since 2000.

Note that, for the time being, the two-year Masters by Coursework degree offered at the University of Melbourne has been added to the honours data, boosting these numbers. In addition, the completions in 2014 and 2015 were relatively high but reverted to their more usual level in 2016 and 2017.

The proportion of women completing honours degrees has not been impressive in the past few years. In the 1980s the average proportion of women completing an honours degree was 26 per cent, in the 1990s this increased to 31 per cent. Unfortunately, in the last decade the proportion of female honours completions has declined to below 25 per cent.

Figure 2.17 Honours degree completions in the mathematical sciences by gender 2001–2018

Source: *Johnston (2019).*



According to AMSI University Survey responses, average bachelors degree with honours enrolments have not increased since 2011, as table 2.18 shows. Note that in the AMSI survey, the coursework masters enrolments are reported separately (see table 2.21).

Table 2.18 Average Bachelor (with Honours) enrolments in the mathematical sciences per university (in EFTSL) 2011–2018

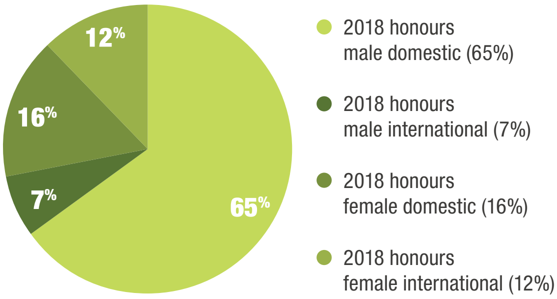
Source: *AMSI Survey 2012–2018. Note that changes in alignments of ATN and IRU have been backdated to 2011 to allow for comparison.*

Honours	2011	2012	2013	2014	2015	2016	2017	2018
Average Go8 universities	15	14	13	15	15	15	12	15
Average ATN universities	5	4	5	1	12	3	5	3
Average RUN universities	<1	<1	5	1	1	1	2	1
Average IRU universities	5	4	3	3	3	2	1	1
Average unaligned universities	3	5	3	<1	4	2	3	3
Average all universities	7	7	6	6	7	6	5	5

With regard to the composition of the student population achieving the bachelors degree with honours, figure 2.19 shows that according to AMSI survey responses, 28 per cent of enrolments in bachelors degrees with honours in the mathematical sciences were female in the 2018 cohort; but only 16 per cent were domestic female students.

Figure 2.19 Bachelor (Honours) student profile by gender and domestic/international status at participating universities in 2018

Source: AMSI Survey 2018. Data from 19 universities.



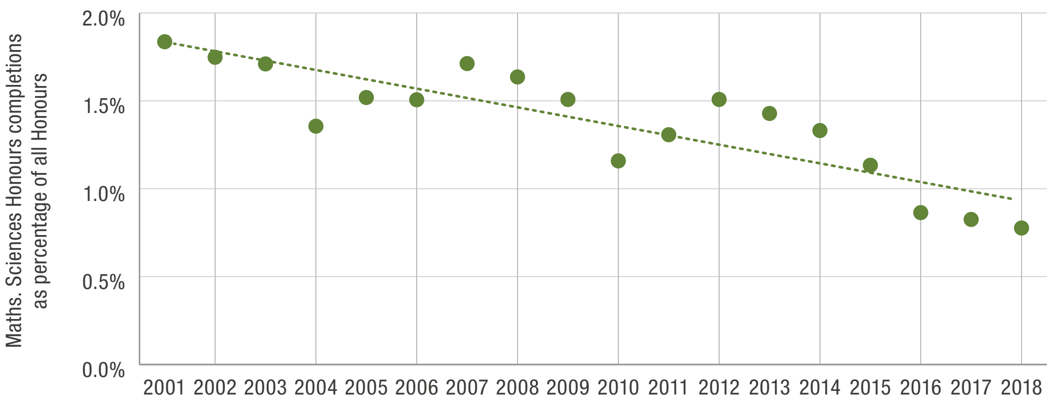
It is also important to note that the total number of honours completions in the mathematical sciences has not kept pace with the overall increase in honours completions in other fields of education (see figure 2.20).

The number of bachelors degree with honours completions in all fields of education in Australia has risen by 169 per cent since 2001. Between 2014 and 2018 alone, honours completions in all fields of education increased by 69 per cent.

By contrast, according to the AustMS data collection, honours completions in the mathematical sciences were 14 per cent higher in 2018 than in 2001. This suggests that honours completions in the mathematical sciences have completely missed this trend.

Figure 2.20 Bachelor (Honours) completions in mathematical sciences as a proportion of honours degrees in all fields of education 2001–2018

Source: Johnston (2019), Department of Education, Skills & Employment (2019).



Higher degrees

Table 2.21 Average higher degree enrolments in mathematical sciences per university 2011–2018

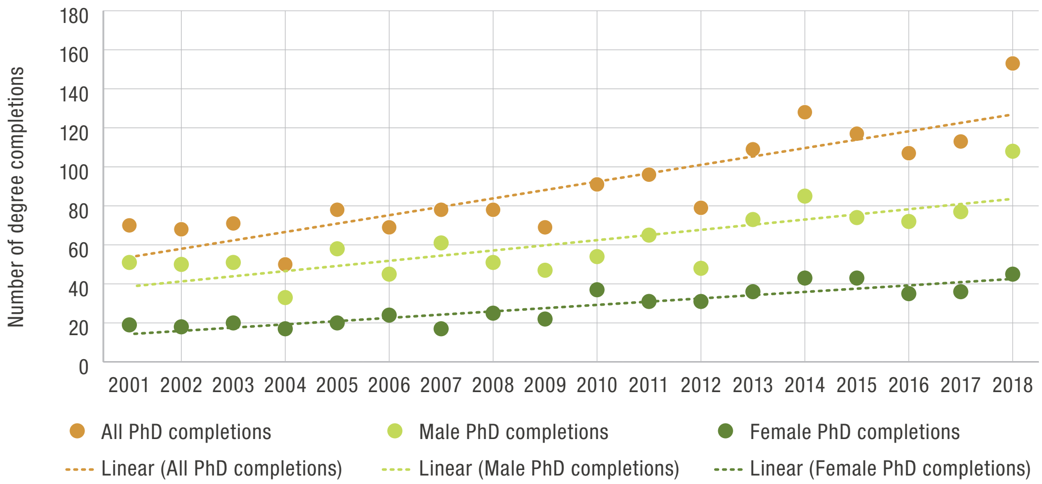
Source: AMSI Survey 2012–2018. Note that changes in alignments of ATN and IRU have been backdated to 2011 to allow for comparison.

Masters by Coursework	2011	2012	2013	2014	2015	2016	2017	2018
Average Go8 universities	20	19	16	20	24	27	35	69
Average ATN/RUN/IRU universities	10	13	20	3	12	5	42	30
Average unaligned universities	7	5	4	3	10	1	2	3
Average all universities	12	13	14	8	15	11	31	35
Masters by Research	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Average Go8 universities	5	4	4	6	3	4	2	5
Average ATN/RUN/IRU universities	1	1	1	<1	1	1	<1	<1
Average unaligned universities	1	2	2	1	3	2	4	2
Average all universities	2	2	2	2	2	2	2	2
PhD	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Average Go8 universities	36	38	37	45	42	39	46	42
Average ATN/RUN/IRU universities	9	10	8	4	10	13	12	7
Average unaligned universities	23	23	16	16	21	18	21	17
Average all universities	21	23	18	21	23	22	25	21

According to Table 2.21, average enrolments in Masters by Coursework degrees have increased considerably since 2016. However, this increase is concentrated at a very small number of universities such as the University of Melbourne which offers a two-year masters degree as part of the "Melbourne Model". Many universities have only a few, or no Masters by Coursework enrolments in the mathematical sciences. The number of Masters by Research degree enrolments has remained at the same low level since 2011.

Figure 2.22 PhD completions in the mathematical sciences in the period 2001–2018 by gender

Source: Johnston (2019).

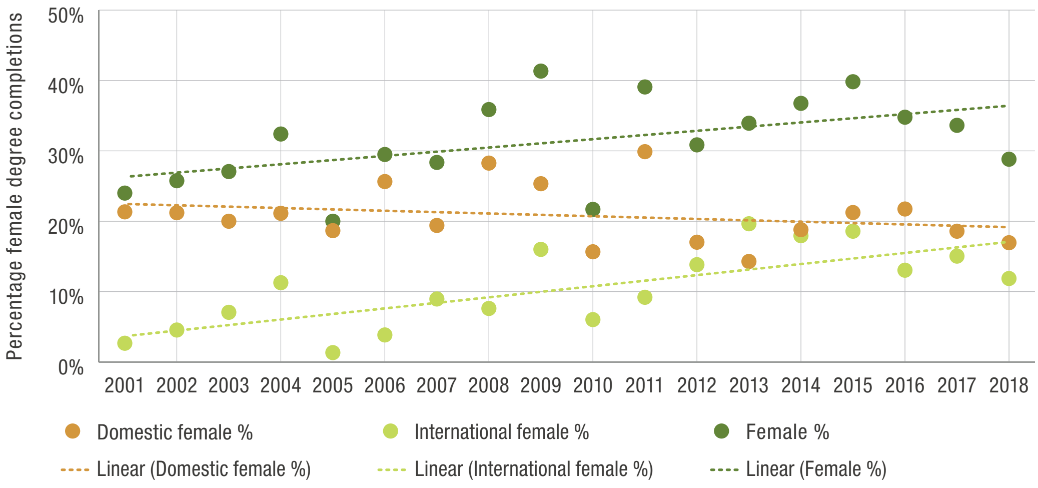


Over the past 30 years, the number of PhD completions in the mathematical sciences has increased according to the AustMS data collection (which is more comprehensive than the Higher Education statistics). This growth is partly due to a rise in the number of women completing a PhD (see figure 2.22) during this period.

In the 1980s, the average proportion of women completing a PhD in mathematics and statistics was only 12 per cent; this rose to 23 per cent in the 1990s and in the first decade of this century, 29 per cent of PhD graduates were female.

Since 2010 the average female proportion of PhD completions has risen to 33 per cent. However, as shown in figure 2.23, this is likely due to the contribution of international female students, while the proportion of domestic female students has remained largely stagnant.

Figure 2.23 Female proportion of PhD degree completions in the mathematical sciences by domestic/international status 2001–2018



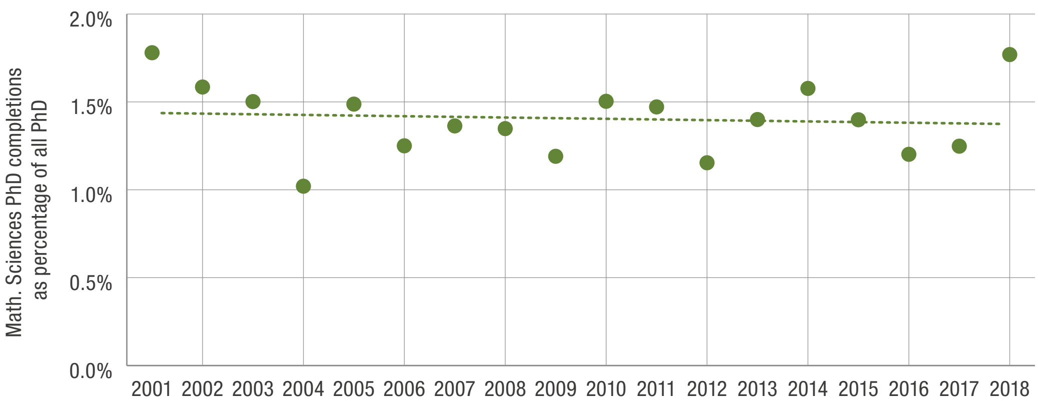
Source: *Department of Education, Skills & Employment (2019), data provided to AMSI. Note that Johnston (2019) does not distinguish between international and domestic completions.*

Despite an upward trend in the number of PhD completions within the mathematical sciences, it should be noted that the number recorded is barely keeping pace with increases recorded for PhD degrees in other disciplines.

In most years since 2001, the mathematical sciences have covered less than 1.5 per cent of PhD degrees in all fields of education (see figure 2.24 below). Since 2001, the number of PhDs in all fields of education has increased by 120 per cent, and by 43 per cent in the last ten years (Department of Education, Skills and Employment 2019). In the same period, PhD completions in the mathematical sciences have grown by 119 per cent since 2001 (and 68 per cent since 2010) (Johnston 2019).

While it may look like PhD completions in the mathematical sciences have kept up with the general trend in PhD completions, note that in 2018 the number of PhD completions in the mathematical sciences was unusually high compared to earlier years while the number of PhD completions in all fields of education was lower than the previous year.

Figure 2.24 PhD completions in mathematical sciences as a proportion of PhD degrees in all fields of education 2001–2018



Source: *Johnston (2019), Department of Education, Skills & Employment (2019).*

Student experience and course satisfaction

The annual QILT Student Experience Survey asks current students about their impressions of the quality of the courses they are undertaking. The survey includes questions on skills development, learner engagement, teaching quality, student support and learning resources, and asks for students' overall assessment of the quality of their educational experience.

The results of this survey for the year 2018 shows that in general, mathematics students were most content about the teaching quality and the learning resources, which received an approval rating of 87 per cent (see Table 2.25).

The respondents were also relatively happy with the overall quality of their educational experience. However, in two areas mathematics students rated their experience slightly less positively than other students: skills development (which covers notions such as critical and analytical thinking, solving complex problems, as well as working effectively with others, written and spoken communication skills, and work-related knowledge and skills), and learner engagement (which covers myriad ways of connection to the institution and to other students, such as having a sense of belonging to the institution and opportunities for interaction with other students inside and outside study requirements).

Table 2.25 The undergraduate student experience, by study area, 2018 (% positive rating)

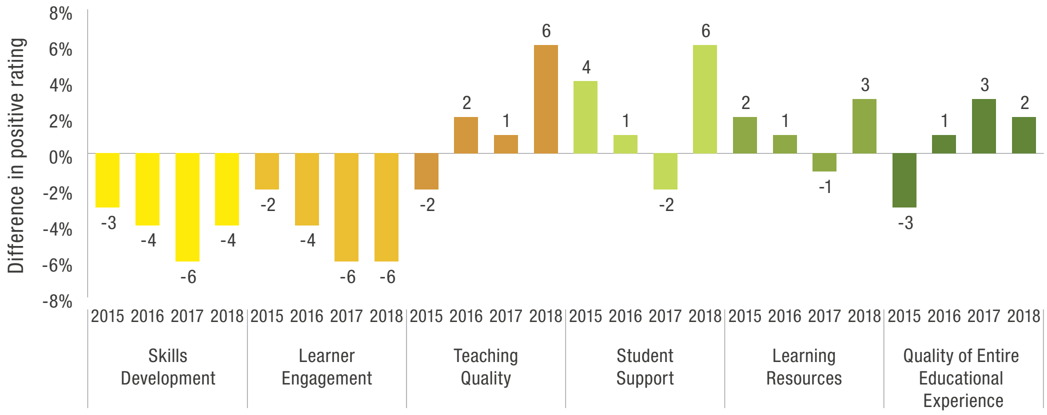
Source: QILT (2019c), data extracted from table 60, page 104.

2018	Skills Development %	Learner Engagement %	Teaching Quality %	Student Support %	Learning Resources %	Quality of Entire Educational Experience %
Science and mathematics	**80**	**61**	**84**	**75**	**88**	**81**
* Natural & Physical Sciences	79	59	83	73	88	80
* Mathematics	77	54	87	79	87	81
* Biological Sciences	84	63	86	77	90	84
* Medical Science & Technology	81	65	85	76	89	82
All fields of education	**81**	**60**	**81**	**73**	**84**	**79**

While the mathematics students' assessment follows roughly the same pattern as the approval rating by other students, comparison with students of all fields of education shows that the rating for learner engagement and skills development has been consistently lower for mathematical sciences students in the period 2015–2018 (see figure 2.26) than for other students. Comparison of results between institutions, cohorts and disciplines should be treated with caution. Lower ratings for learner engagement and skills development have not necessarily led to a lower rating of the overall quality of the student experience and how students rank the relative importance of the various elements of the student experience is not known.

Figure 2.26 Student experience of mathematical sciences students compared to student in all fields of education (difference in % positive rating)

Source: QILT (2016) Appendix 8, page 64; QILT (2017) Table 61, page 85; QILT (2018a) Table 59, page 95; QILT (2019c) Table 60, page 104.



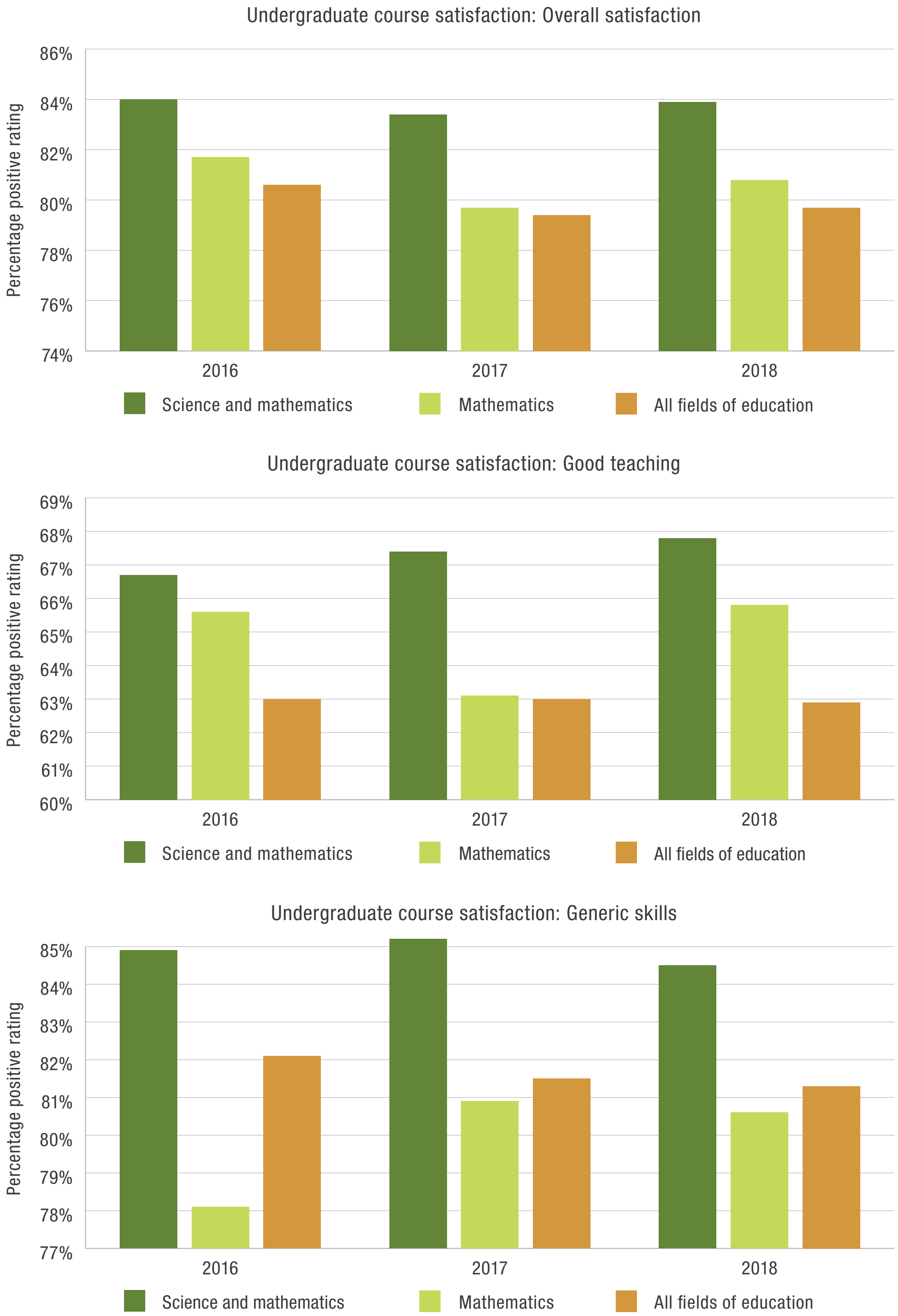
Four months after completion of their degree, former students from Australian universities are asked to complete a questionnaire, which includes questions on how satisfied they are with the education they have received. The new graduates are asked to rate the quality of the teaching, the generic skills they have acquired and their overall satisfaction with the educational experience.

Figure 2.27 sets out the satisfaction of those who received an undergraduate degree in the years 2016 to 2018. Given the relatively low number of respondents (around 400) of graduates in the mathematical sciences, the results should be viewed with some caution. However, it is interesting to note that while "science and mathematics" graduates responses taken together consistently indicate a higher course satisfaction than the general cohort of graduates in all fields of education, separating the mathematics students from the other science students reveals some differences. It seems that mathematics graduates' rating of their course is generally lower than for science graduates in general. While the differences are small, they are consistent.

Former mathematical sciences students rate their "generic skills" consistently lower than science and mathematics students overall, as well as students from all fields of education. "Generic skills" include teamwork, analytical, problem-solving and planning skills, written communication, and self-confidence to tackle unfamiliar problems. As such, it overlaps with the "skills development" evaluated via the Student Experience Survey.

Figure 2.27 Course satisfaction: generic skills, good teaching and overall satisfaction

Source: *QILT (2019a) (2019b), table 54; (2018b), table 40.*



In Australia, around 33,000 people have a qualification in the mathematical sciences

Most of them **(66%)** have a bachelor degree, and around **30%** hold a postgraduate degree. This represents only **0.7%** of all people with a university degree. **See page 54**

A rapidly ageing mathematical workforce

In 2016, **17%** of people with a mathematical sciences qualification was **65** or older, up from **7%** in 2006. Labour force participation declined from **75%** in 2011 to **71%** in 2016. **See page 54**

Employment prospects for newly graduated mathematical scientists with an undergraduate degree is around the average for all new graduates

About **73%** of new bachelors find full time work within **4 months** after completing their degree. **See page 59**

The top three occupations for mathematical scientists in 2016

- Secondary school teachers
- Software & applications programmers
- University lecturers & tutors

See page 61

But the largest employment growth for mathematical scientists can be found in other professional occupations.

There has been increased demand for actuaries, statisticians and mathematicians, management and organisational analysts and professionals in “new” jobs such as data science. **See table 3.13**

3 MATHEMATICAL SCIENCES IN THE WORKFORCE

NUMERACY SKILLS, COMPETENCY & CHARACTERISTICS OF THE MATHEMATICAL WORKFORCE

Numeracy is a key cognitive and workplace skill and an indicator of mathematical competency in the workplace and the wider population. The average numeracy proficiency of the Australian population is slightly higher than the OECD average. In 2011, about 43 per cent of the Australian adult population had numeracy skills ranging from more than basic to advanced. There is however a significant gap in numerical competency between men and women across all age bands between 15 and 74 years of age.

According to the 2016 Census, over 31,000 people in Australia have a university degree in the mathematical sciences. About 43 per cent of them are women, compared to 39 per cent in 2006. While the mathematical workforce has grown modestly in recent years, it is ageing more rapidly than most other STEM disciplines.

A large proportion of mathematicians work in education and training (as secondary school teachers or university lecturers and tutors); professional, scientific and technical services; and finance and insurance services.

In most of mathematicians' and statisticians' top twenty occupations employment is expected to grow in the near future.

The decade between 2006 and 2016 has seen employment grow for mathematicians and statisticians in relatively new professional occupations, including data scientists. Employment for actuaries, mathematicians and statisticians has also increased. Other occupations employing more mathematical scientists include management and organisation analysts and university lecturers and tutors.

3.1 Numeracy skills in the adult population

In the modern, post-industrial economy information processing and numeracy skills are becoming ever more important.

To measure key cognitive and workplace skills, the Programme for the International Assessment of Adult Competencies (PIAAC) uses a scale with six levels to measure numeracy in its international survey—level five is the highest and below level one is the lowest.

According to analysis of PIAAC survey outcomes, numeracy skills are linked to better outcomes in employment, wages and health.

For example, those who scored level four or five in the survey were about seven per cent more likely to have a job than individuals who scored at or below level one (Jonas 2018, page 49). They also had an average hourly income that was 13 per cent higher than those in level one or below (Jonas 2018, page 53). There is also a strong correlation between numeracy skills and health, with adults scoring at level four or five 22 per cent more likely to report good to excellent health (Jonas 2018, page 66).

Shown in figure 3.1 are the PIAAC results across Australia's adult population. In Australia, 11 per cent of the adult population (1.8 million) has numeracy skills at level four, and 1.4 per cent (230,000) at level five. Of the adult population, 31 per cent (5.2 million) fall into level three. The majority, 53.5 per cent of the Australian population had numeracy skills at or below level two in 2011.

These results mean that over half of Australian adults have at most basic numeracy skills: calculation with whole numbers and common decimals, percentages and fractions, and the interpretation of relatively simple data and statistics in texts, tables and graphs. The 43.4 per cent of the Australian adult population in level three and above understand mathematical information that may be less explicit, and more complex. It may require being able to choose problem-solving strategies and being able to perform tasks which require several steps. The average numeracy proficiency in Australia is slightly higher than the current OECD average—see figure 3.2.

Figure 3.1 Proportion of Australian adult population at each numeracy level 2011–2012

Source: ABS (2013).

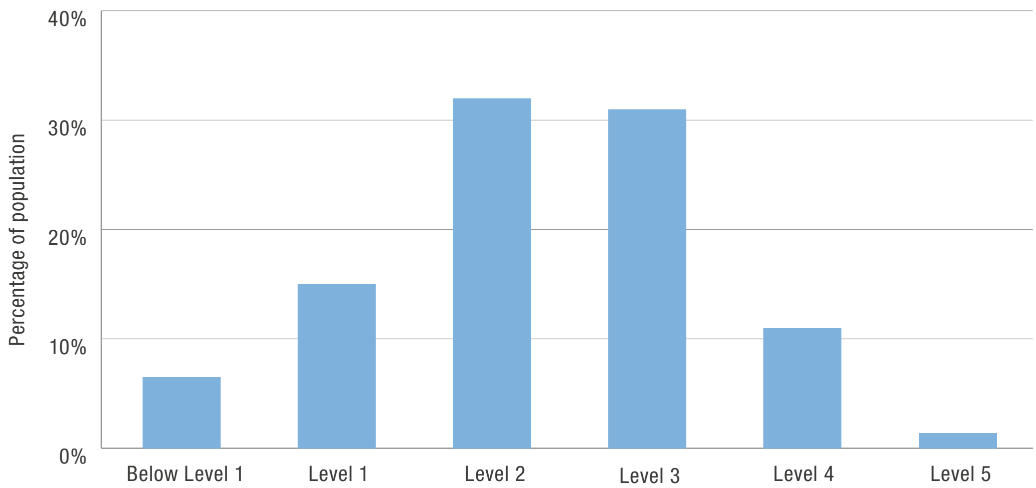
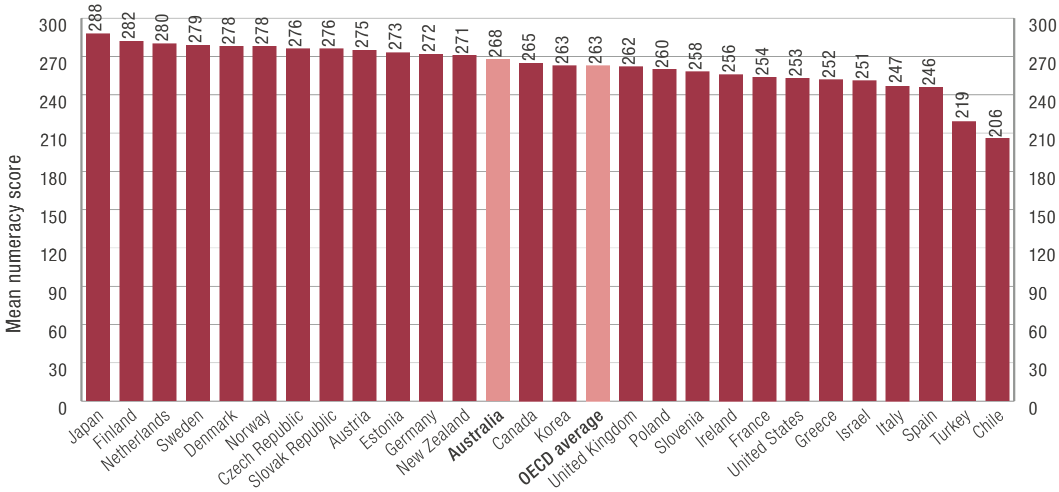


Figure 3.2 Mean numeracy score in the Survey of Adult Skills (PIAAC)

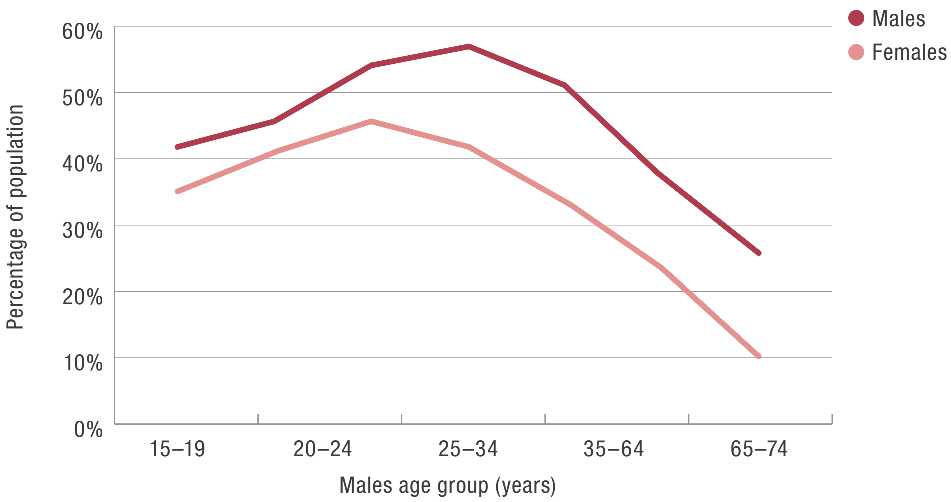
Source: *OECD (2015).*



The data shown in figure 3.3 suggests that numeracy competency is closely related to age and gender. Numeracy skills for both genders tend to drop after peaking between the ages of 35 and 44 and fall to their lowest for people of retirement age (65 years and over). The data also illustrates the consequences of the under-representation of girls and young women in school and university level mathematical education. There is a significant, and constant, gap in the mathematical skills between Australian men and women.

Figure 3.3 Proportion of Australian adult population at numeracy level 3 or above, by gender and age group 2011–2012

Source: *ABS (2013).*



3.2 Mathematicians and statisticians in the workforce

According to the most recent ABS Census of 2016, in response to an open question about the main field of study of their highest qualification, 33,454 people reported they had a qualification in the mathematical sciences. This was an increase of about 6,300 compared to the previous Census in 2011 (Australian Bureau of Statistics ABS 2018a).

In Australia vocational tertiary degrees in the mathematical sciences (typically TAFE and similar degrees) as such are not offered. The highest qualifications of mathematical scientists are therefore almost exclusively university degrees (94 per cent, or 31,333 people)—note that not everyone with a mathematical sciences qualification will have received it in Australia.

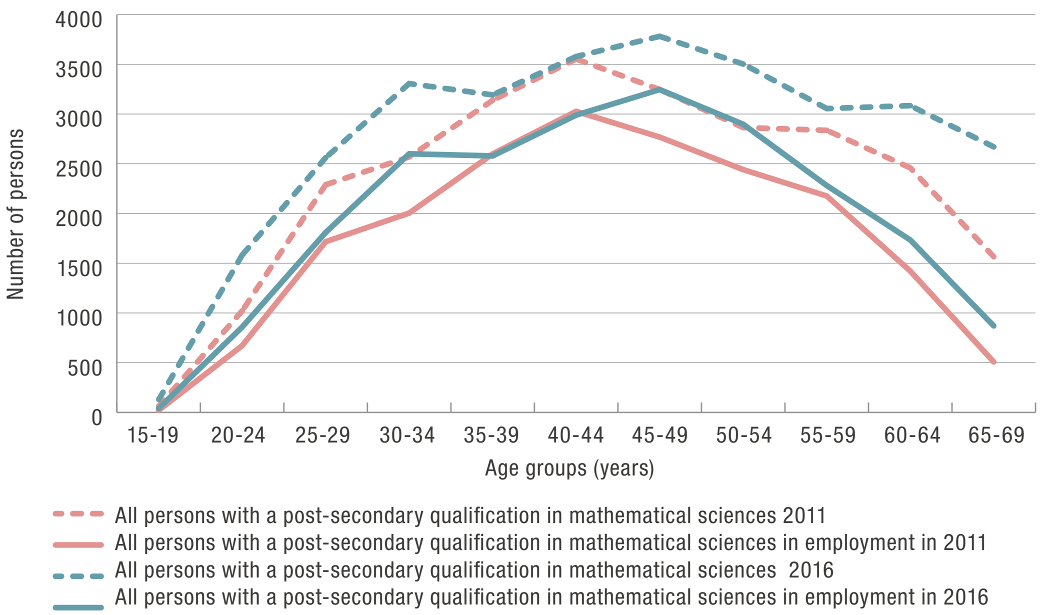
Despite the increase in the number of people with a mathematical qualification, the proportion of mathematical sciences university graduates decreased from 0.8 per cent to 0.7 percent of all people with a university degree since 2011. In 2016, most mathematical scientists (66 per cent) had a bachelor degree as their highest level of qualification. About 17 per cent held a masters degree, and 12 per cent a PhD degree. This is the lowest percentage of doctoral degrees of the "traditional" science disciplines physics, biology and chemistry (OCS 2020, page 102. Data provided by Office of Chief Scientist, March 2020).

Figure 3.4 below sets out the composition of the mathematical workforce in 2016, compared to 2011. The figure includes everyone with a post-secondary qualification in the mathematical sciences (both university and non-university degrees).

Although the number of people with mathematical qualifications has increased since 2011, most of the increase is in the older age groups, and the net growth of people in actual employment was about 3,800. In 2011, 11 per cent of all mathematical sciences degree holders was 65 years of age or older, up from seven per cent in 2006. In 2016, this percentage had increased even further to 17 per cent. At the same time, labour force participation (meaning in employment or looking for employment) declined from 75 per cent in 2011 to 71 per cent in 2016.

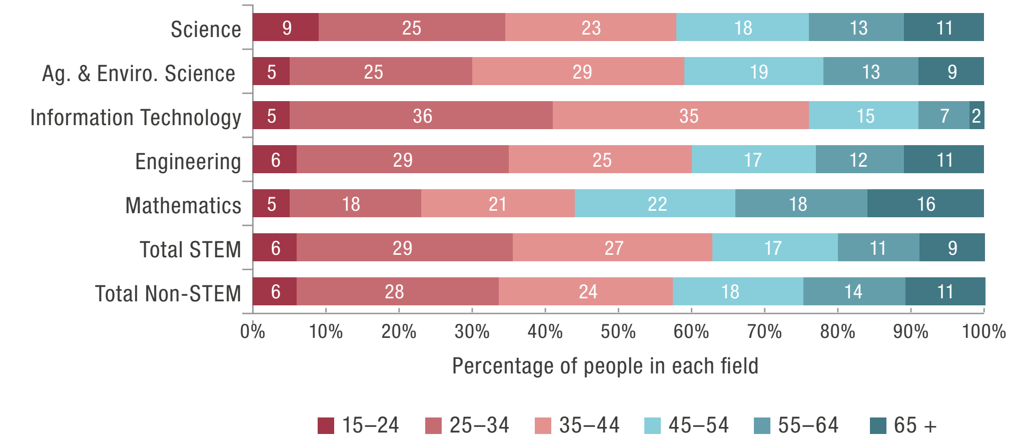
Figure 3.4 Mathematical workforce in 2011 and 2016

Source: *ABS (2018a).*



The population with university qualifications in mathematical sciences is the oldest of all of the university STEM-qualified populations in Australia. While the STEM qualified population overall is already older than the non-STEM population, 56 per cent of university-qualified mathematical scientists are 45 years or over (see figure 3.5). The proportion of people aged up to 34 years old is, at 23 per cent, far lower than the other STEM disciplines.

Figure 3.5 Proportion of university qualified people in each age group



Source: *Figure provided by Office of Chief Scientist upon request, March 2020.*

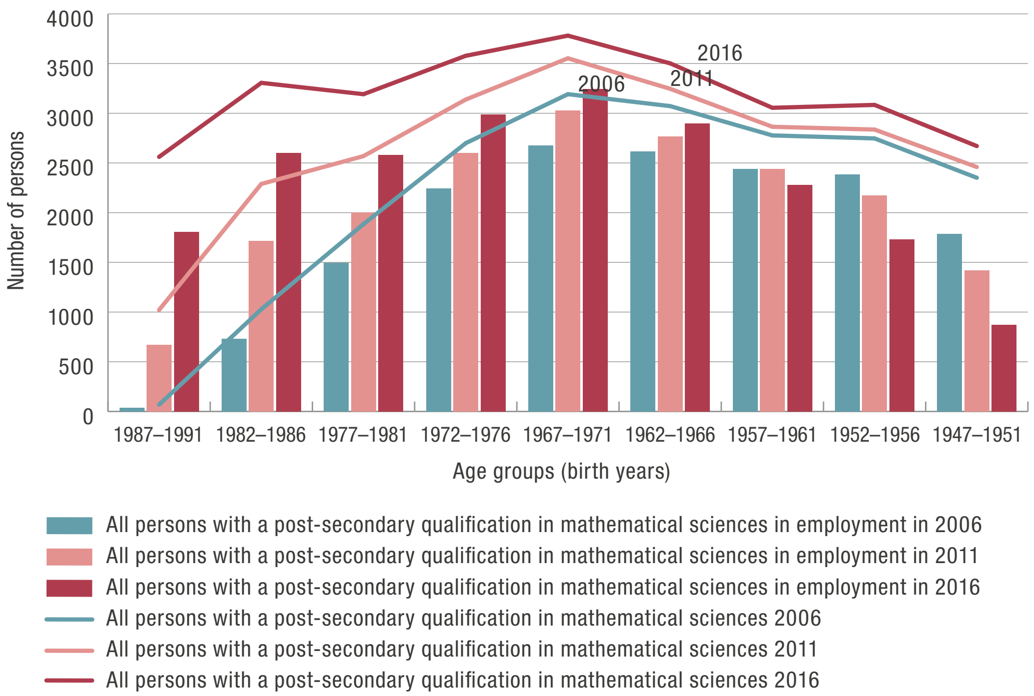
A closer look at the employment levels of mathematicians and statisticians in different birth cohorts (see figure 3.6) reveals that growing employment numbers in each cohort born since 1962 have compensated for the gradual retirement of the oldest cohorts — so far.

The largest cohort of mathematical scientists was born between 1967 and 1971 (45–49 years old in 2016). This cohort also had the highest employment rate, at 86 per cent. The employment rate for the youngest cohort depicted here, between 25 and 29 years old in 2016, was only 71 per cent, with 24 per cent not participating in the labour force at the time. This cohort possibly included a fairly large proportion still studying, and its employment levels are likely to increase before the next Census.

However, to compensate for the eventual retirement of the older cohorts (those born between 1962–1966 are likely to gradually start moving to retirement within the next decade) as well as fulfilling any future additional demand for mathematicians and statisticians, the mathematical workforce might need to grow more convincingly than the last ten years.

There could also be room for further growth in the labour force participation rates of the cohorts born between 1977 and 1986 (aged between 30–39 in 2016) which at 79 and 81 per cent was significantly lower than for those who were in their forties in 2016.

Figure 3.6 Mathematical sciences workforce qualifications and employment levels by cohort 2006–2016



Source: *ABS (2018a).*

Figure 3.7 shows the gender distribution of those with a mathematical sciences qualification.

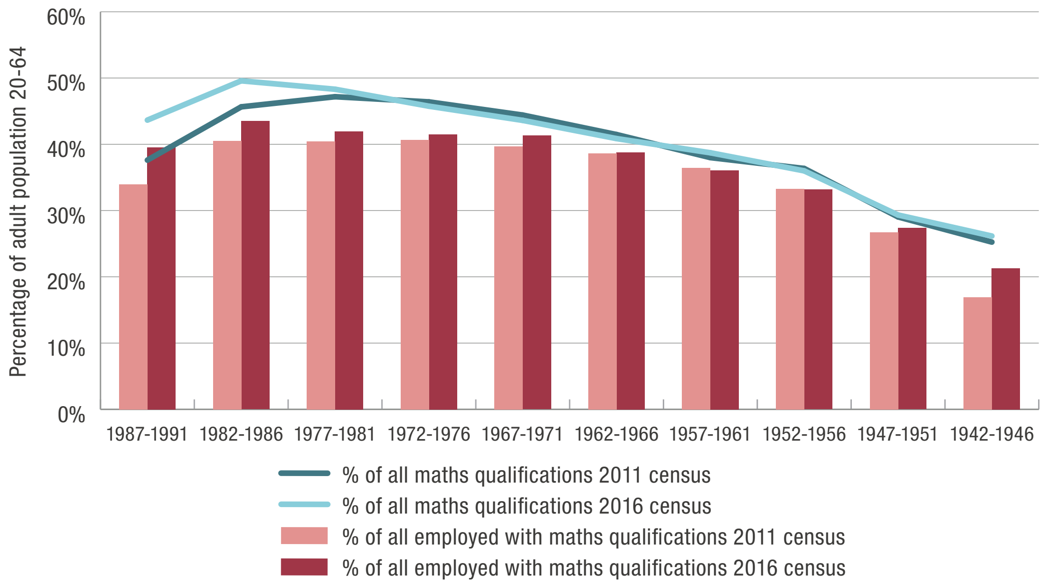
Among the adult population between the ages of 20 and 64 with a university degree in the mathematical sciences, women made up 43 per cent in 2016, up from 41 per cent in 2011 and 39 per cent in 2006 (ABS 2018a).

Figure 3.7 shows the gender balance becoming more equal the younger the cohort, for every population cohort born since 1942. In the cohort born between 1982 and 1986 (aged between 30 and 34 in 2016), just about 50 per cent of people with a mathematical qualification was female.

The cohort born between 1987 and 1991 (aged 25–29 in 2016) might also yet achieve gender balance as they fully complete their education. However, it is worth noting that the female employment rate has not quite increased in the same way as the qualification rate.

Figure 3.7 Female proportion of mathematical science qualifications and employment by birth cohort - 2011 and 2016

Source: *ABS (2018a).*



Of the mathematical sciences graduates in the labour force, 71 per cent were employed in the private sector, 17 per cent worked for national government and 12 per cent for a state or territory government (ABS 2018a).

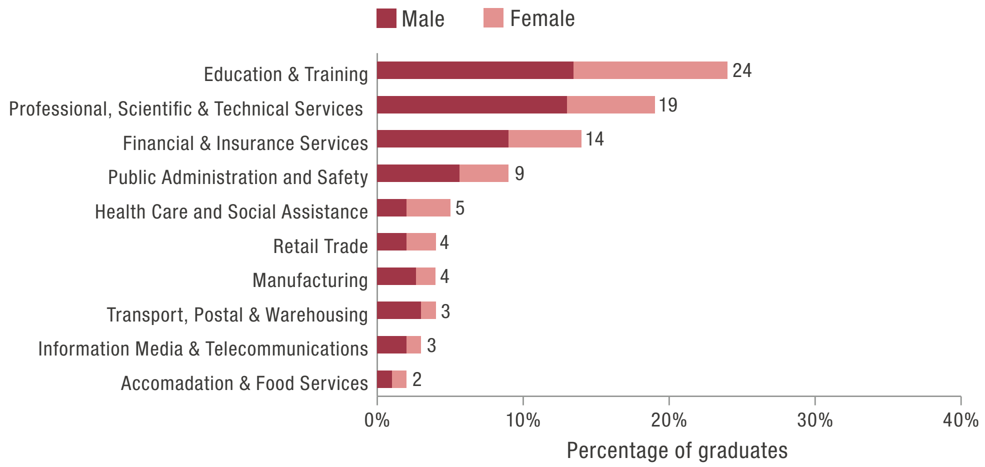
The top ten industry divisions in which mathematicians and statisticians were employed are displayed in figure 3.8. Education and training (24 per cent) and professional, scientific and technical services (19 per cent) employed nearly half of all mathematicians and statisticians.

It is interesting to note the difference in gender balance across industry divisions. Most industries employed more male than female mathematical scientists.

However, in education and training the proportion of females was around 46 per cent, in financial and insurance services around 36 per cent, while in professional, scientific and technical services the female proportion was 30 per cent.

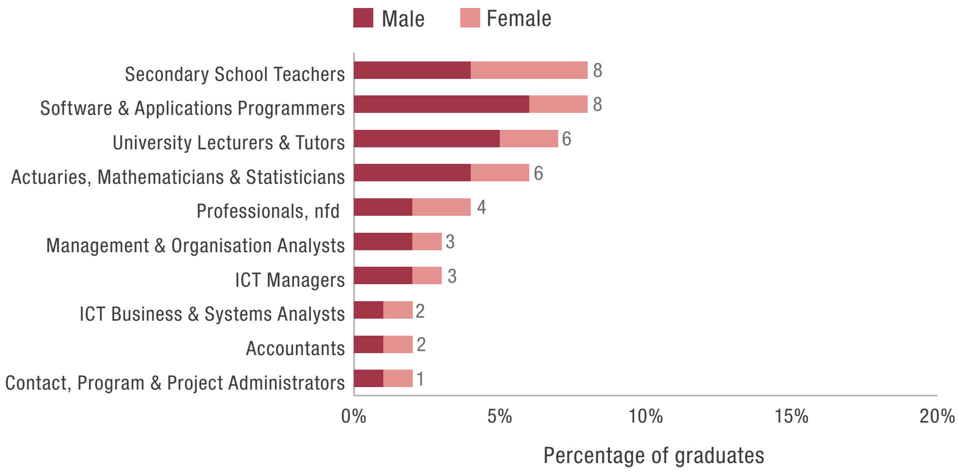
Figure 3.8 Top ten industry divisions of employment for Mathematical Sciences graduates with qualifications at bachelor level and above, by gender

Source: *Figure provided by Office of Chief Scientist upon request, March 2020.*



The differences in gender balance are even more pronounced when viewed across the top 10 mathematical science occupations. The vast majority of mathematicians and statisticians classified themselves as professionals (60 per cent)—most commonly in the sub-groups "Business, Human Resource and Marketing Professionals", "Education Professionals", and "ICT Professionals". Figure 3.9 sets out the top occupations in more detail. Among secondary school teachers the gender balance was even, whereas for university lecturers and tutors the proportion of women was more like 29 per cent (which is consistent with results from the AMSI University Survey as discussed in Chapter 2). What is also clear from this graph is that many mathematical scientists have ended up in a range of ICT-related occupations. That is, as programmers, managers, business analysts or not-further-defined ICT professionals.

Figure 3.9 Top ten unit group level occupations of Mathematical Sciences graduates with qualifications at bachelor level and above, by gender

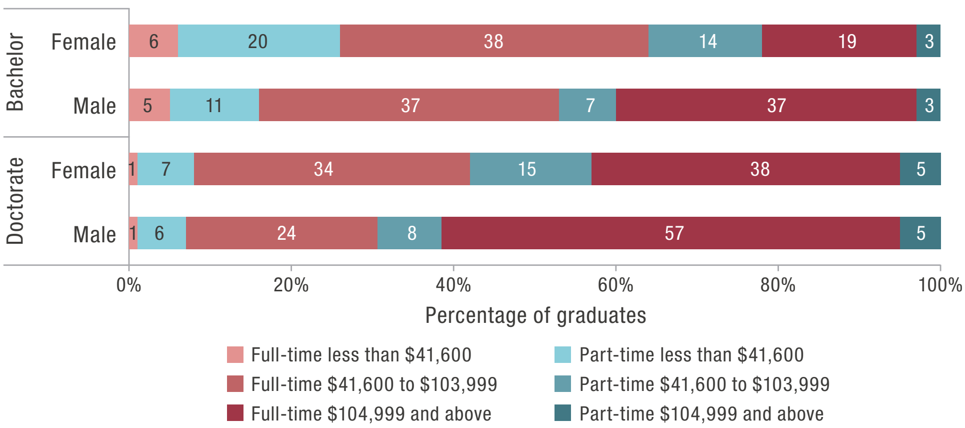


Note: *nfd - Not further defined*

Source: *Figure provided by Office of Chief Scientist upon request, March 2020.*

Figure 3.10 highlights how graduate income levels depend on the type of degree, with 62 per cent of male, and 43 per cent of female doctorate degree holders located in the highest income bracket. However, gender and part-time versus full-time employment were also strong predictors of income level. In most income brackets more women than men worked part-time. The part-time workers were more heavily presented in the lower and middle income brackets.

Figure 3.10 Personal annual income of Mathematical Sciences graduates working full-time and part-time, by field, gender and level of qualification



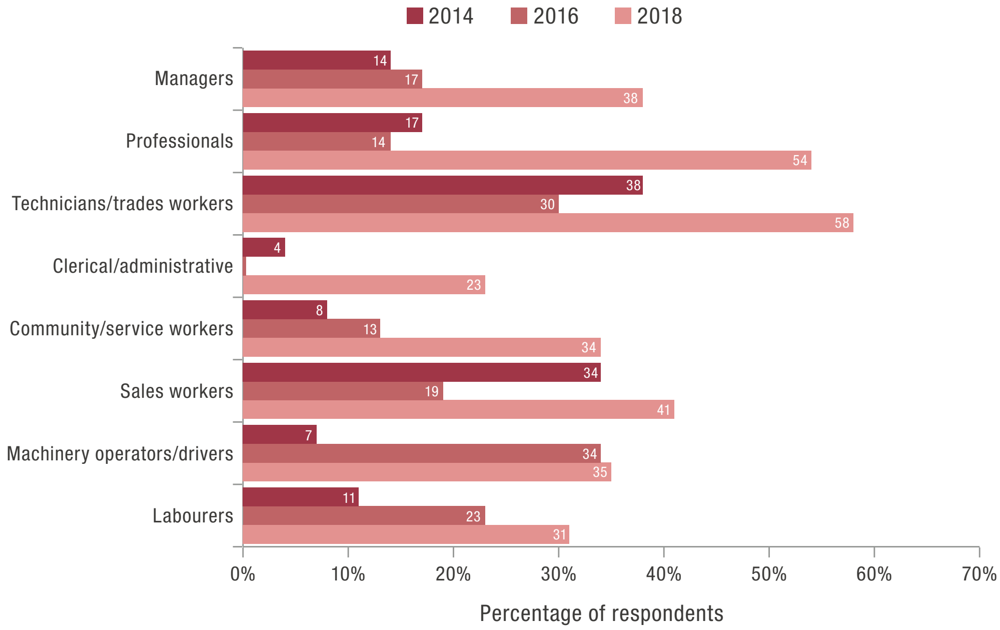
Source: *Figure provided by Office of Chief Scientist upon request, March 2020.*

3.3 Future workforce demand

Evidence on the future demand for people with STEM skills, particularly mathematical sciences skills, is diverse. There is some evidence to support that STEM skills in general are in high demand. For instance, the Australian Industry Group's 2018 Workforce Development Needs Survey indicated a marked increase in difficulties to recruit employees with STEM skills compared to earlier surveys in 2014 and 2016 (see figure 3.11).

Figure 3.11 Employers reporting difficulties recruiting employees with STEM skills

Source: *AIGroup 2018, chart 14, page 15.*



The 2018 LinkedIn report on emerging jobs signals there is high demand for technological skills in combination with "soft skills".

Job search platform SEEK recorded a year on year growth of 22 per cent in the science and technology sector (SEEK 2018, online).

The relatively new occupations of data scientist, full stack engineer and cyber security specialist all appeared in the top five of emerging jobs (LinkedIn 2018, page 7).

However, the employment prospects of newly graduated bachelors in science and mathematics may appear to be less than optimal, with less than 65 per cent finding full time employment within four months after graduating (see table 3.12a and 3.12b). Therefore, some advise against putting disproportionate emphasis on STEM skills (Pennington & Stanford 2019, page 48). Others are in favour of acknowledging differences in demand for Science compared to Technology, Engineering and Mathematics (e.g. Andrew Norton in Patty, 2019), with mathematical and statistical skills — not biology and chemistry skills—at the heart of many of the emerging jobs.

To assess demand for mathematical and statistical skills in particular it is worth pointing out that among science and mathematics graduates it is far more common than in other fields of education to continue with further study after obtaining a bachelor's degree. Where fewer than 20 per cent of undergraduates normally progress to a further degree, for over 40 per cent of science and mathematics graduates an undergraduate degree is only the beginning.

Analysis of employment prospects after science and mathematics degrees must therefore take into account postgraduate as well as undergraduate degree outcomes. In addition, employment prospects differ significantly among the various science disciplines.

For the purpose of analysing future employment prospects of mathematicians and statisticians, it is important to disaggregate them from the combined employment prospects of all science and mathematics graduates.

According to Tables 3.12a and 3.12b, 73 per cent of those who received an undergraduate (bachelor) degree in the mathematical sciences in 2018 and sought full-time employment found it within four months after graduating — around the average for all disciplines combined. Full time employment rates were substantially higher than for science and mathematics graduates combined, but lower than for engineering. However, compared to other areas of study, a high percentage — nearly 31 per cent — of bachelor graduates in the mathematical sciences proceeded to further full-time study. Most proceeded with a further degree in the natural and physical sciences. Fewer than 10 per cent chose to enrol in an education degree — despite the shortage of mathematics teachers.

The employment prospects of those who had completed further study in 2018 increased to approximately 86 per cent for postgraduate coursework graduates. The few PhD graduates responding to the survey reported a high employment rate of 88 per cent. The median starting salary for those with a further degree was considerably higher than the starting salary of $62,800 for those with an undergraduate degree. Postgraduate coursework graduates reported a starting salary of $86,900, and new PhD graduates of $92,000. By far the most graduates at any degree level found work as professionals.

Table 3.12a 2018 graduates in mathematical sciences

Source: *ABS (2018a); (2018b).*

2018 Mathematics graduates	Undergraduate			Postgraduate by Coursework			Postgraduate by Research		
	M	F	Total	M	F	Total	M	F	Total
Survey responses	293	140	433	96	59	156	30	8	38
Gender: mathematics (%)	68	32		62	38		79	21	

Full time employment 4 months after graduation	Undergraduate			Postgraduate by Coursework			Postgraduate by Research		
	M	F	Total	M	F	Total	M	F	Total
In full time work: mathematics (%)	72.2	74.5	73.0	89.6	80.4	86.3	92.6	71.4	88.2
In full time work: science & mathematics (%)			64.6			76.5			83.5
In full time work: computing & information systems (%)			73.2			84.3			77.6
In full time work: engineering (%)			83.1			84.6			85
In full time work: teacher education (%)			83.3			85.8			87.6
In full time work: all fields of education (%)	72.2	73.3	72.9	87.8	86.3	86.9	83.4	81.4	82.3

Median starting salary	Undergraduate			Postgraduate by Coursework			Postgraduate by Research		
	M	F	Total	M	F	Total	M	F	Total
Median salary: mathematics	60,000	63,000	62,800	85,000	87,200	86,900	92,000	n/a	92,000
Median salary: all fields of education	63,000	60,000	61,000	92,500	79,000	83,300	90,200	90,000	90,000

Occupation level	Undergraduate		Postgraduate by Coursework		Postgraduate by Research	
	Mathematics	All fields of education	Mathematics	All fields of education	Mathematics	All fields of education
Managers	2.6	6.0	5.5	14.5	3.0	6.6
Professionals	73.3	54.1	89.8	70.8	93.9	85.2
Technicians & trade workers	2.9	3.6	1.6	1.6	0.0	1.8
Community & personal services workers	4.2	12.5	0.0	4.2	3.0	1.7
Clerical & administrative workers	6.2	10.1	0.8	6.1	0.0	3
All other occupations	10.7	13.7	2.4	2.8	0.0	1.7

Table 3.12b 2018 graduates in mathematical sciences

Further full time study			
	Undergraduate		
	Male undergraduate	Female undergraduate	Total undergraduate
In full time study: mathematics (%)	34.3	23.7	30.9
In full time study: science and mathematics (%)	40.6	41.0	40.9
In full time study: all fields of education (%)	20.6	18.7	19.4

Study area of undergraduates in further full-time study (%)				
	Mathematics graduates			All fields of education
	M	F	Total	
Natural and physical sciences	49.5	50.0	49.6	13.2
Information technology	14.0	10.0	13.0	2.4
Education	9.7	10.0	9.8	9.8
Engineering & related technologies	10.8	3.3	8.9	5.1
Health	4.3	16.7	7.3	29.2
Society and culture	6.5	6.7	6.5	19.8
Management and commerce	4.3	3.3	4.1	6.9

Source: *ABS (2018a); (2018b).*

Table 3.13 sets out the top 20 occupations of mathematicians and statisticians according to the 2016 Census, as well as the change since 2006. The largest increase is in the category of "professionals, not further defined" which is a likely indication of the uptake of relatively new occupations such as "data scientist" that have not been included yet as a separate occupation in the ABS classification. Other jobs that employ significantly more mathematicians and statisticians than a decade earlier include the job category of actuaries, mathematicians and statisticians, and management and organisation analysts. There has also been a significant increase in the number of university lecturers and tutors. The general employment outlook to 2023 for most of the listed occupations in the top 20 is in line with the average projected growth of 7.1 per cent for all occupations, although employment numbers in some occupations are expected to decline.

Table 3.13 Top 20 occupations of persons with a mathematical sciences qualification in 2016

Source: ABS (2018a); (2018b).

Top 20 occupations of persons with a qualification in the mathematical sciences in 2016	Number employed	Change of number of mathematicians/ statisticians in these occupations since 2006	Projected employment growth for these occupations 2018–2023 (%)
Secondary school teachers*	1,717	141	7.1%
Software & applications programmers	1,625	-25	21.0%
University lecturers & tutors	1,344	286	8.3%
Actuaries, mathematicians & statisticians	1,239	317	7.8%
Professionals, nfd**	901	477	4.8%
Management & organisation analysts	694	311	10.3%
ICT managers	673	139	13.9%
ICT business & systems analysts	425	14	9.5%
Accountants	363	79	4.0%
Sales assistants (general)	333	150	1.4%
Contract, program & project administrators	322	17	-14.5%
General clerks	304	98	4.9%
Database & systems administrators, and ICT security specialists	282	-51	7.6%
Retail managers	254	63	1.8%
Private tutors & teachers	252	118	5.5%
Financial dealers	247	100	1.6%
Advertising & marketing professionals	244	77	12.5%
ICT support technicians	243	8	18.5%
Advertising, public relations & sales managers	228	26	9.8%
ICT professionals, nfd	220	-96	10.0%
Total	11,910	2,249	
Average projected growth top 20 occupations of mathematicians and statisticians			7.29%***

Notes: *nfd - Not further defined*

** Secondary school teachers with a mathematical sciences qualification are only a small subset of all mathematics teachers in Australia — the vast majority of whom are likely to have indicated they have an Education qualification. Also note that the projected employment growth 2018–2023 covers all secondary school teachers — there will likely be differences between teachers in different subject specialisations.*

*** The current ABS occupational classification does not include the relatively new occupation of "data analyst" or "data scientist". The category "professionals, nfd" is a likely category to be used by persons in newer occupations such as these.*

**** The average projected growth for all occupations 2018–2023: 7.1%.*

Since 2011, **the mathematical sciences have had a higher average success rate for research grants** from the Australian Research Council than other STEM disciplines

See page 66

The mathematical sciences **produce between 2% and 3% of Australia's research output**

See page 71

The **mathematical research disciplines** participating in the Excellence in Research Australia (ERA) are all deemed to be at world standard, **with the vast majority above, or well above world standard**

See pages 72–73

4 RESEARCH

OUTCOMES OF RESEARCH IN THE MATHEMATICAL SCIENCES AND THE AUSTRALIAN ECONOMY

Innovations which can be traced back to mathematical research are pivotal to many industries, including finance, transport, computing, mining, insurance and telecommunications. Monetary investment is however modest, with business contributing a small fraction of its Research and Development (R&D) expenditure on mathematical or statistical research. In the last decade the two most important and consistent sources of funding of mathematical sciences research were Higher Education funding and Commonwealth funding through the Australian Research Council (ARC).

The mathematical sciences have been relatively successful in obtaining ARC funding, most notably in the form of Discovery Projects. In terms of volume output, the mathematical sciences are a small discipline in Australia, generating between 2 and 3 per cent per cent of the total number of scientific publications. In the latest Excellence in Research Australia (ERA) evaluation in 2018, all universities received a ranking at or above world standard for their mathematical sciences discipline.

4.1 The importance of mathematical sciences research for the Australian economy

The advanced physical and mathematical (APM) sciences (mathematics, statistics, physics, chemistry and earth sciences research, undertaken and applied in the past 20 years) contribute substantially to the Australian economy.

Many innovations used by industry find their origin in scientific research and development.

This is certainly the case for mathematical sciences research which often is fundamental in nature.

Practical application of new results in mathematical sciences research can be many decades in the making. However, important insights from basic mathematical research that do not find an industry application initially, can form the basis of progress in other areas of research and trigger profound technological advances. This explains why many business sectors rely on advances in knowledge and technology that are ultimately based on mathematical and statistical research.

This is certainly the case for sectors such as finance, transport and computing, as shown in Table 4.1.

Table 4.2 shows that dominant industries which use knowledge from multiple advanced physical and mathematical sciences disciplines (mining, insurance, and telecommunications) also, as a rule, rely on advances in mathematical or statistical research.

Table 4.1 Sector based on a single core science discipline

Industry		Single core science discipline	Science-based GVA ($ billion)
6221	Banking	Maths	5
7000	Computer System Design & Related Services	Maths	5
4610	Road Freight Transport	Maths	4
1841	Human Pharmaceutical & Medicinal Product Manufacturing	Chemistry	2
6240	Financial Asset Investing	Maths	2
6330	Superannuation Funds	Maths	2
1912	Rigid & Semi-Rigid Polymer Product Manufacturing	Chemistry	2
All other industry classes based on a single core science discipline			25
Total			47
Total (share of total GVA)			3.6%

Note: *To express APM based GVA as a share of total GVA, the ownership of dwellings industry was excluded from the total the GVA, as it's imputed by the ABS and the industry does not employ any people (it makes up 9% of the total).*

Source: *AAS (2015), Table 8.1., page 57).*

Table 4.2 Sector based on multiple APM sciences disciplines

Industry class	APM scientific disciplines		Science-based GVA ($ billion)
700	Oil & Gas Extraction	Maths, physics, chemistry & earth sciences	16
6322	General Insurance	Maths, earth sciences	8
801	Iron Ore Mining	Maths, earth sciences	7
804	Gold Ore Mining	Maths, earth sciences	7
5801	Wired Telecommunications Network Operation	Maths, physics	7
8520	Pathology & Diagnostic Imaging Services	Maths, physics & chemistry	5
5802	Other Telecommunications Network Operation	Maths, physics	4
600	Coal Mining	Maths, physics, chemistry & earth sciences	4
All other industry classes based on combinations of disciplines			37
Total			94
Total (share of total GVA)			7.3%

Note: *To express APM (Advanced Physical and Mathematical Sciences) based GVA as a share of total GVA, the ownership of dwellings industry was excluded from the total the GVA, as it is imputed by the ABS and the industry does not employ any people (it makes up 9% of the total).*

Source: *AAS (2015) Table 8.2, page 57.*

4.2 Research funding

Despite the broad potential impact of mathematical sciences research, monetary investment is modest.

Table 4.3 shows that according to the latest available figures, compared to other STEM fields together with the Medical Sciences (commonly abbreviated as STEMM) the mathematical sciences received the lowest expenditure on research and development from most main funding sources.

Higher education expenditure in Research and Development (HERD) contributed the most to mathematical sciences research ($205 million or 1.89 per cent of funding). Government funding (GOVERD) amounted to $67 million, or 2.06 per cent of funding, mostly in the shape of research grant funding supplied through ARC.

The business sector spent 0.61 per cent of its R&D expenditure on the mathematical sciences. Even though this represents the lowest relative percentage of all main funding sources, business expenditure in 2017/18 was by far the highest it had been in a decade (see figure 4.4).

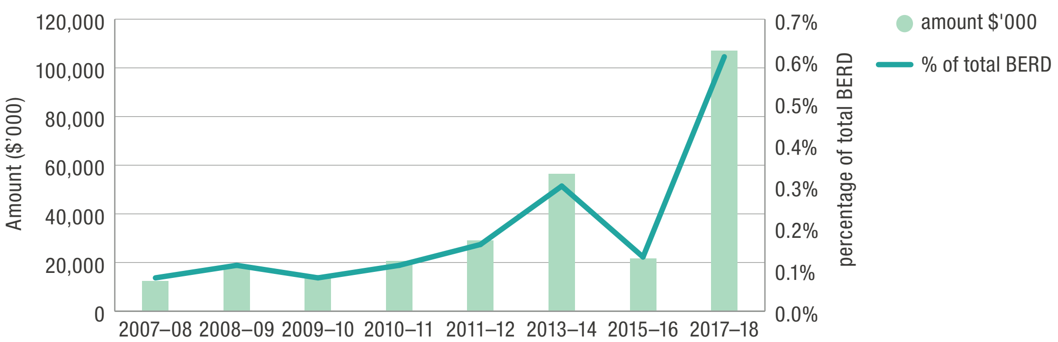
The spike in R&D spending in the business sector appears to be an exception, since comparison of R&D expenditure on mathematical sciences research from higher education, government and industry sources in the last decade confirms that funding has been consistently low, see figure 4.4.

Table 4.3 Australian Research and Development expenditure by sector

	HERD (2016)		BERD (2017–18)		GOVERD (2016–17)	
Field	$ '000	%	$ '000	%	$ '000	%
Total	10,877,517	*	17,437,585	*	3,278,755	*
STEMM	7,834,295	72.02	17,037,503	97.71	3,103,598	94.66
Breakdown of STEMM	$ '000	%	$ '000	%	$ '000	%
Agricultural & Veterinary Sciences	408,683	3.76	654,046	3.75	573,844	17.50
Biological Sciences	1,020,725	9.38	231,970	1.33	309,784	9.45
Chemical Sciences	335,681	3.09	431,150	2.47	148,976	4.54
Earth Sciences	298,041	2.74	158,118	0.91	222,885	6.80
Engineering	1,114,518	10.25	4,710,279	27.01	494,463	15.08
Environmental Sciences	392,718	3.61	170,354	0.98	225,432	6.88
Information & Computing Sciences	394,399	3.63	6,747,648	38.70	293,131	8.94
Mathematical Sciences	205,084	1.89	107,164	0.61	67,412	2.06
Medical & Health Sciences	3,086,858	28.38	1,958,471	11.23	501,789	15.30
Physical Sciences	365,246	3.36	77,066	0.44	156,908	4.79
Technology	212,342	1.95	1,791,237	10.27	108,974	3.32

Source: *ABS (2019a), ABS (2019b), ABS (2019c).*

Figure 4.4a Business expenditure on R&D in the mathematical sciences 2007/8-2017/18



Source: *ABS (2019a), ABS (2019b), ABS (2019c).*

Figure 4.4b Government expenditure on R&D in the mathematical sciences 2008/9-2016/17

Source: ABS (2019a), ABS (2019b), ABS (2019c).

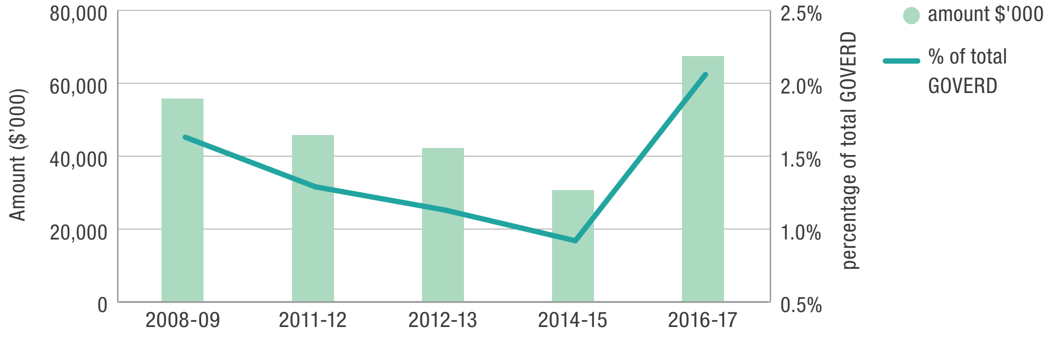
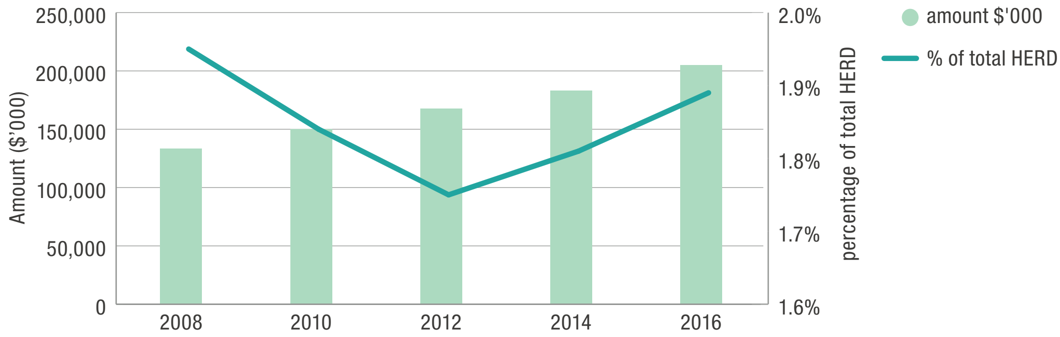


Figure 4.4c Higher education expenditure on R&D in the mathematical sciences 2008-2016

Source: ABS (2019a), ABS (2019b), ABS (2019c).



Mathematical research is mostly dependent on university support and competitive grant funding from the government.

The discipline has been relatively successful in obtaining funding from the ARC, most notably in the form of ARC Discovery Projects.

According to ARC data, proposal success rates in the mathematical sciences between 2001–2011 were on par with or better than those in engineering and information and communication technologies (ARC 2013).

Since 2011, Discovery Project proposal success rates in the mathematical sciences as shown in figure 4.5 significantly outstripped other disciplines in the four years from 2011 to 2014, before edging closer to the success rates in other STEMM areas. The ARC success rate for Discovery Projects declined overall, from 22 per cent in 2011 to 18 per cent or below in the period 2015–2017 before bouncing back in 2018 and 2019.

In summary, viewed in comparison with other science fields, the mathematical sciences discipline has maintained a relatively strong ARC grant success rate for most of this century.

Figure 4.5 ARC success rates of Discovery Project proposals 2011–2019 (%)

Source: ARC (2019a).

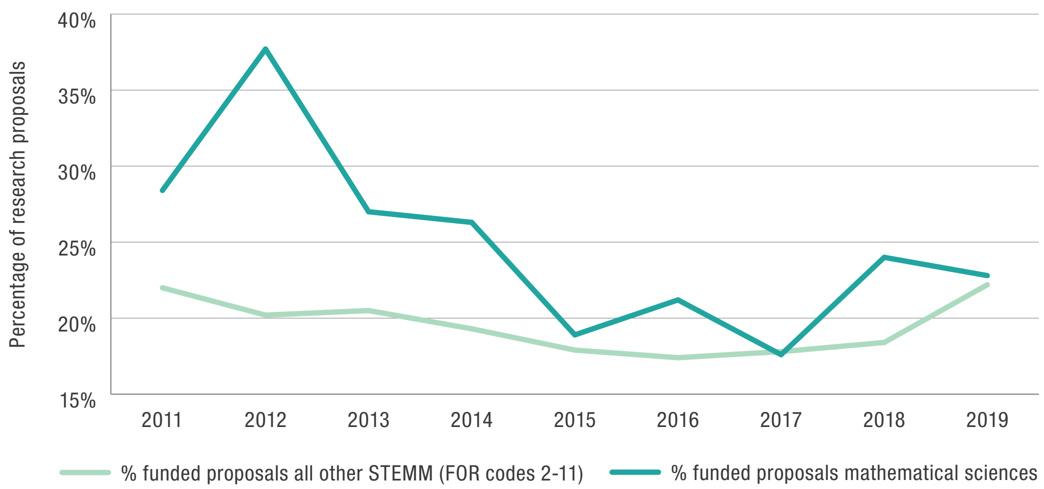
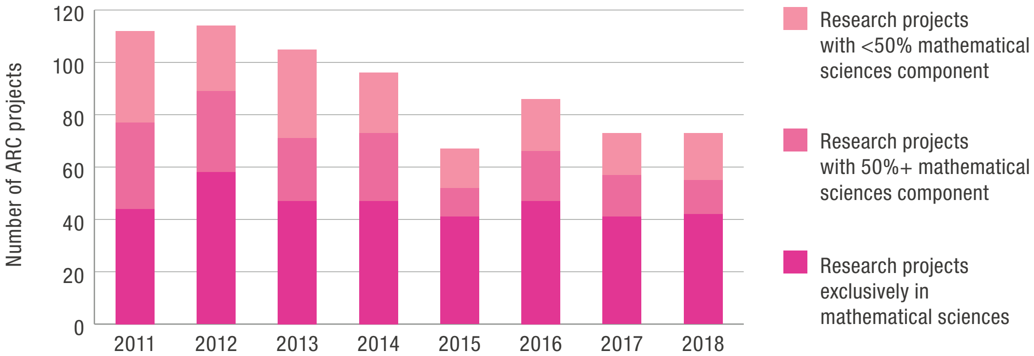


Figure 4.6 Number of ARC projects in the mathematical sciences by year of commencement 2011–2018



Note: This graph includes research projects that were partially or completely attributed to FoR Division 01-Mathematical Sciences. Researchers can attribute their research to various fields of research and in various proportions. The graph distinguishes between projects that were exclusively coded to fields within FoR Division 01, or were coded either 50% or more, or less than 50% to FoR Division 01. Linkage projects awarded for commencement in 2017, 2018 and 2019 were not added yet to the ARC database.

Source: ARC (2019b).

Figure 4.6 shows all ARC projects which are partly or completely attributed to the mathematical sciences. According to this figure, the number of new projects in the mathematical sciences has somewhat declined, in line with an overall decline in the number of research projects funded by the ARC.

In the period 2011 to 2018, 726 research projects commenced in the mathematical sciences, of which 367 were exclusively classified as mathematical research by the researchers on these projects.

The researchers of another 173 projects attributed at least 50 per cent of their projects to mathematical fields of research, and the remainder to other disciplines, mostly to Information and Computing, Engineering and Biological Sciences (see figure 4.7).

A further 186 projects were classified as research mainly in another discipline, such as Engineering, Information and Computing, and Physical Sciences, but with a minor mathematical component.

Figure 4.7 Research projects in the mathematical sciences 2011–2018 by mathematical sciences and other discipline components

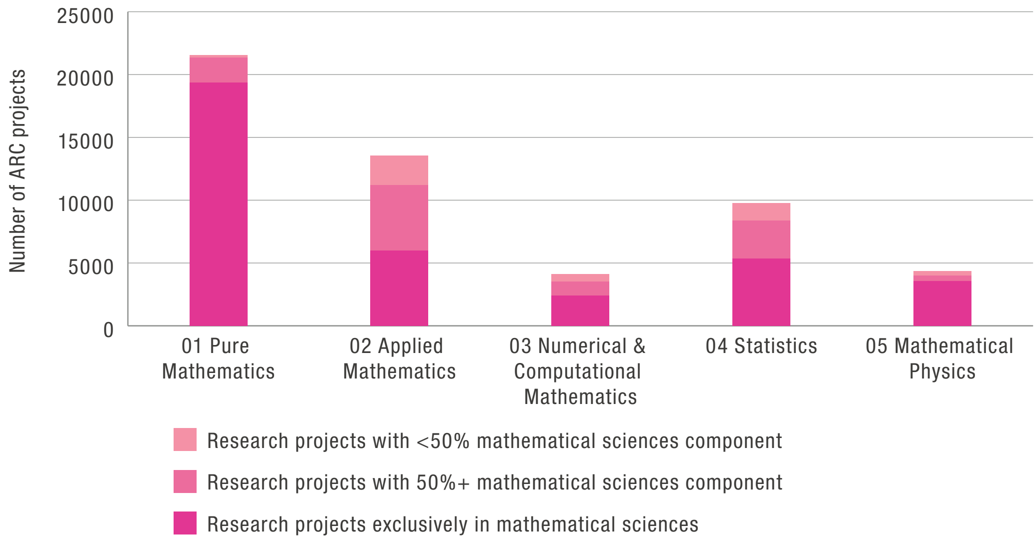
Number of ARC projects

Note: This graph includes research projects that were partially or completely attributed to FoR Division 01-Mathematical Sciences. Researchers can attribute their research to various fields of research and in various proportions. The graph distinguishes between projects that were exclusively coded to fields within FoR Division 01, or were coded either 50% or more, or less than 50% to FoR Division 01. Linkage projects awarded for commencement in 2017, 2018 and 2019 were not added yet to the ARC database.

Source: Source: ARC (2019b).

Figure 4.8 sets out the relative contribution of each of the main five subdisciplines in the mathematical sciences to the ARC-funded research, according to their proportional attribution to each field of research (FoR) group (pure mathematics, applied mathematics, and so on). From this figure it is clear that mathematical sciences research is mostly attributed to pure mathematics, followed by applied mathematics and statistics. Applied mathematics and statistics projects incorporate the most interaction with other research fields outside of mathematics.

Figure 4.8 Research projects in the mathematical sciences 2011–2018 by subdiscipline



Note: *This graph includes research projects that were partially or completely attributed to FoR Division 01-Mathematical Sciences. Researchers can attribute their research to various fields of research and in various proportions. The graph distinguishes between projects that were exclusively coded to fields within FoR Division 01, or were coded either 50% or more, or less than 50% to FoR Division 01. This graph displays the aggregated attributions of these projects to the following four-digit FoR Groups within Division 01: 0101, 0102, 0103, 0104 and 0105. Linkage projects awarded in 2017, 2018 and 2019 were not added yet to the ARC database.*

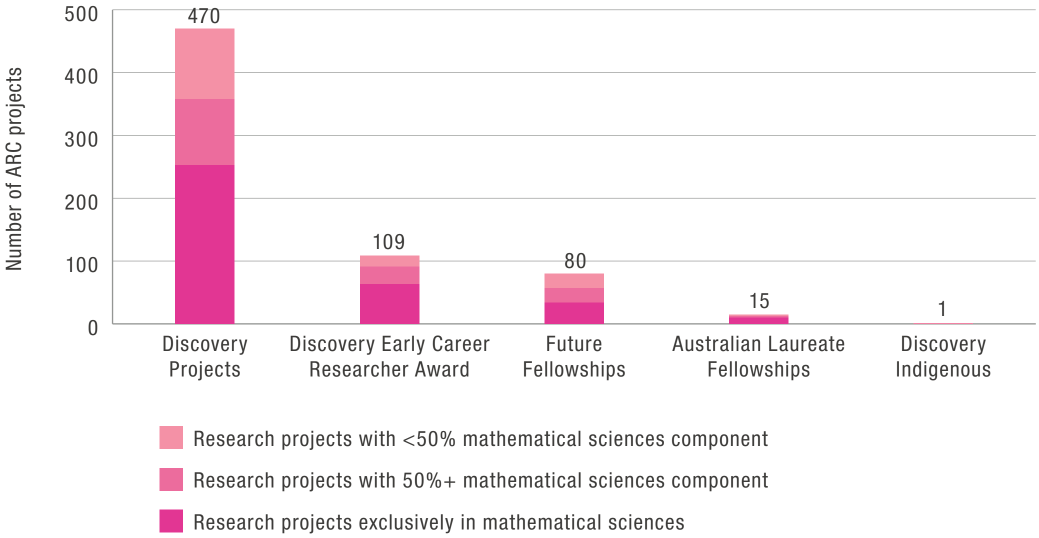
Source: *ARC (2019b).*

Figures 4.9 and 4.10 provide an overview of the number of ARC projects by type of project. The ARC Discovery Program delivers funding to individual researchers and research teams with an emphasis on fundamental or basic research. The ARC Linkage program promotes cooperative research between universities, and research partnerships with business, industry and other organisations.

As far as the mathematical sciences are concerned, the emphasis lies on funding secured through the Discovery Program, through Discovery Projects, Fellowships and Awards for early career researchers. Within the ARC Linkage program, the most significant initiative currently sponsored by the ARC is the ARC Centre of Excellence in Mathematical and Statistical Frontiers (ACEMS) which brings together researchers from seven universities in four states. The mathematical sciences receive only a minimal share of other types of research infrastructure sponsored by the ARC, such as Industrial Transformation Training Centres and Linkage Infrastructure, Equipment and Facilities grants.

The ARC funding of mathematical sciences research is supplemented by initiatives aimed at providing national support and infrastructure for workshops, conferences and international collaboration. These initiatives are made possible by a mix of university and philanthropic funds (AMSI 2019; MATRIX 2019; SMRI 2019).

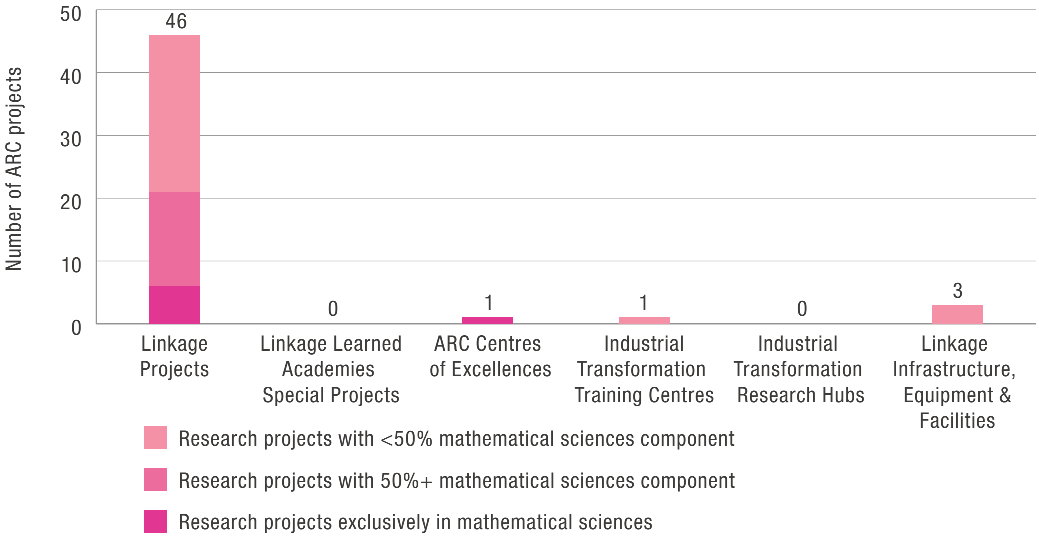
Figure 4.9 ARC projects in the Discovery Program in mathematical sciences 2011–2018 by project type



Note: *This graph includes research projects that were partially or completely attributed to FoR Division 01-Mathematical Sciences. Researchers can attribute their research to various fields of research and in various proportions. The graph distinguishes between projects that were exclusively coded to fields within FoR Division 01, or were coded either 50% or more, or less than 50% to FoR Division 01.*

Source: *ARC (2019b).*

Figure 4.10 ARC projects in the Linkage Program in the mathematical sciences 2011–2018 by project type



Note: *Note: This graph includes research projects that were partially or completely attributed to FoR Division 01-Mathematical Sciences. Researchers can attribute their research to various fields of research and in various proportions. The graph distinguishes between projects that were exclusively coded to fields within FoR Division 01, or were coded either 50% or more, or less than 50% to FoR Division 01. inkage projects awarded in 2017, 2018 and 2019 were not added yet to the ARC database.*

Source: *ARC (2019b).*

Table 4.11 shows the distribution of ARC funding among universities according to the AMSI University Survey. Such funding is largely limited to Go8 universities. On average, Go8 universities estimated their ARC funding success rate at 27 per cent between 2015 and 2017. Estimates by other universities fluctuate enormously—from very high success rates to no ARC funding success at all.

Table 4.11 Number of ARC grants held and hosted at participating universities 2012–2018

	Discovery Projects							Linkage Projects						
Universities	2012	2013	2014	2015	2016	2017	2018	2012	2013	2014	2015	2016	2017	2018
Total Go8	139	159	133	149	180	98	94	14	12	15	7	11	5	5
Total ATN	9	8	1	8	7	3	3	3	2	1	4	2	1	1
Total RUN	3	3	3	4	3	4	3	0	0	0	0	0	1	0
Total IRU	7	8	8	7	3	1	4	0	1	1	1	1	0	2
Total unaligned	21	20	27	20	18	16	21	7	3	6	9	4	2	2
Total all participating	179	198	172	188	211	122	125	24	18	23	21	18	9	10

Source: *AMSI University Survey 2012–2018.*

ARC research projects can have multiple Chief Investigators, spanning more than one university and more than one discipline— although there is always one lead university that administers the grant, and one primary FoR assigned to every project.

Table 4.12 contains the total number of academic staff in mathematical sciences departments who are Chief Investigators in ARC projects.

Most Chief Investigators are involved in projects which have mathematical sciences as the primary FoR. However, there are also a number of mathematicians and statisticians involved in projects which are primarily related to a different discipline. This table again reinforces the large difference between Go8 universities and others in terms of involvement in ARC-funded research.

Table 4.12 Number of academic staff in mathematical sciences departments who are Chief Investigators in ARC-funded research projects in 2018

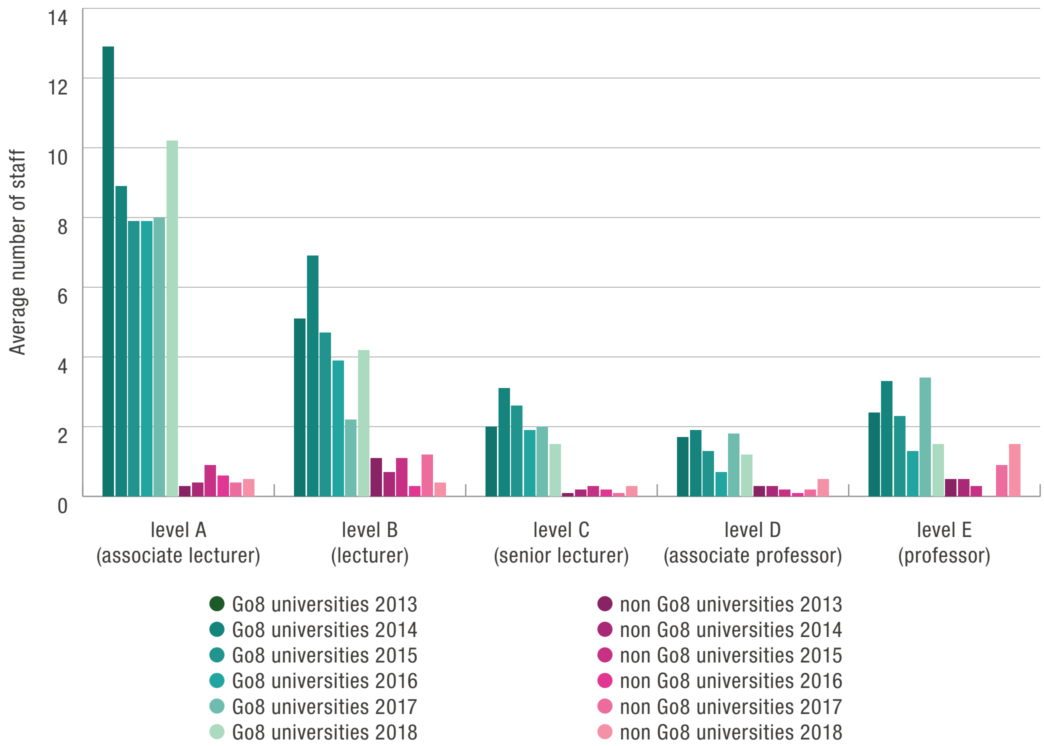
Source: *AMSI University Survey 2018.*

	Chief Investigators with primary FoR code in the mathematical sciences	Chief Investigators without primary FoR code in the mathematical sciences
Total Go8 universities (6/8)	188	25
Total non Go8 universities (15/31)	61	38
Total all participating universities	**249**	**63**

Figure 4.13 depicts comparative ARC funded staff levels at Go8 universities (in green) and other universities (in purple) from 2013 to 2018 according to AMSI Survey results. These figures confirm Go8 universities are in a position to employ many more research-only staff, a very high proportion of whom are employed at levels A and B.

Figure 4.13 Average number of ARC-funded staff at participating universities 2013–2018

Source: *AMSI University Survey 2013–2018.*



4.3 Research output and quality

By share of international output, the Australian mathematical sciences are a small area of research. Table 4.14 shows that in the period 2002–2012 the mathematical sciences generated around 20,000 publications or 2.15 per cent of the world total—a proportion similar to chemical and physical sciences.

Table 4.14 STEM publications by field 2002–2012

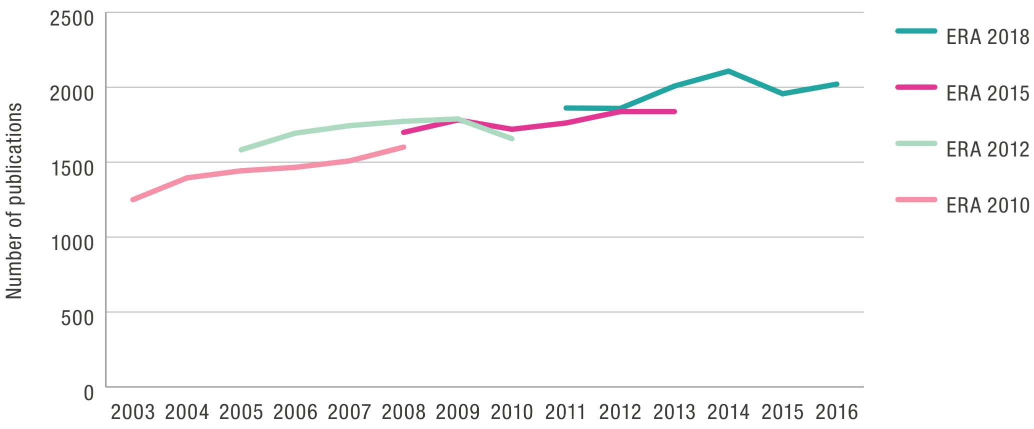
Field	Australia Total	Australia % world	World total
All STEM publications	429,161	3.07	13,982,435
Biomedical & clinical health sciences	106,949	3.36	3,179,977
Biological sciences	72,213	4.12	1,754,641
Engineering	62,112	2.46	2,521,292
Chemical sciences	36,880	1.98	1,858,227
Physical sciences	34,375	2.26	1,523,329
Agricultural & veterinary sciences	30,553	4.97	614,921
Environmental sciences	20,944	7.49	279,683
Mathematical sciences	20,123	2.15	935,577
Earth sciences	18,917	5.00	378,670
Information & computing technology	17,599	3.13	562,889
Technology	8,496	2.28	373,229

Source: *OCS (2014), table 2-2, page 9.*

According to publication outputs reported to the ARC for the periodical ERA evaluation, the number of publications in the mathematical sciences has steadily increased, from 1,250 in 2003 to over 2,000 in 2016 (see figure 4.15).

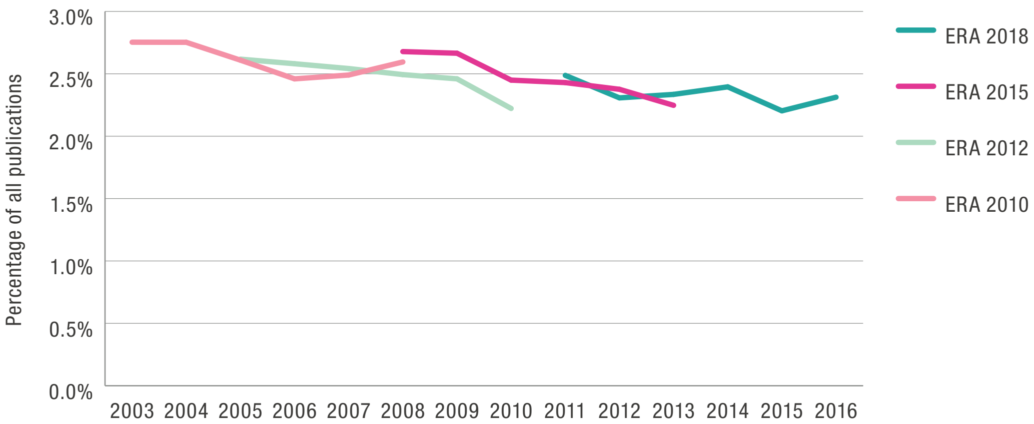
Despite the increasing number of publications, as a proportion of the national research output mathematical sciences research represents between two and three per cent of all research publications produced in Australia, see figure 4.16.

Figure 4.15 Number of mathematical sciences publications submitted to ERA 2003–2016



Source: *ARC (2010, 2012, 2015, 2018).*

Figure 4.16 Mathematical sciences publications submitted to ERA as a proportion of all publications 2003–2016



Source: *ARC (2010, 2012, 2015, 2018).*

The ERA framework has been put in place to evaluate the strength and quality of Australian research.

Evaluations have taken place in 2010, 2012, 2015 and 2018. The ERA measures the research performance within disciplines (Units of Evaluation, or UoEs) with a certain volume of research output (more than 50 publications). The research output is assessed by peer review (for pure mathematics) or by citation scores (the other mathematical sciences subdisciplines), with each UoE receiving a rating from one (low) to five (high). A rating of three indicates “at world standard”. When compared to earlier evaluations (Table 4.17), the 2018 ERA results show that mathematical sciences research ratings have steadily increased since the first evaluation in 2010.

In 2018, mathematical sciences disciplines (at the two-digit level 01-mathematical sciences) at 27 out of 42 universities were assessed. The vast majority of universities assessed received a rating of five (well above world standard) or four (above world standard) for their mathematical research. All were deemed to be performing at or above world standard. Moreover, all stabilised or increased their rating compared to 2015.

Note: *the classification 0199 — Other Mathematical Sciences has been left out as no UoEs were assessed in this subdiscipline.*

Source: *ARC (2010, 2012, 2015, 2018).*

Table 4.17 Summary of ERA ratings by discipline and subdiscipline in the mathematical science

	ERA 2010						ERA 2012						ERA 2015						ERA 2018					
Number of ratings	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics
not rated																1								
1-Well below world standard		1						1																
2-Below world standard	6	3			4		5	2	2		1												1	
3-At world standard	10	8	8	3	6		11	6	7	3	2	3	8	2	3			6	2	1	4		3	1
4-Above world standard	6	4	8		1	3	8	6	11	1	6	3	11	7	15	2	1		13	4	8	1	5	3
5-Well above world standard	2	2	1	2	1	3	3	2	2	1	1		7	6	5	1	11		12	10	13	3	8	
Total UoEs evaluated	**24**	**18**	**17**	**5**	**12**	**6**	**27**	**17**	**22**	**5**	**10**	**6**	**26**	**15**	**23**	**4**	**12**	**6**	**27**	**15**	**25**	**4**	**17**	**4**

Analysis of the subdisciplines at the four-digit level reveals that:

- The number of universities evaluated for pure mathematics research output has been steadily decreasing since 2010 (18 universities) with 17 in 2012 and 15 in 2015 and 2018. By contrast, the number of applied mathematics units of evaluation increased markedly from 17 in 2010 to 25 in 2018. While mathematical physics and numerical and computational mathematics' number of assessed units have declined, statistics has risen to 17 in 2018.

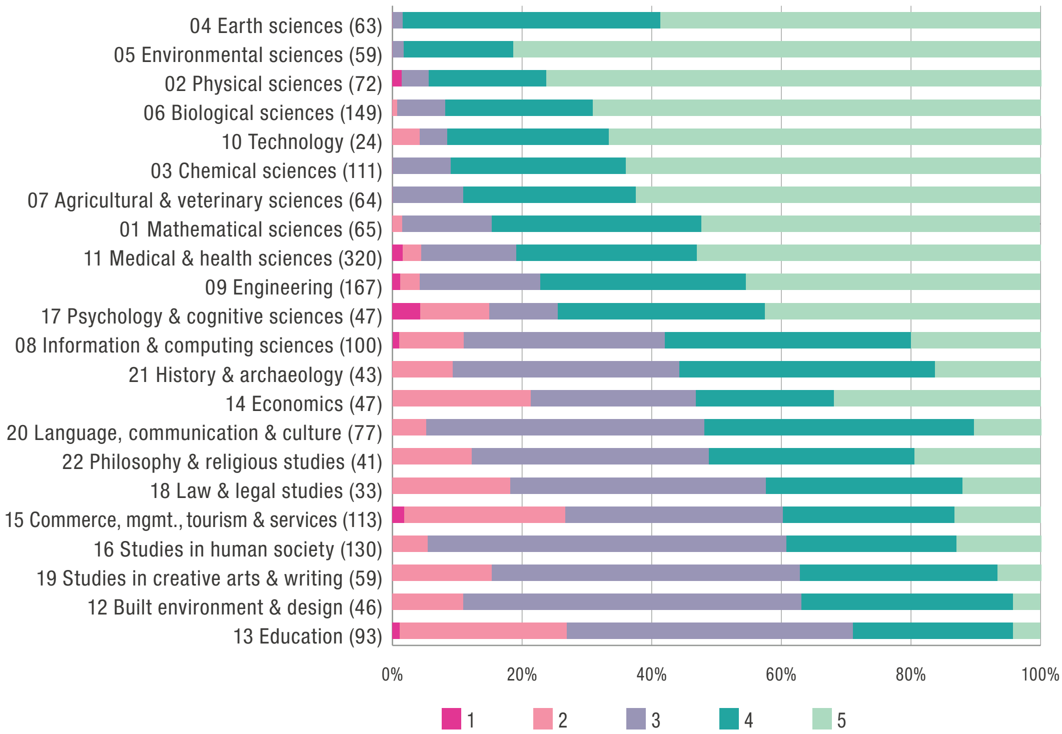
- The subdisciplines pure and applied mathematics received the highest ratings in 2018, and numerical and computational mathematics also improved its rating overall. For mathematical physics the picture was more uneven, with higher ratings but fewer units evaluated than in 2015. Statistics received fewer ratings at the highest level than in 2015.

- All except one unit in the various subdisciplines at the four-digit level attracted a rating at or above world standard (or 98 per cent, against 92 per cent of UoEs in all research disciplines), with 52 per cent of the evaluated units receiving the highest rating of five (against 40 per cent of UoEs in all research disciplines).

To compare these results with other disciplines, see aggregated sub-discipline level ratings for all 22 research disciplines in figure 4.18.

Figure 4.18 Distribution of UoE ratings or four-digit UoEs (grouped into two-digit FoR code level)

Source: *ARC (2018).*



References

Australian Academy of Science (AAS). (2006). *Mathematics and Statistics: Critical skills for Australia's future, The national strategic review of mathematical sciences research in Australia*. Retrieved from science.org.au.

Australian Academy of Science (AAS). (2015), *The importance of advanced physical and mathematical sciences to the Australian economy.* Retrieved from science.org.au.

Australian Bureau of Statistics (ABS). (2013). *Programme for the International Assessment of Adult Competencies, Australia, 2011-2012, 4228.0*. Retrieved from abs.gov.au/ausstats.

Australian Bureau of Statistics (ABS). (2018a). *ABS Census TableBuilder, data from the 2006, 2011 and 2016 Census*.

Australian Bureau of Statistics (ABS). (2018b). *2018 Employment projections – for the five years to May 2023*. Retrieved from lmip.gov.au.

Australian Bureau of Statistics (ABS). (2019a). *Business expenditure in R&D, by fields of research, 2007/08-2015/2016, 8104*. Retrieved from abs.gov.au/ausstats.

Australian Bureau of Statistics (ABS). (2019b). *Government expenditure on R&D, by fields of research, 2008/09-2016/17, 8109*. Retrieved from abs.gov.au/ausstats.

Australian Bureau of Statistics (ABS). (2019c). *Higher education expenditure on R&D, by location – by fields of research, 2008-2016, 8111.* Retrieved from abs.gov.au/ausstats.

Australian Council for Educational Research (ACER). (2014a). *Staff in Australia's Schools 2013*. Retrieved from docs.education.gov.au.

Australian Council for Educational Research (ACER). (2014b). *Profiles of teachers in selected curriculum areas: further analyses of the STAFF in Australia's Schools 2013 survey*. Retrieved from docs.education.gov.au.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2018). *2018 NAPLAN Achievement Reading, Writing, Language Conventions and Numeracy: National report for 2018*. Retrieved from nap.edu.au/results-and-reports/national-reports.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2019a). *NAPLAN 2019 summary results*. Retrieved from reports.acara.edu.au/NAP (as accessed 12 December 2019).

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2019b). *Year 12 subject enrolments dataset*. Retrieved from acara.edu.au/reporting/national-report-on-schooling-in-australia-data-portal/year-12-subject-enrolments.

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2020). *Senior Secondary Australian Curriculum: Mathematics*. Retrieved from australiancurriculum.edu.au/senior-secondary-curriculum/mathematics/.

Australian Education Union (AEU) (2019). *State of our Schools 2018 Report*. (Provided to AMSI on request).

Australian Mathematical Sciences Institute (AMSI). (2019). *AMSI and AustMS/ANZIAM Workshop funding*. Retrieved from research.amsi.org.au/workshop-funding/.

Australian Research Council (ARC). (2010). *Excellence in Research for Australia 2010, National Report*. Retrieved from arc.gov.au/excellence-research-australia/archived-era-reports.

Australian Research Council (ARC). (2012). *Excellence in Research for Australia 2012, National Report*. Retrieved from arc.gov.au/excellence-research-australia/archived-era-reports.

Australian Research Council (ARC). (2013). *ARC Support for Research in the Mathematical Sciences, a Summary of Trends—Submit Years 2001 to 2011.*

Australian Research Council (ARC). (2015). *State of Australian University Research 2015-2016, ERA National Report*. Retrieved from arc.gov.au/excellence-research-australia/archived-era-reports.

Australian Research Council (ARC). (2018). *State of Australian University Research 2018-2019, ERA National Report*. Retrieved from arc.gov.au/excellence-research-australia.

Australian Research Council (ARC). (2019a). *ARC NCGP: success rate of applications received since commencement year 2011 (inclusive) by scheme and primary 4-digit FoR code*. Retrieved from arc.gov.au/grants-and-funding/apply-funding/grants-dataset.

Australian Research Council (ARC). (2019b). *ARC National Competitive Grants Dataset – NCGP Projects Field of Research Collection (all funded Projects).* Retrieved from arc.gov.au/grants-and-funding/apply-funding/grants-dataset.

Department of Education, Skills and Employment. (2019), *Higher Education Statistics – data supplied to AMSI.*

Dobson, I. (2018). *STEM in Australia: The statistical patterns of university science and technology in the twenty-first century*. Australian Council of Deans of Science. Retrieved from acds.edu.au/publications/.

Department of the Prime Minister and Cabinet. (2019), *Closing the Gap-report 2019*, Canberra: Australian Government. Retrieved from pmc.gov.au/news-centre/indigenous-affairs/closing-gap-2019-report.

Goss, P. & Sonnemann, J. (2016). *Widening Gaps: What NAPLAN tells us about student progress*. Melbourne: Grattan Institute. Retrieved from grattan.edu.au/report/widening-gaps/.

Goss, P. & Sonnemann, J. (2018). *Measuring student progress – a state-by-state report card*. Melbourne: Grattan Institute. Retrieved from grattan.edu.au/report/measuring-student-progress/.

Hine, G. (2018). Teachers' perceptions on declining student enrolments in Australian senior secondary mathematics courses, *Issues in Educational Research 28* (3), 635–654.

Hine, G. (2019). Reasons why I didn't enroll in a higher-level mathematics course: Listening to the voice of Australian senior secondary students. *Research in Mathematics Education*, doi: 10.1080/14794802.2019.1599998.

Hinz, B., Walker, L. & Witter, M. (2019). *Learning from the best: What makes an excellent teacher of mathematics?* Australian Association of Mathematics Teachers/PIVOT Professional Learning. Retrieved from pivotpl.com/paper-launch-new-research-identifies-key-characteristics-of-great-maths-teachers/.

International Mathematical Research Institute MATRIX. (2019). Information retrieved from matrix-inst.org.au/.

James, S. (2018). *Year 12 Mathematics Participation Rates in Australia 2008-2017.* Retrieved from amsi.org.au/publications/year-12-mathematics-participation-in-australia-2008-2017/.

Johnston, P. (2019). Higher Degrees and Honours Bachelor Degrees in Mathematics and Statistics Completed in Australia in 2018. *AustMS Gazette 46* (5), 271–277. (Longitudinal data collection provided to AMSI.)

Jonas, N. (2018), *Numeracy practices and numeracy skills among adults*, OECD Education Working Papers, no. 177, Paris: OECD Publishing.

Joyce, C., Hine, G., & Anderton, R. (2017). The association between secondary mathematics and first year performance in health sciences. *Issues in Educational Research 27*(4), 770–783.

Kennedy, J., Lyons, T., & Quinn, F. (2014). The continuing decline of science and mathematics enrolments in Australian high schools. *Teaching Science 60* (2), 34–46.

King, D. & Cattlin, J. (2015). The impact of assumed knowledge entry standards on undergraduate mathematics teaching in Australia. *International Journal of Mathematical Education in Science and Technology 46* (7), 1032–1045.

Koch, I. & Li, N. (2017). *Teacher Confidence, Education and Experience: CHOOSEMATHS Teachers Survey 2016, No.1*. Melbourne: Australian Mathematical Sciences Institute. Retrieved from amsi.org.au/publications/teacher-confidence-education-experience-choose-mathsteachers-survey-2016/.

Kniest, P. (2018). *The flood of insecure employment at Australian universities*. Melbourne: National Tertiary Education Union.

LinkedIn. (2018). *Emerging Jobs: Australia – the fastest growing jobs in the country*. Retrieved from business.linkedin.com/talent-solutions/talent-intelligence/emerging-jobs/au-emerging-jobs-report. (accessed 26 August 2019).

Mathematical Association of New South Wales (MANSW). (2014). *Report on the MANSW 2013 Secondary Mathematics Teacher Survey*.

McMillan, J. & Edwards, D. (2019). *Performance in first year mathematics and science subjects in Australian universities: Does senior secondary mathematics background matter? – final report*, Melbourne: Australian Council for Educational Research/Australian Council of Deans of Science. Retrieved from acds.edu.au/performance-in-first-year-mathematics-and-science-subjects-in-australian-universities-does-senior-secondary-mathematics-background-matter/

Murray, S. (2011). Declining participation in post-compulsory secondary school mathematics: students' views of and solutions to the problem. *Research in Mathematics Education 13* (3), 269–285.

Nicholas, N., Poladian, L., & Wilson, R. (2015). Mathematics preparation for university: entry, pathways and impact on performance in first year science and mathematics subjects. *International Journal of Innovation in Science and Mathematics Education 23* (1), 37–51.

O'Connor, M. & Thomas, J. (2019). *Australian secondary mathematics teacher shortfalls: A deepening crisis, AMSI Occasional Paper 2*. Melbourne: Australian Mathematical Sciences Institute. Retrieved from amsi.org.au/publications/amsi-occasional-paper-2-australian-secondary-mathematics-teacher-shortfalls-a-deepening-crisis/.

OCS (2014). *Benchmarking Australian Science, Technology, Engineering and Mathematics*. Retrieved from chiefscientist.gov.au/2014/12/benchmarking-australian-science-technology-engineering-mathematics.

Organisation for Economic Co-operation and Development (OECD). (2015). *Mean numeracy scores in the Survey of Adult Skills*. Retrieved from gpseducation.oecd.org/IndicatorExplorer.

Organisation for Economic Co-operation and Development (OECD). (2019). *Programme for International Student Assessment (PISA), Selected data from PISA 2003–2018*. Retrieved from oecd.org/pisa/.

Patty, A. (2019). Not enough jobs for science graduates challenges STEM hype. *Sydney Morning Herald 14 April 2019*.

Pennington, A. & Stanford, J. (2019). *The Future of Work for Australian Graduates: The Changing Landscape of University-Employment Transitions in Australia.* Canberra: The Centre for Future Work at the Australia Institute.

Pitt, D. (2015). On the scaling of NSW HSC marks in mathematics and encouraging higher participation in calculus-based courses. *Australian Journal of Education 59* (1), 65–81.

Poladian, L. & Nicholas, N. (2013). Mathematics Bridging Courses and Success in First year Calculus. In: King, D., Loch, B. & Rylands, L. (Eds.). *Shining through the fog - Proceedings of Lighthouse Delta 2013: the 9th Delta Conference on teaching and learning of undergraduate mathematics and statistics* (150–159). Sydney: University of Western Sydney.

Prince, G. & O'Connor, M. (2018). *Crunching the numbers on out-of-field teaching, AMSI Occasional Paper 1.* Melbourne: Australian Mathematical Sciences Institute. Retrieved from: amsi.org.au/publications/amsi-occasional-paper-1/.

Quality Indicators in Learning and Teaching (QILT). (2016). *2015 Student Experience Survey – National Report*. Canberra: Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/student-experience.

Quality Indicators in Learning and Teaching (QILT). (2017). *2016 Student Experience Survey – National Report.* Canberra: Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/student-experience.

Quality Indicators in Learning and Teaching (QILT). (2018a). *2017 Student Experience Survey – National Report*. Canberra: Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/student-experience.

Quality Indicators in Learning and Teaching (QILT). (2018b). *2017 Graduate Outcomes Survey – National Report.* Canberra: Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/graduate-employment.

Quality Indicators in Learning and Teaching (QILT). (2019a). *2016-2018 Graduate Outcomes and Course Satisfaction* (data supplied to AMSI).

Quality Indicators in Learning and Teaching (QILT). (2019b). *2018 Graduate Outcomes Survey – National Report*. Canberra:

Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/graduate-employment.

Quality Indicators in Learning and Teaching (QILT). (2019c). *2018 Student Experience Survey – National Report*. Canberra: Social Research Centre. Retrieved from qilt.edu.au/qilt-surveys/student-experience.

Sadler, P. & Tai, R. (2007). The two high-school pillars supporting college science. *Science 317* (5837), 457–458.

SEEK. (2018). *Latest trends: Job opportunities are up 14.7% and STEM skills are in demand*. seek.com.au/career-advice/latest-trends-job-opportunities-are-up-147-and-stem-skills-are-in-demand. (Accessed 26 August 2019).

The Australian Industry Group (AIGroup). (2018). *Skilling: A National Imperative- Survey Report Workforce Development Needs*. Retrieved from cdn.aigroup.com.au/Reports/2018/.

Thomson, S., de Bortoli, L., Underwood, C., & Schmid, M. (2019). *PISA 2018: Reporting Australia's results, Volume I Student performance.* Melbourne: Australian Council for Educational Research. Retrieved from research.acer.edu.au/ozpisa.

Thomson, S., Wernert, N., O'Grady, E. & Rodrigues, S. (2017). *TIMSS 2015: Reporting Australia's results*. Melbourne: Australian Council for Educational Research. Retrieved from research.acer.edu.au/timss_2015/2/.

Trends in International Mathematics and Science Study (TIMSS). (2015). *Selected data from 1995–2015*. Retrieved from timss.org.

University of Sydney Mathematical Research Institute (SMRI). (2019). Retrieved from sydney.edu.au/research/centres/mathematical-research-institute.html.

Weldon, P. (2015). *The Teacher workforce in Australia: Supply, demand and data issues, Policy Insights Issue 2*. Melbourne: Australian Council for Educational Research.

Weldon, P. (2016). *Out-of-field teaching in Australian secondary schools, Policy Insights Issue 6*, Melbourne: Australian Council for Educational Research.

YouthInsight. (2019). *Youth in STEM Research*, Canberra: Department of Industry, Innovation and Sciences. Retrieved from industry.gov.au/data-and-publications/youth-in-stem-research.

Glossary

AAS: Australian Academy of Science

ABS: Australian Bureau of Statistics

ACARA: Australian Curriculum, Assessment and Reporting Authority

ACER: Australian Council for Educational Research

AEU: Australian Education Union

APM sciences: advanced physical and mathematical sciences encompassing the core physical sciences of physics, chemistry, the earth sciences and the mathematical sciences. 'Advanced' means science undertaken and applied in the past 20 years.

ARC: Australian Research Council

ATN: Australian Technology Network, alignment of universities consisting of Curtin University, University of South Australia, RMIT University, and University of Technology Sydney

AustMS: Australian Mathematical Society

BERD: Business Expenditure Research & Development

CIE: Centre of International Economics

ESCS: Social and Cultural Status Index

EFTSL: Equivalent Full Time Student Load

ERA: Excellence in Research for Australia

FTE: Full Time Equivalent

Go8: Group of Eight universities, alignment of universities consisting of University of Sydney, University of New South Wales, University of Adelaide, University of Melbourne, Monash University, Australian National University, University of Western Australia and University of Queensland

GOVERD: Government Expenditure Research & Development

GVA: Gross Value Added

HERD: Higher Education Expenditure Research & Development

ICSEA: Index of Community Socio-Educational Advantage

IRU: Innovative Research Universities, alignment of universities consisting of Charles Darwin University, Flinders University, Griffith University, James Cook University, La Trobe University, Murdoch University and Western Sydney University.

MANSW: Mathematical Association of New South Wales

NAPLAN: National Assessment Program- Literacy and Numeracy

NMS: National Minimum Standard (NAPLAN)

OCS: Office of the Chief Scientist

OECD: Organisation for Economic Co-operation and Development

QILT: Quality Indicators in Learning and Teaching

PISA: Programme for International Student Assessment

RUN: Regional Universities Network, alignment of universities consisting of Central Queensland University, Southern Cross University, Federation University Australia, University of New England, University of Southern Queensland, Charles Sturt University and University of the Sunshine Coast. Note that Charles Sturt newly joined RUN in 2019 and has been included with non-aligned universities in this publication.

STEM: Science, Technology, Engineering and Mathematics

TIMSS: Trends in International Mathematics and Science Study

UoE: Unit of Evaluation (ERA)

Acknowledgments

This publication includes information from many sources and would not have been possible without the input from many people. It provides a helicopter view of data and analysis published and provided by government, government agencies, non-government organisations and societies. Every effort has been made to accurately and clearly present any data, graphs and tables generated by other organisations. Any errors or omissions are entirely our own.

Much of the information contained in Chapters 2 and 4 is provided to AMSI by university mathematical sciences departments and schools through an annual survey. AMSI wishes to thank its members and non-member universities for their generous cooperation with this survey.

While it is impossible to thank everyone who has contributed to this publication, AMSI would like to specifically thank the following people and organisations for providing us with information, advice and suggestions: Dr Susan James, A/Prof Peter Johnston, The Office of the Chief Scientist of Australia and Dr Ian Dobson.

Lastly, my personal thanks to former and current AMSI colleagues for their help and support in producing this Discipline Profile. I am very grateful for the thorough proofreads by Melissa Trudinger, Nathan Smith, Laura Carmichael and Clint Rodgers. Above all I would like to thank Michael Shaw for his admirable work to design this document.

Maaike Wienk, May 2020

AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

AMSI.ORG.AU

BUILDING 161, C/- THE UNIVERSITY OF MELBOURNE, VICTORIA 3010 AUSTRALIA

T: +61 3 8344 1777 **E:** ENQUIRIES@AMSI.ORG.AU