DISCIPLINE PROFILE
OF THE MATHEMATICAL SCIENCES

RESEARCH

INDUSTRY

HIGHER ED

SCHOOLS

2017

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

AMSI Mission Statement

THE RADICAL IMPROVEMENT OF MATHEMATICAL SCIENCES CAPACITY AND CAPABILITY IN THE AUSTRALIAN COMMUNITY THROUGH:

- The support of high quality mathematics education for all young Australians
- Improving the supply of mathematically well-prepared students entering tertiary education by direct involvement with schools
- The support of mathematical sciences research and its applications including cross-disciplinary areas and public and private sectors
- The enhancement of the undergraduate and postgraduate experience of students in the mathematical sciences and related disciplines

CONTENTS

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Note: *this document does not currently cover the research enterprise of Australia's government agencies such as ABS, BoM, CSIRO and DSTO, or the private sector in areas such as finance and mining. Research training is predominantly the domain of universities with some co-supervision and postdoctoral training taking place at the agencies.*

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Fundamental to social and economic prosperity, the mathematical sciences underpin Australia's capacity to innovate on the global stage.

In its sixth edition, this report provides a detailed snapshot of the state of the discipline and its impact on all stages of the pipeline from the classroom and higher education to research development, workforce trends and industry innovation. As well as AMSI, key stakeholders, government and business rely on this data to inform policy development and drive debate.

New in this document are the 2015 results of both the PISA and TIMSS surveys, along with an overview of circumstances influencing mathematical performance among school students.

As always, we include the latest NAPLAN data, as well as the preliminary data from AMSI's 2016 survey of Australian university mathematical sciences departments.

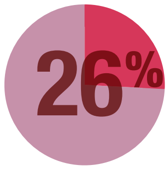
Australia's deepening mathematics deficit must be considered a call to action as we continue to see a shortage of maths trained teachers in secondary classrooms, particularly across Years 7–10.

This is contributing to the continued stagnation in Year 12 advanced and intermediate mathematics participation, particularly amongst girls. While there is a high need for these skills within industry, current mathematics and statistics university graduate numbers are failing to meet demand.

This document should be read in conjunction with the latest version of AMSI's policy document *Improving Australia's Maths Grades*.

FROM CLASSROOM
TO INDUSTRY

EDUCATION
NEEDS TO CHOOSE MATHS



Shortage of qualified maths teachers in secondary schools, especially in regional areas

At least 26% of Years 7–10 maths teachers are **not** fully qualified. (pages 24 & 25)

Inequality in the maths performance of school students is **worsening**

Most students who receive low numeracy achievement scores in Year 3 never catch up with their peers, falling even further behind by Year 9 (pages 19 & 20)

Maths achievement is closely aligned to socioeconomic status

And students who start off behind their peers due to socioeconomic factors **never catch up**, falling further behind each year (Figures 1.7 & 1.22)

Half of Australia's students in Year 8 dislike maths, significantly more than the international average

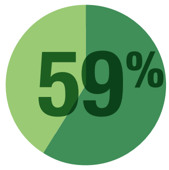
It's also significantly more than those who dislike science (Figure 1.20)

Australia's international position in school maths performance has **declined sharply**

The proportion of students choosing Year 12 advanced maths has declined by 20% from 2000 to 2015, and by 32% from 1995 to 2016 (pages 21 & 22)

HIGHER ED
A FORGOTTEN PATH TO SUCCESS

The number of universities **requiring at least intermediate maths** for entry into science and commerce degrees remains low (page 24)



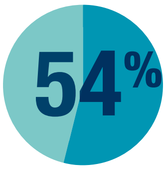
Only 59% of engineering degrees **include maths as a prerequisite** (page 24)

Small universities often **lack the capability** to offer a major in the mathematical sciences (page 34)

Despite Australia's ageing mathematics workforce, the number of students pursuing a maths degree is not increasing. This points to a **shortage in the future workforce** (Figure 2.17)

THE ECONOMICS
OF MATHS & STATS

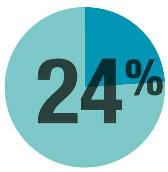
The direct impact of advanced physical and mathematical research is estimated at **$145 billion or 11.2% of the Australian economy annually** (page 51)



54% of Australian adults have only **basic numeracy skills**, only just over the current OECD average (page 43)

The ageing of the mathematical workforce is **worse than in the other STEM workforce sectors** (page 47)

24% of Mathematical Sciences graduates end up working in the **education and training sector**, as teachers and lecturers



This is closely followed by those employed in professional, scientific and technical services (20%), including research and ICT (Figures 3.11 & 3.12)

RESEARCHING
OUR WAY TO THE TOP

The mathematical sciences have on average had **a higher success rate** for research grants from the Australian Research Council than other disciplines since 2011 (page 53)

Citation rates of Australian mathematical research in statistics and applied mathematics **outperforming 15 countries** within the European Union

While the mathematical sciences are amongst the smallest areas of research in Australia, internationally they hold their own (pages 57 & 58)

AT RISK:
THE PROSPECTS OF CREATING A SCIENTIFICALLY LITERATE POPULATION

GENDER SUMMARY

GENDER ACROSS THE PIPELINE: UNREALISED POTENTIAL

ENGAGEMENT OF WOMEN AND GIRLS IN MATHEMATICS REMAINS A KEY AMSI POLICY priority, as we seek to secure Australia's mathematical capability and capacity and future prosperity. Addressing the gender challenge, a deepening issue across all STEM disciplines, is critical to ensure skill supply can meet industry need into the future. Gender balance is also a critical priority to boost skill supply as ageing contracts the mathematical workforce.

Adult numeracy data paints a worrying picture with Australian men continuing to outperform women at every life stage. The gap is smallest in the younger age bands of 15–19 years and 20–24 years, but starts to rise 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

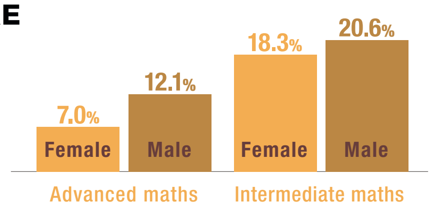
CLASSROOM BEGINNINGS

According to 2016 NAPLAN data the percentage of Year 9 students reaching the national minimum standard in numeracy has remained largely static, with 95.7 per cent of girls at or above minimum standard against 94.7 per cent of boys. However, the story changes in the higher achievement bands with the gender gap widening. Representation at band 9 was just 13.5 per cent for girls and 15.1 per cent for boys, with representation in band 10 falling to 9.7 per cent for boys and just 6.6 per cent for girls. Further analysis of NAPLAN data reveals a worrying trend with girls 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 don't excel in maths as often as boys. **See page 15**

Trends in International Mathematics and Science (TIMSS) and the Programme for International Student Assessment (PISA) confirm a small difference with a narrow gap between the performance of boys and girls. Comparatively girls outperform boys in literacy by a much larger margin. It should be noted that other factors such as school geographic location, indigenous status and parental occupation outweigh gender in their impact on numeracy achievement. **See pages 13–17**

MISSING THE MARK FOR A STEM FUTURE

Perhaps most concerning is the report card for Year 12 participation in mathematics, which threatens capacity to build a STEM workforce for the future. In 2016 only 7.0 per cent of female Year 12 students took advanced maths compared with 12.1 per cent of male students. These figures rise to 18.3 per cent and 20.6 per cent respectively for intermediate enrolments. **See page 22**



Year 12 participation in mathematics

HIGHER EDUCATION

A DEEPER DIVIDE

Further down the pipeline, the gender divide deepens at university level. In 2016 female students accounted for an estimated 33 per cent of undergraduate mathematics students, consisting of about 25 per cent domestic female students and 8 per cent international. **See Figure 2.15 on page 35**

Annual completion figures for domestic female students studying bachelor degrees in mathematical science have remained below 100 since 2012 **See Figure 2.18 on page 36**

This mirrors general gender trends for this century with the proportion of women completing bachelor degrees (Honours) declining to below 25 per cent. **See Figure 2.21 on page 37**

The proportion of domestic female students enrolled in honours courses in 2016 was 20 per cent, with domestic female students comprisng 18 per cent, and international female students 2 per cent of all enrolments. **See Figure 2.22 on page 38**

POSTGRADUATES

AN INTERNATIONAL BOOST

The news is not all bad with growth in the number of PhDs 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 almost 35 per cent. This is largely attributable to a rising influx of international students—domestic female participation in PhD degrees has remained stagnant. **See Figures 2.24 and 2.25 on pages 38–39**

According to OECD reporting, the proportion of women awarded university mathematics degrees in Australia has risen from 37 per cent in 2000 to 39 per cent in 2012. Despite this, Australia continued to trail OECD and EU averages (42 per cent and 44 per cent in 2000, and 46 per cent and 50 per cent in 2012) by 5 points (OECD) and 7 points (EU) in 2000 and 7 points (OECD) and 11 points (EU) in 2012. **See Table 2.29 on page 41**

WORKFORCE

RECORDS BEST LEFT UNBROKEN

The academic mathematical workforce remains predominantly male, with only 23 per cent of reported staff (excluding casuals) female. This is one of the lowest percentages of women in any academic discipline. **See Figures 2.7, 2.8 and 2.9 on pages 31–32**

A WORKFORCE DEFICIT

Women account for approximately 40 per cent of Australia's mathematically qualified workforce. A low influx of younger women is negatively skewing the age distribution of the female proportion of the mathematical workforce, with a greater number of older female mathematicians. **See Figure 3.6 on page 46**

SOME SECTORS MORE EQUAL THAN OTHERS

Gender distribution across the mathematical sciences differs between employment divisions and occupations. Female mathematical scientists outnumber males within the Healthcare and Social Assistance sectors. The percentage of women in the Education and Training, and Finance and Insurance industries is about 40 per cent, while the proportion in Professional, Scientific and Technical Services drops to approximately 30 per cent. While gender balance is equitable for secondary school teachers, female representation drops significantly at university level to close to 25 per cent for lecturers and tutors. **See Figures 3.11 and 3.12 on page 49**

PART-TIME VERSUS FULL-TIME

Employment structure also differs with approximately 36 per cent of women with mathematical bachelor degrees working part-time compared to 19 per cent of males. At the doctorate level, 24 per cent of female PhDs work part-time compared to 15 per cent of males. The lower and middle-income brackets have the highest representation of part-time employment. If we look at full-time employees only, 33 per cent of men versus 15 per cent of women with bachelor degrees earn in the highest income bracket. Of the doctorate degree holders 49 per cent of men and 33 per cent of women are represented in the highest income brackets. **See Figure 3.13 on page 49**

INDIGENOUS AND REGIONAL **ENGAGEMENT**

TACKLING DISADVANTAGE ACROSS THE MATHEMATICAL PIPELINE

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 of these schools in regions dependent on STEM industry, this gap threatens future economic stability and skill supply across regional growth areas. AMSI's own work with regional and high-indigenous population schools confirms that interactive approaches contextualised with real-world application is key to strengthening student engagement, in particular when working with indigenous students.

Australia's minority group of well-resourced, high-performing schools cannot bear the sole burden of mathematical skill supply.

Critically, with a majority of the nation's future teaching workforce unlikely to be produced by these schools, failure to address educational disadvantage will only deepen the current teacher shortage and increase rates of out-of-field teaching.

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

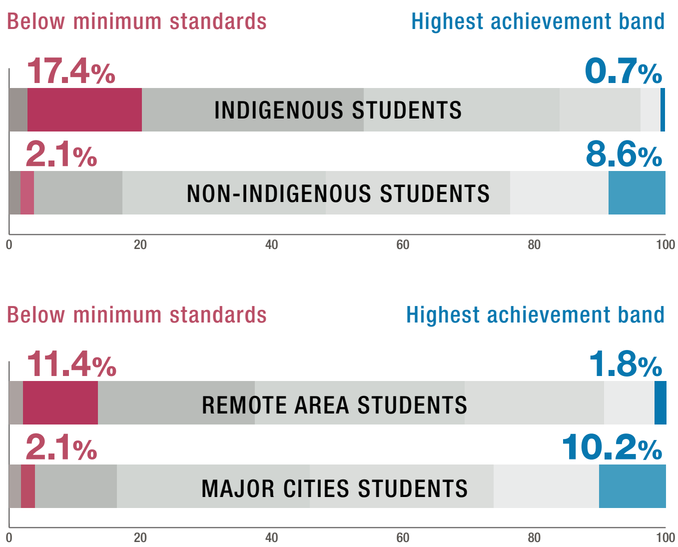
DISADVANTAGE IN THE CLASSROOM

The mathematical capability gap is widening for Australia's indigenous student population. Recent NAPLAN data reveals 17.4 per cent of Year 9 indigenous students failed to achieve minimum maths standards (Year 5) in 2016, compared to only 2.1 per cent of non-indigenous Year 9 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 extremely low with only 0.7 per cent of indigenous students reaching band 10 compared to 8.6 per cent of non-indigenous students. **See page 15**

Recent PISA, NAPLAN and TIMSS data reveals the impact of geographic location in deepening the mathematics gap with students in metropolitan and inner-regional areas significantly outperforming those in regional and remote areas. NAPLAN 2016 revealed over 11 per cent of students in remote regions were below minimum standards (Year 5). This figure soared to 37.9 in very remote areas. The number of students in the highest bands in remote and very remote areas is vastly lower than in major cities and inner regional schools. Only 0.6 per cent of students in very remote areas achieved band 10 climbing to 1.8 per cent in remote areas. This is in comparison to 10.2 per cent of students in major cities**.** **See page 17**

THE WIDENING CAPABILITY GAP

Year 9 Numeracy



Figures reproduced from table 1.9 and 1.14, Year 9 Numeracy in 2016

FAILING TO MATHEMATICALLY EQUIP STUDENTS CREATES BARRIERS TO EMPLOYMENT AND RISKS LOCAL AND REGIONAL PROSPERITY

The application of the Grattan Institute's time-based measure *equivalent year levels* to interpretation of Victorian NAPLAN data revealed some worrying discrepancies. As shown in figure 1.22 of the Discipline Profile low numeracy achievers almost never catch up, falling further behind by Year 9 with a gap of on average 3 years and 8 months. As well as geographic location, parental education remains a significant factor in student progress. **See pages 19-20**

The gap between students whose parents have low versus high levels of education increases from 10 months in Year 3 to 2.5 years in Year 9. Those whose parents have a degree or above significantly outperform those who have no or limited tertiary education.

These figures increase to 1 year and 3 months in Year 3 and 3 years and 8 months in Year 9 for those in disadvantaged schools. Even those who score highly in Year 3 numeracy at disadvantaged schools will fall behind, making at least 2 years and 5 months less progress by Year 9 than those in high-advantage schools. This serves to highlight entrenched disadvantage in the Australian education system, as it is the school attended rather than student capability that determines outcomes. **See page 20**

STRENGTHENING TEACHER SUPPLY

In Australia, at least 26 per cent of Year 7 to 10 maths classes do not have a maths-qualified teacher. Unfortunately regional and remote schools are the most likely to have severe out-of-field teaching. Data dating back to 2010 illustrates the wide variance of teacher training between metropolitan, regional and remote areas. Table 1.37 in the Discipline Profile shows the proportion of Years 7 to 10 teachers with three or more years of tertiary maths was 45 per cent in metro areas falling to 37 per cent in regional and 40 per cent in remote areas. In Years 11 and 12 this gap widens with 57 per cent of regional and 43 per cent of remote teachers having three or more years of tertiary maths compared to 64 per cent of metropolitan teachers. **See page 27**

While not specific to maths, PISA 2015 findings show teacher shortages and out-of-field teaching are highest in disadvantaged schools. With many of these schools producing future generations of teachers, this issue quickly becomes systemic. Engagement of students in low SES, disadvantaged, regional and remote schools needs to be part of a broader strategy to address out-of-field teaching in mathematics. **See page 27**

Delivery of training and personal development to build capability and confidence of the existing teacher workforce and skill continuity, in particular indigenous teacher support staff, is critical to improving engagement and retention of maths-qualified teachers.

In addition to training existing teachers, a national effort to recruit indigenous students from Australia's mathematical sciences departments must be a priority. A recent Queensland report shows social contribution and equity plays a more powerful role in indigenous students selecting teaching as a career than for their non-indigenous peers. Recruitment of indigenous mathematics teachers from Australia's mathematical sciences departments remains a significant priority.

RESEARCH & HIGHER EDUCATION

Disadvantage is also reflected in the numbers of ATSI staff and students in Australia's university mathematical sciences departments. In 2015, AMSI members reported just four staff members who identified as ATSI and 151 students out of more than 10,000 studying mathematical sciences subjects at university. This under representation does not bode well for the supply of indigenous mathematics teachers for ATSI communities.

MATHS IN DEMAND: REGIONAL GROWTH CORRIDORS

Many of the top mathematics graduate employers in the Office of the Chief Scientist's *Australia's STEM Workforce 2016* report have a strong regional presence. From manufacturing, transport, warehousing, wholesale trade to mining and resources and agriculture, there is clear demand for these skills in regional growth corridors. **See page 49**

EDUCATION
NEEDS TO CHOOSE MATHS

Shortage of qualified maths teachers in secondary schools, especially in regional areas

At least 26% of Years 7–10 maths teachers are **not** fully qualified (pages 24 & 25)

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It's also significantly more than those who dislike science (Figure 1.20)

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1 School Education

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

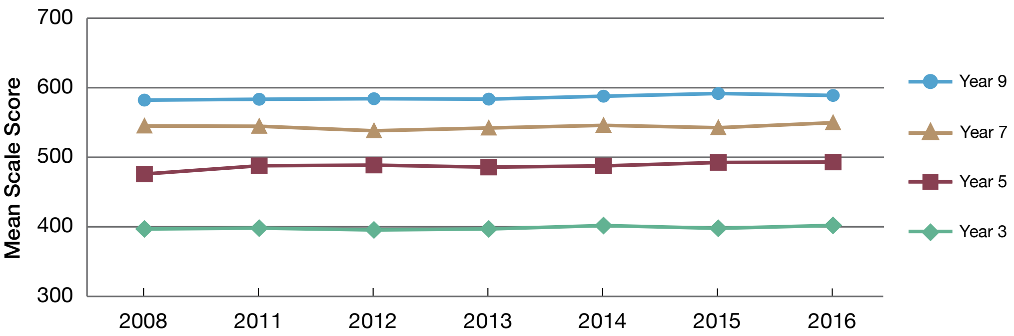
In Australia, the mathematical performance of students overall has remained static for some time. When compared to other countries, Australia's ranking has been in long-standing decline according to both the Programme of International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) surveys. Within the school population, the inequality between low performing and high performing students has increased. Students starting off at a disadvantage never catch up, falling further behind during their schooling years.

A high proportion of secondary school teachers, particularly in Years 7-10, have no methodology training in mathematics, and vacancies for mathematics teachers remain difficult to fill, making out-of-field-teaching a necessity for many schools. In Year 12, most students still choose to take mathematics, but the proportions of students choosing advanced or intermediate mathematics as their most advanced mathematics subject have declined in the last two decades. Many universities no longer require intermediate or advanced mathematics as an entry requirement for science, business or engineering degrees. The proportion of girls taking advanced mathematics in Year 12 is about 7 per cent, against 13 per cent of boys.

1.1 STUDENT PERFORMANCE IN NUMERACY AND MATHEMATICS

Despite the introduction of programs to improve mathematical performance, NAPLAN national reports show overall student performance in numeracy has not lifted at all over the past nine years. Figure 1.1 shows the 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. Between 2008 and 2016 most scores show no significant difference. The Year 5 results indicate a modest increase in the mean numeracy achievement between 2008 and 2016, but otherwise there has been no significant movement either up or down.

Figure 1.1 Achievement of students in numeracy, 2008, 2011–2016



Students		2008	2011	2012	2013	2014	2015	2016	Nature of the difference 2008 vs. 2016	Nature of the difference 2015 vs. 2016
Year 9	Mean / (S.D.)	582.2 (70.2)	583.4 (72.1)	584.2 (72.4)	583.6 (82.2)	587.8 (70.9)	591.7 (67.8)	588.9 (66.8)	■	■
	% at or above NMS	93.6	93.0	93.7	90.6	94.1	95.7	95.2	■	■
Year 7	Mean / (S.D.)	545.0 (73.2)	544.6 (73.7)	538.1 (73.9)	542.1 (71.4)	545.9 (73.0)	542.5 (68.6)	549.7 (70.4)	■	■
	% at or above NMS	95.4	94.5	93.8	95.0	95.1	95.9	95.5	■	■
Year 5	Mean / (S.D.)	475.9 (68.8)	487.8 (68.2)	488.7 (70.9)	485.8 (71.5)	487.6 (69.0)	492.5 (68.0)	493.1 (70.6)	△	■
	% at or above NMS	92.7	94.4	93.3	93.4	93.5	95.1	94.3	■	■
Year 3	Mean / (S.D.)	396.9 (70.4)	398.1 (70.6)	395.5 (72.6)	396.9 (65.8)	401.8 (73.0)	397.8 (74.3)	402.0 (73.4)	■	■
	% at or above NMS	95.0	95.6	93.9	95.7	94.6	94.4	95.5	■	■

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.
***Source:** 2016 NAPLAN Report, Table and Figure TS.N1, page 279.*

This lacklustre performance is echoed in the results of international surveys of student performance in mathematics. TIMSS shows that between 2003 and 2015, the educational achievement of Australian students in Year 4 remained steady after a slight increase since 2007, and was the same as in 2003 for students in Year 8 (despite a dip in 2007). The average achievement of Australian students has not moved closer to the highest country average achievement. In fact, while Australian achievement has remained stagnant, the number of countries surpassing Australia has increased (Figure 1.2 and 1.3).

__Source:__ 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 wrong to conclude that the higher ranking for Year 8 is an indication of a relatively better performance than for Year 4.

Figure 1.2 TIMSS: comparative achievement of Australian students in maths in Year 4 2003–2015

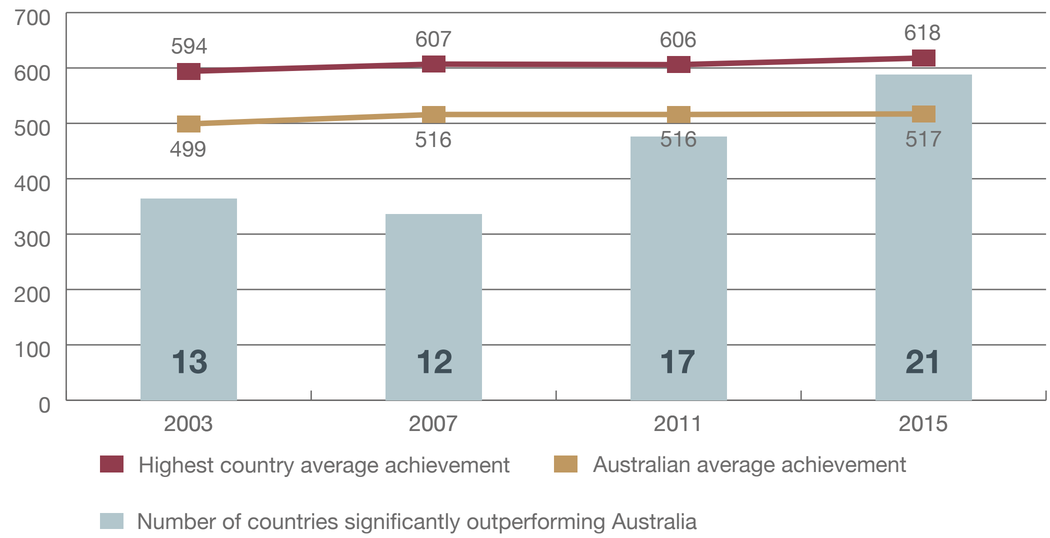


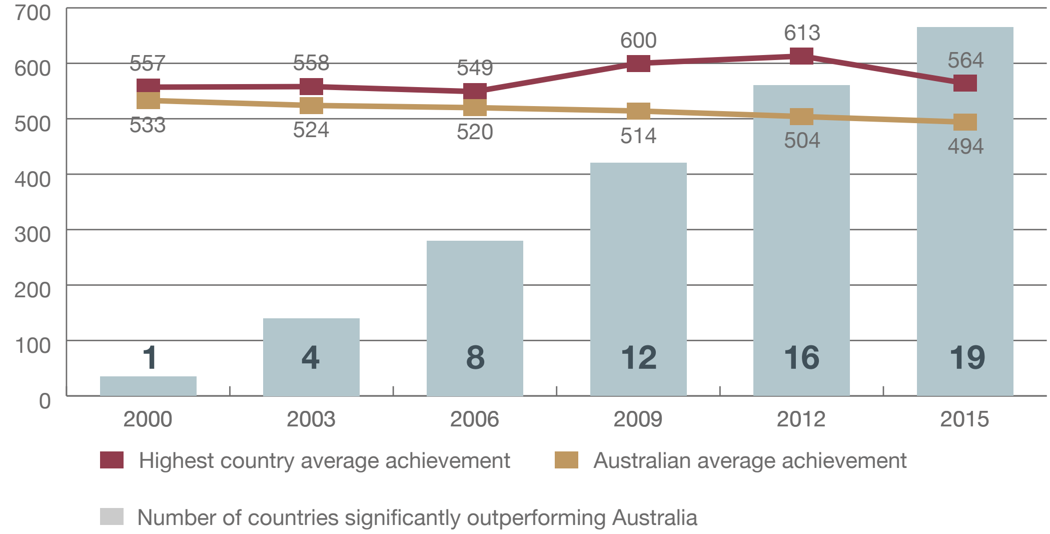
Figure 1.3 TIMSS: comparative achievement of Australian students in maths in Year 8 2003–2015

The second major international survey, PISA, assesses mathematical literacy, focusing 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 2000–2015 indicate that:

- the Australian average mathematical literacy performance has declined in absolute terms over this period;
- a gap has opened up between the Australian mean score and the highest mean country score since 2009;
- the number of countries that significantly outperform Australia has steadily increased (Figure 1.4).

In both the TIMSS and PISA surveys, countries in South-East Asia (Republic of Korea, parts of China, Singapore, Japan) are the consistent top performers. Other countries out-performing Australia in both the 2015 TIMSS and PISA surveys are Canada, Ireland, and Slovenia.

Figure 1.4 PISA: comparative mathematical literacy of Australian 15-year-old students 2000–2015



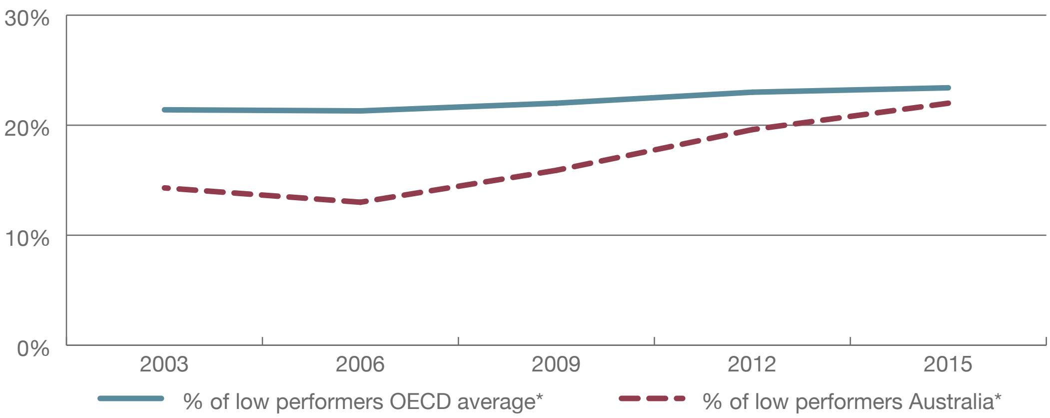
Source: *Selected data from PISA 2000, 2003, 2006, 2009, 2012 and 2015.*

1.2 DISTRIBUTION OF MATHEMATICAL ACHIEVEMENT

The persistent and in some aspects deepening performance inequality amongst Australian students is of significant concern. In particular, we see large gaps between high and low performers when comparing students from different socio-economic backgrounds.

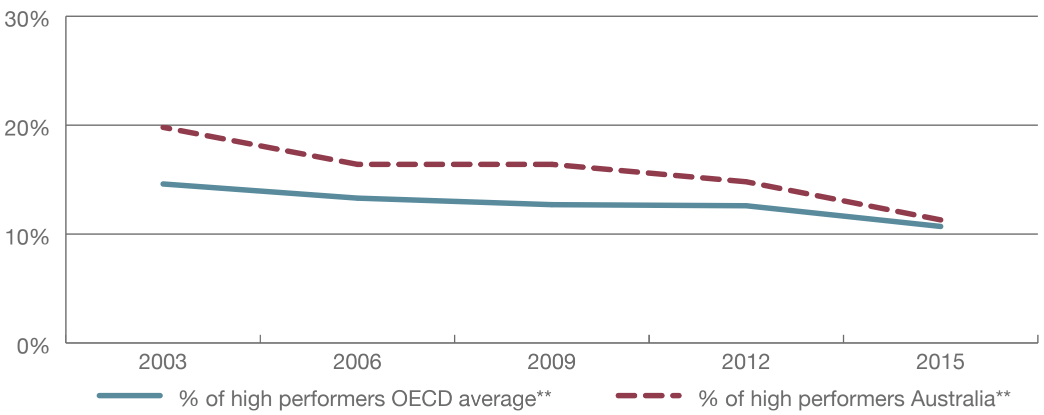
The Australian PISA survey results in the period 2003–2015 show a decrease in students performing very well in mathematical literacy, and an increase of students performing poorly. While in 2003 Australia was doing significantly better than the OECD average on both counts, since then low performance has been on the rise, and high performance in decline. Both are now very close to the OECD average (Figures 1.5 and 1.6). The OECD average has also seen an increase in low performance and a decrease in high performance, albeit not as pronounced.

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



Source: *PISA selection of data international reports 2003, 2006, 2009, 2012 and 2015.*

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



Source: *PISA selection of data international reports 2003, 2006, 2009, 2012 and 2015.*

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 factors that have an impact to varying degrees on how well students perform in mathematics.

Student-related factors—*Socio-economic background*

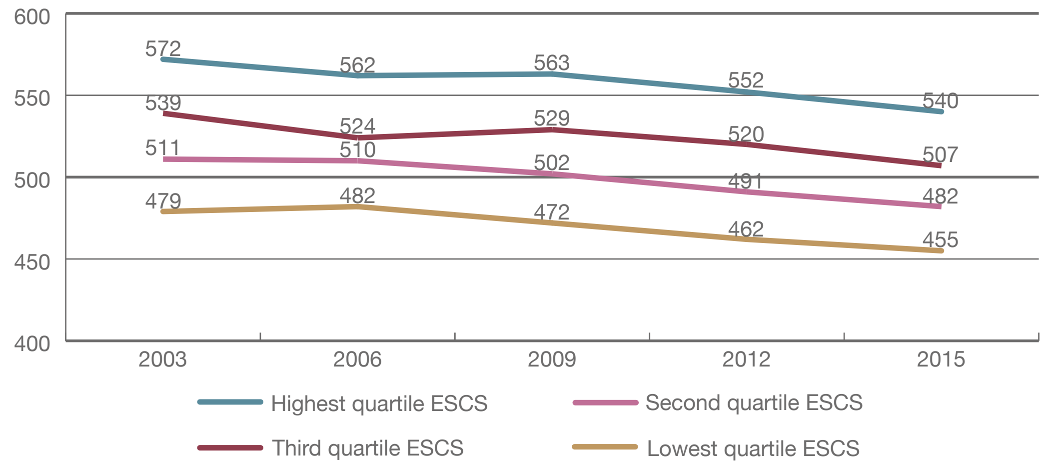
All studies—NAPLAN, PISA and TIMSS—show clearly that the socio-economic background of students determines how well they perform in mathematics. Factors such as parental education and occupation, as well as other proxy indicators like the number of books and other learning resources in the home, are paramount.

Figure 1.7 illustrates this over time. In Australia, there are significant differences in mathematical literacy performance between students from all four quartiles on the economic, social and cultural status index (ESCS), which persist over the whole period to 2015. (Note that the performance for mathematical literacy in the PISA survey has declined for students of all socio-economic backgrounds since 2003.) In 2015, the difference between students from the highest and lowest quartiles was 85 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 socioeconomic background

Source: *PISA 2015: Reporting Australia's results, extract Figure 5.24, page 188.*

ESCS index: economic, social and cultural status index.



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, correlates significantly with 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

Source: *TIMSS 2015: Reporting Australia's results, extract Figures 3.19 and 3.20, page 67.*

	Mean	< Low	Low	Intermediate	High	Advanced
Many books	541	5	15	31	35	14
Average number of books	515	6	22	39	26	6
A few books	468	21	34	29	12	3

Student-related factors—*Indigenous background*

Being of Aboriginal or Torres Strait Islander background unfortunately puts students at an extreme disadvantage compared to other Australian students, and this is no different when it comes to mathematical performance. The 2016 NAPLAN data illustrates the achievement gap between indigenous and non-indigenous students in Year 9. Less than 80 per cent of indigenous students reach the national minimum standard in numeracy compared to 96.1 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 86.3 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 2016

NAPLAN Year 9 Numeracy in 2016	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 Indigenous Status, 2016								
Indigenous	2.8	17.4	33.8	29.8	12.4	3.0	0.7	79.7
Non-Indigenous	1.7	2.1	13.4	31.0	28.1	15.0	8.6	96.1
Achievement of Year 9 Indigenous Students by Geolocation, 2016								
Major cities	3.2	10.5	31.7	33.9	15.4	4.1	1.2	86.3
Inner regional	2.7	12.1	34.2	32.5	14.5	3.3	0.6	85.2
Outer regional	2.5	17.5	37.9	29.4	10.1	2.3	0.4	80.1
Remote	4.4	31.7	36.8	20.0	5.7	1.4	0.0	63.9
Very Remote	1.1	51.1	29.6	13.6	3.8	0.7	0.1	47.8

Source: *2016 NAPLAN report, Table 9.N3, page 240 and 9.N6, page 243.*

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, but in the majority of cases the difference in achievement is not deemed statistically significant. For instance, in TIMSS 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 2016 NAPLAN report shows no real difference between female and male students when it comes to reaching the national minimum standard. However, male students are represented more in the highest achievement bands 9 and 10, and girls in the "middle of the range" achievement bands 7 and 8.

Table 1.10 Year 9 Numeracy in 2016

NAPLAN Year 9 Numeracy in 2016	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 Sex, 2016								
Male	2.3	3.0	14.1	29.1	26.7	15.1	9.7	94.7
Female	1.4	3.0	15.0	32.8	27.8	13.5	6.6	95.7

Source: *2016 NAPLAN report, Table 9.N2, page 239.*

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

Being of a non-English speaking background or immigrant background seems to influence performance in both directions. Students from a non-English speaking background more often perform in the highest mathematical achievement bands (17 per cent versus 6 per cent of students who speak English at home). They are 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 1.11 with data from the latest TIMSS survey illustrates this.

Table 1.11 Mathematics achievement in Year 8 according to whether a language other than English is spoken at home

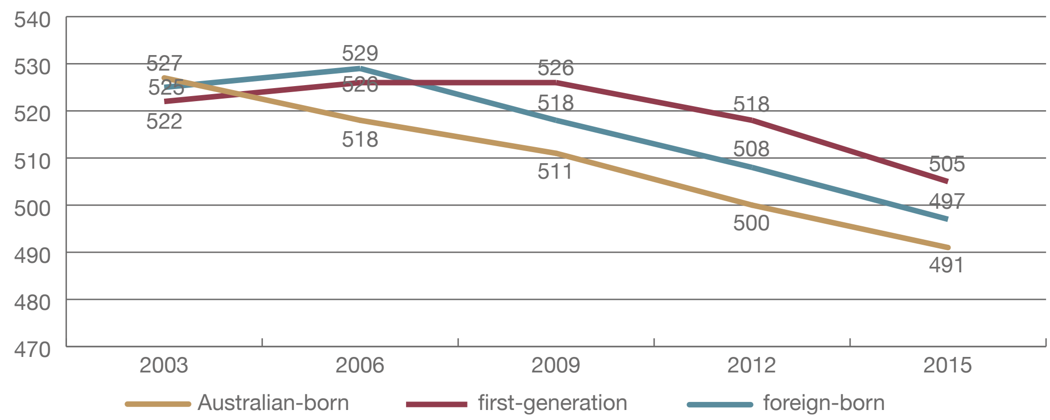
	Mean	< Low	Low	Intermediate	High	Advanced
English	505	10	25	35	24	6
Other	518	**15**	21	24	24	**17**

Source: *TIMSS 2015: Reporting Australia's results, extract Figures 3.28 and 3.29, page 72.*

With regard to immigrant background, from Figure 1.12 it is clear that first-generation and foreign-born students have not escaped the decline in performance evident from the PISA results. However, foreign-born and first-generation students seem to have a slight advantage when it comes to mathematical literacy. The advantage in performance in 2015 between first-generation students and Australian-born students is equivalent to about half a year of schooling.

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

Source: *PISA 2015: Reporting Australia's results, extract Figure 5.27, page 191.*

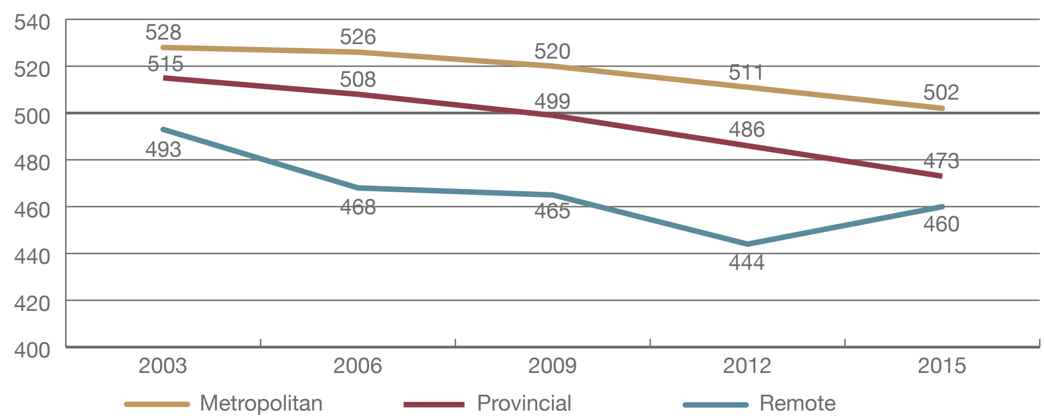


School and teaching—*Geographic location*

The location of the school is an important determining factor in the mathematical achievement of Australian students. 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 1.13 shows the differences in PISA results over time, and it is disturbing to see how the difference in performance between metropolitan and provincial areas has more than doubled from 13 points in 2003 to 29 points in 2015—which equates to around one year of schooling. Students from remote schools have increased their performance in 2015 compared to 2012, nevertheless the difference with metropolitan students still amounts to about one-and-a-half years of schooling.

Figure 1.13 Average student performance for mathematical literacy over time, by geographic location

Source: *PISA 2015: Reporting Australia's results, extract Figure 5.21, page 185.*



The 2016 NAPLAN report (see Table 1.14) introduced a slightly more sophisticated location distinction—between major cities, inner regional, outer regional, remote and very remote locations. It is noteworthy that there are vast differences in the performance of all students in the various regions. However, if we compare exclusively non-indigenous students in the various regions, the difference in mathematical performance between students in different locations becomes much smaller, at least with regard to reaching the national minimum standard. In the high achievement bands 9 and 10, the gap between major cities and all other regions remains substantial.

Table 1.14 Year 9 Numeracy in 2016

NAPLAN Year 9 Numeracy in 2016	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, 2016								
Major cities	1.8	2.1	12.5	29.4	28.0	16.0	10.2	96.1
Inner regional	1.9	3.8	18.4	34.8	26.6	10.9	3.6	94.3
Outer regional	1.7	4.9	20.5	35.9	24.7	9.6	2.7	93.4
Remote	2.1	11.4	23.9	32.0	21.2	7.7	1.8	86.4
Very Remote	1.1	37.9	27.4	20.5	9.3	3.1	0.6	61.0
Achievement of Year 9 Non-Indigenous students by Geolocation, 2016								
Major cities	1.8	1.8	11.9	29.3	28.4	16.3	10.5	96.4
Inner regional	1.8	3.1	17.2	35.1	27.5	11.5	3.8	95.1
Outer regional	1.5	2.8	17.6	37.0	27.1	10.8	3.1	95.7
Remote	1.1	2.1	17.8	37.3	28.5	10.7	2.6	96.8
Very Remote	1.3	3.1	20.9	39.8	22.8	10.1	2.1	95.6

Source: *2016 NAPLAN Report, Table 9.N5, page 242, and Table 9.N7, page 244.*

School and teaching—*School sector*

The average mathematical literacy performance across the government, independent and Catholic school sectors shows significant differences. In 2015, 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 are adjusted for student and school socio-economic background, most of the remaining differences are no longer statistically relevant.

Table 1.15 Average mathematical literacy performance 2015 by school sector

	2015		Difference in raw score	Difference in scores after student and school level socioeconomic background is accounted for
Independent	532	Independent-Catholic	28	13
Catholic	503	Independent - government	55	5*
Government	477	Catholic-government	26	-7*

Note: ** difference not statistically significant.*

Source: *PISA 2015: Reporting Australia's results, extract Figure 5.13, page 177 and extract Table 5.7, page 178.*

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 1.16 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.

Table 1.16 Mathematics achievement in Year 8 according to school emphasis on academic success (according to teachers)

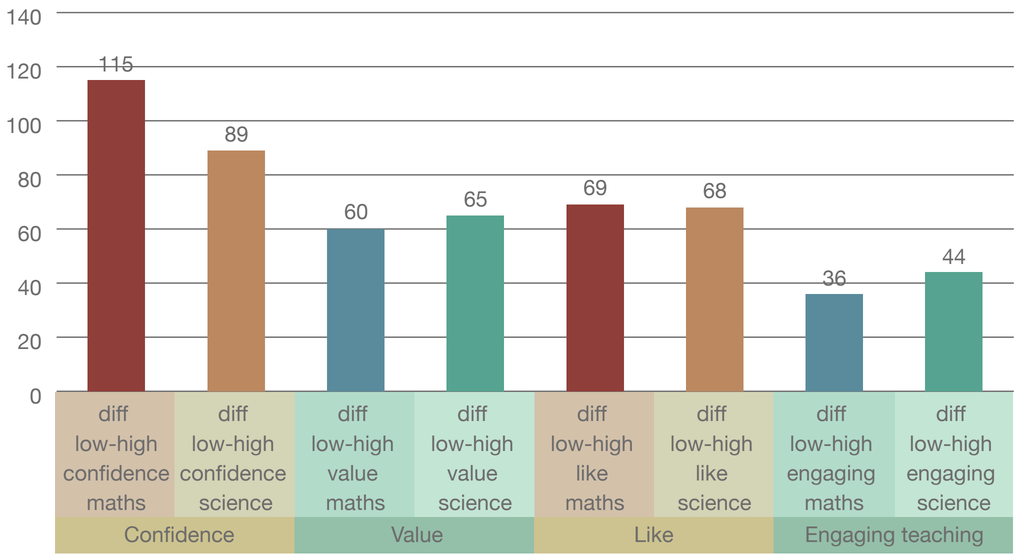
	average achievement	% of students	international average	% of students
Very high emphasis	543	8	515	5
High emphasis	523	48	495	46
Medium emphasis	484	44	464	49

Source: *TIMSS 2015 International Results in Mathematics, Exhibit 6.5.*

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 1.17 displays the difference 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 is 115 points.

Figure 1.17 Difference in mean achievement in mathematics and science by student attitudes and experiences in Year 8

Source: TIMSS 2015 International Results in Mathematics, extracts from Exhibits 10.2, 10.4, 10.6 and 10.7.



From anecdotal evidence, a common cultural message to Australian students seems to be that it is "OK" not to excel in mathematics and that they do not need mathematics in "real life". However, when we look at the TIMSS results for Year 8 we see that Australian students do not place less value on mathematics than the international average (see Figure 1.18). By contrast, Australian Year 8 students place a lot less value on science, both compared to the international average and to mathematics. The confidence Australian students have in their own mathematical ability lies very close to the international average as well (Figure 1.19).

Figure 1.18 Value placed on mathematics and science in Year 8 compared to international average

Source: TIMSS 2015 International Results in Mathematics and Science, Extracts Exhibit 10.7.

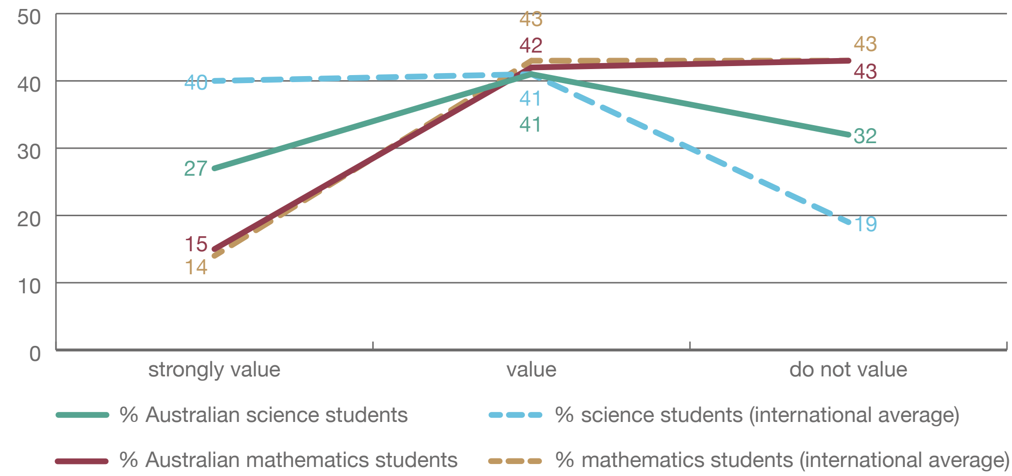
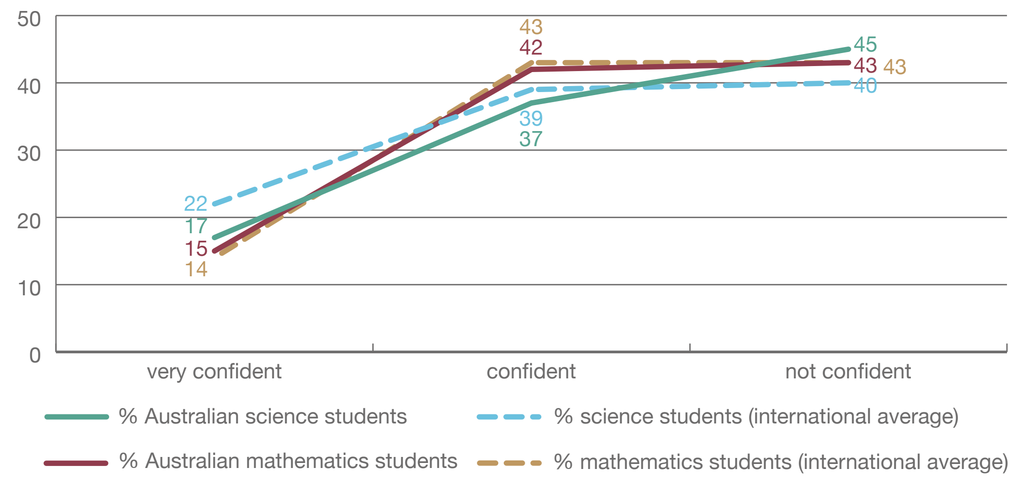


Figure 1.19 Student confidence in mathematics and science in Year 8 compared to international average

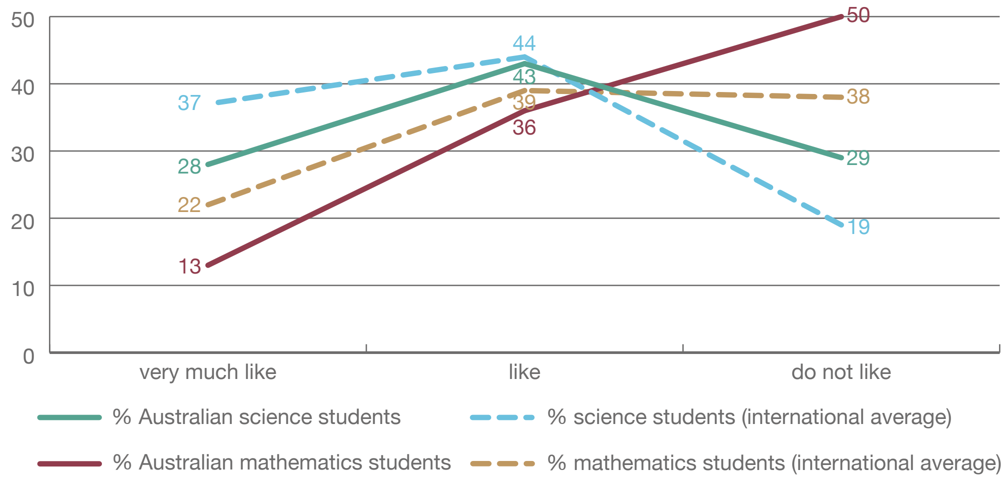
Source: TIMSS 2015 International Results in Mathematics and Science, Extracts Exhibit 10.6.



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 do not like mathematics, significantly higher than the international average of 38 per cent. Science does a bit better, with 29 per cent admitting they do not like the subject (compared to 19 per cent internationally)—Figure 1.20.

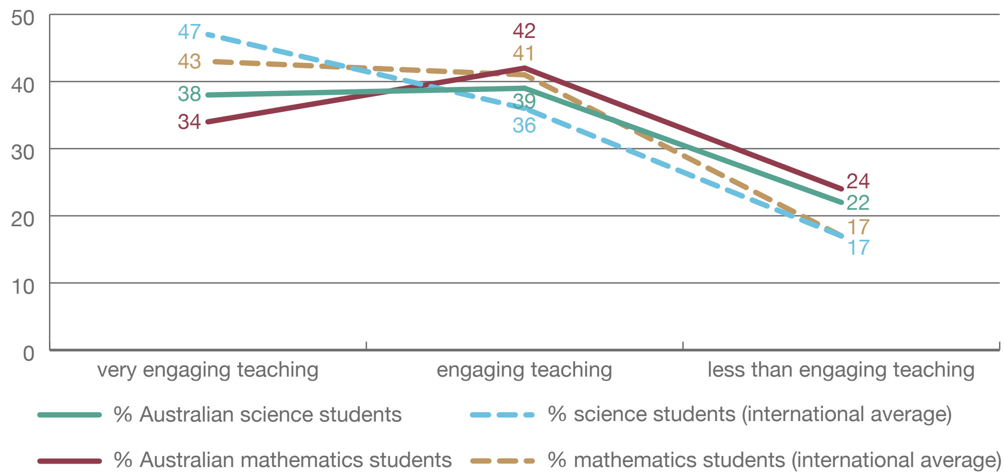
24 per cent of students in Year 8 find mathematics teaching less than engaging (see Figure 1.21).

Figure 1.20 Enjoyment of mathematics and science in Year 8 compared to international average



Source: *TIMSS 2015 International Results in Mathematics and Science, Extracts Exhibit 10.4.*

Figure 1.21 Students' view of engaging teaching in mathematics and science in Year 8 compared to international average



Source: *TIMSS 2015 International Results in Mathematics and Science, Extracts Exhibit 10.2.*

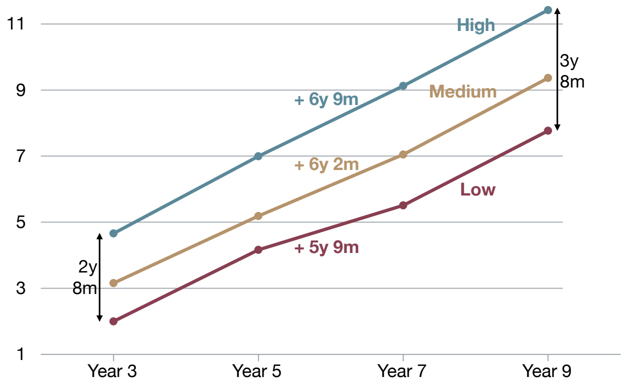
School and teaching—*Growing inequality*

The Grattan Institute has proposed a new time-based measure entitled "equivalent year levels" to interpret the yearly NAPLAN data and measure the actual gaps in achievement between students. Converting the NAPLAN scores into "years of progress" allows comparison of different groups of students within the same cohort. When applied to the NAPLAN numeracy data from the state of Victoria for the 2009–2015 cohort, some troubling disparities come to light:

- Low achievers in numeracy never catch up with their peers, but fall even further behind by Year 9 (Figure 1.22);
- The gap between students whose parents have low and high levels of education increases from 10 months in Year 3 to 2.5 years in Year 9 (Figure 1.23);
- Students in disadvantaged schools are 1 year and 3 months behind in Year 3, and fall even further back to 3 years and 8 months by Year 9 (Figure 1.24);
- Students in disadvantaged schools who score high on numeracy in Year 3, end up making 2 years and 5 months less progress by Year 9 than similarly capable students in high advantage schools (Figure 1.25).

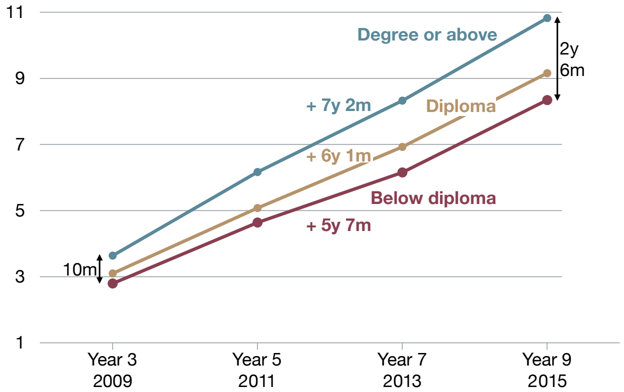
This last result in particular highlights how the Australian education system further entrenches numeracy performance inequality, as it is not the students' innate capabilities which determine their educational outcomes in numeracy, but the school they have attended.

Figure 1.22 Growth of disadvantage—Estimated progress of low, medium and high achievers



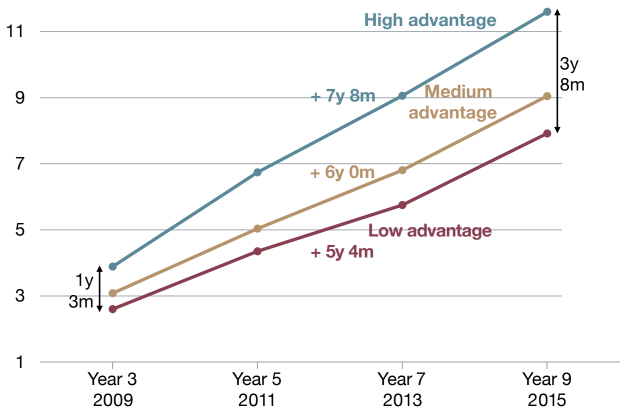
Notes: *Results show the estimated progress of low, medium and high achievers (students who scored at the 20th, 50th and 80th percentiles in Year 3) between Years 3–9. Black values indicate the gap between highest and lowest groups. Coloured values are the years of progress gained over the six-year period from Years 3–9.*
Source: *Grattan analysis of VCAA (2015) and ACARA (2014b), 1h Widening gaps: what NAPLAN tells us about student progress, Grattan Institute 2016..*

Figure 1.23 Growth of disadvantage—Estimated progress of students grouped by their parents' education



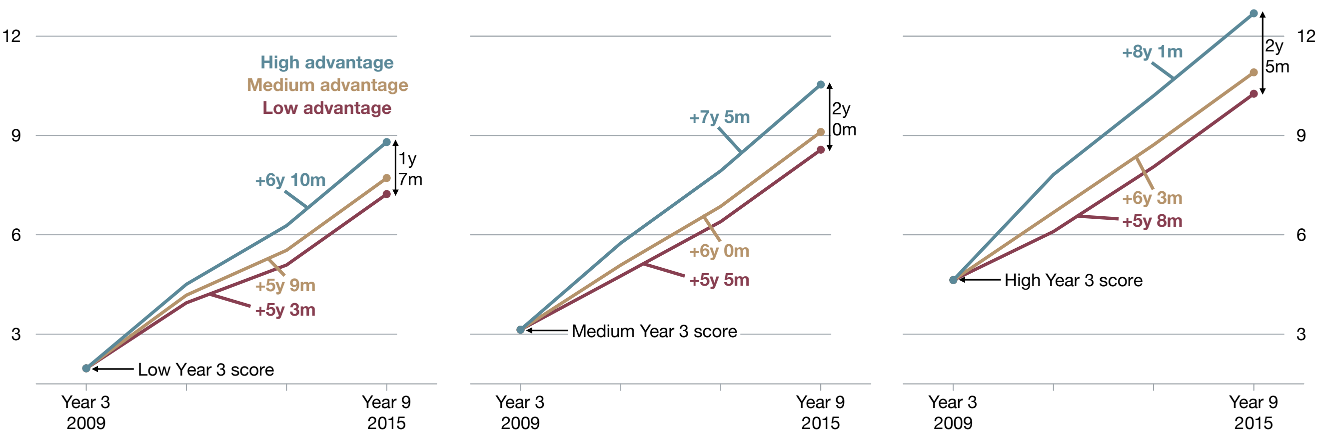
Notes: *Equivalent year level, numeracy, median, Victoria, 2009–15. Results show the estimated progress of students grouped by their parents' highest level of education as a proxy for socio-economic status. Black values are the gap between highest and lowest groups. Coloured values are the years of progress gained from Year 3.*
Source: *Grattan analysis of VCAA (2015) and ACARA (2014b), 1h Widening gaps: what NAPLAN tells us about student progress, Grattan Institute 2016.*

Figure 1.24 Growth of disadvantage—Estimated progress of students grouped by their school ICSEA



Notes: *Equivalent year level, numeracy, median, Victoria, 2009–15. Results show the estimated progress of students grouped by their school ICSEA. Low, medium and high advantage schools are the bottom ICSEA quartile, middle two ICSEA quartiles and top advantage ICSEA quartiles respectively. Black values are the gap between highest and lowest groups. Coloured values are the years of progress gained from Year 3.*
Source: *Grattan analysis of VCAA (2015) and ACARA (2014b), 1h Widening gaps: what NAPLAN tells us about student progress, Grattan Institute 2016.*

Figure 1.25 Growth of disadvantage—Estimated 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:*** *Grattan analysis of VCAA (2015) and ACARA (2014b).*

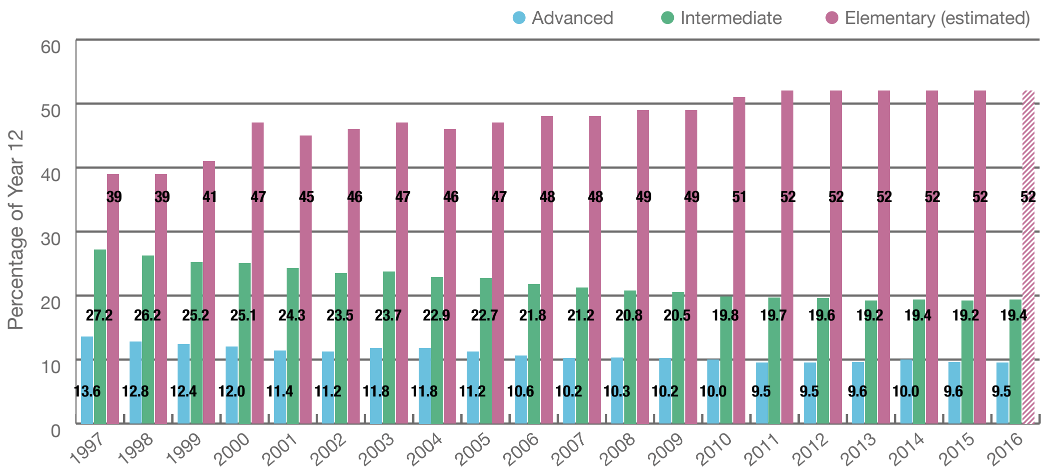
1.3 STUDENT NUMBERS AND PARTICIPATION RATES

The number of students completing Year 12 has been steadily increasing in Australia. For example, in 2013 the Year 12 population was just under 221,000, compared with approximately 200,000 in 2007 and approximately 189,000 in 1992. The proportion of Australian students studying mathematics in Year 12 in some form has remained steady at 80 per cent over the past two decades. However, when we look at 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 been declining in favour of "easier" maths subjects.

Figure 1.26 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 1995 to 2016. 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 1.26 displays the **highest level** of mathematics students are choosing, 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 into university degrees—especially degrees with a mathematical component such as science, engineering and commerce.

The number of Australian Year 12 students studying advanced mathematics declined from 21,665 in 2015 to 21,432 in 2016, the lowest level since 2013. The number of students with intermediate maths as their highest level maths subject increased, from approximately 43,100 in 2015 to 43,999 in 2016. Since 2012 the proportion of students taking intermediate and advanced mathematics at Year 12 has plateaued at a historic 20-year low.

Figure 1.26 Australian Year 12 mathematics students



Source: *Michael Evans and Frank Barrington, Year 12 Mathematics Participation Rates in Australia 1995–2016, data collection provided to AMSI.*

Note: *The following (non-exhaustive) key for basic, intermediate and advanced level mathematics:*
Elementary *- VIC Further Maths, NSW Mathematics General, SA/ACT/NT Mathematics Applications, TAS Maths Applied/General, QLD Maths A, WA Elementary.*
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.*
Advanced *- VIC/ACT/SA/NT Specialist maths, NSW Ext 1+2, TAS Specialised maths, QLD Maths C, WA Specialist 3CD.*

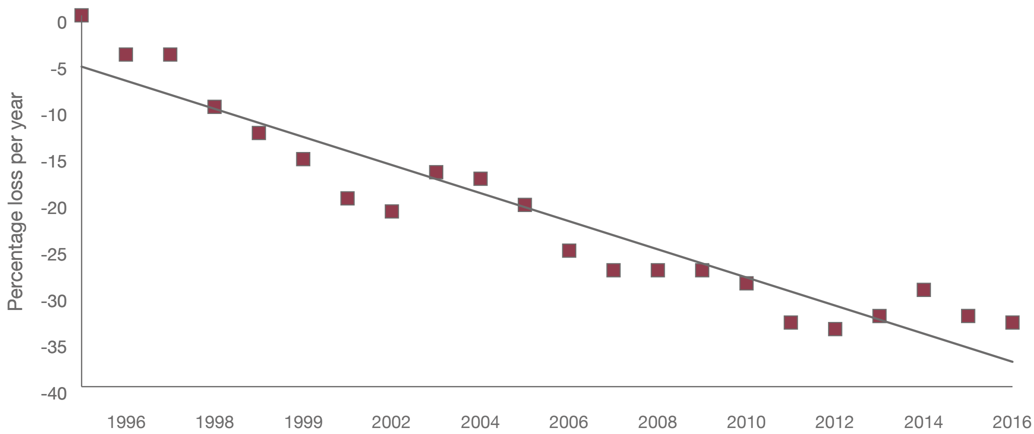
With the introduction of the National Curriculum, new mathematics subjects are being introduced. Level D is considered Advanced, while Level C is considered Intermediate mathematics. Levels A and B mathematics together are for our purposes considered Elementary. The estimates for Elementary students in 2016 are an approximation only.

The proportion of students taking elementary mathematics as their highest level maths subject (those enrolled in an elementary mathematics subject but NOT enrolled in either an intermediate or advanced mathematics subject) has remained steady at 52 per cent, although the 2016 figure is only a conservative estimate.

Despite a slight increase in numbers and participation rate in the past three years, the proportion of Year 12 students taking advanced mathematics in 2014 was 20 per cent lower than it was in 2000 and 32 per cent lower than in 1996—see Figure 1.27.

Source: *Michael Evans and Frank Barrington, Year 12 Mathematics Participation Rates in Australia, data collection commissioned by AMSI.*

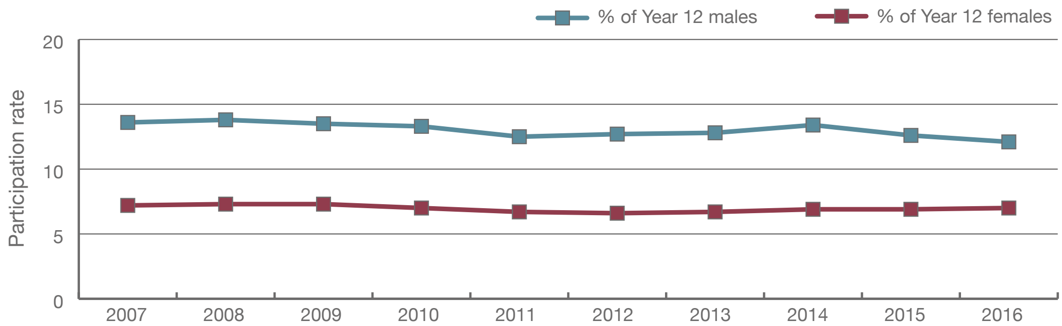
Figure 1.27 Percentage decline proportion of students choosing advanced mathematics



While the percentages of boys and girls taking elementary mathematics was virtually the same in 2015, in 2016 the intermediate mathematics participation rate (that is, the percentage of students taking intermediate mathematics as their highest level maths subject) was 18.3 per cent for girls compared with 20.6 per cent of boys, in both cases a slight increase over 2015 participation rates. The gender gap widens in advanced mathematics, with only 7.0 per cent of girls taking advanced mathematics in 2016, compared with 12.1 per cent of boys (see Figure 1.28). Note that in 2016, the girls' participation rate in advanced mathematics increased slightly (from 6.9 per cent), while the boys' participation rate dropped to the lowest level since 1995.

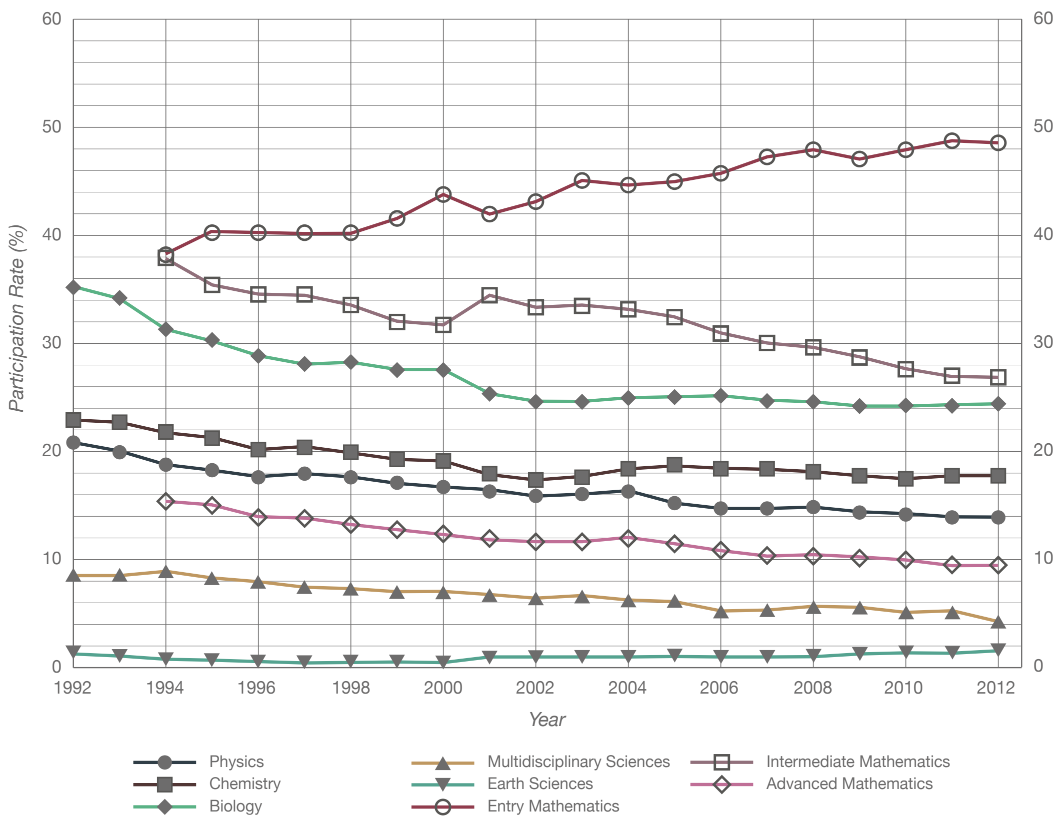
Source: *Michael Evans and Frank Barrington, Year 12 Mathematics Participation Rates in Australia, data collection provided to AMSI.*

Figure 1.28 Year 12 advanced mathematics students in Australia



Source: *John Kennedy, Terry Lyons and Frances Quinn, The continuing decline of science and mathematics enrolments in Australian high schools, Teaching Science, Vol. 60, Number 2, 2014, page 34–46.*

Figure 1.29 Participation rates in science and mathematics subjects 1992–2012



The field of mathematics is not the only field in the Science, Technology, Engineering and Mathematics (STEM) area affected by declining participation. Figure 1.29 shows that other STEM subjects such as Chemistry, Biology and Physics have also seen a decline in participation over the past two decades.

Table 1.30 below sets out enrolment numbers and participation rates in biology, chemistry and physics since 1992 alongside those for mathematics since 1994. It is very clear from this graph that with the notable exception of entry-level mathematics, STEM subjects have seen a significant decline both in participation rates as well as in absolute numbers. This is especially worrying given the fact that the total Year 12 enrolments have increased in that same time period. A few observations:

- The most significant decline seems to have taken place in the period 1992–2012, with chemistry and biology stabilising from 2002;
- The participation in entry-level mathematics has increased—perhaps at the cost of participation in intermediate and advanced level mathematics. This agrees with Barrington and Evans' findings that the participation rate of students doing at least SOME mathematics has been stable at around 80%—it's just that students are opting to do the "easier" maths;
- Since 2012 the fall in intermediate and advanced maths enrolments seems to have been halted. Unfortunately we do not have more recent numbers for the other STEM subjects to see what has happened with these in the past two or three years.

Table 1.30 Year 12 mathematics and science enrolment and participation rate data 1992–2012

Subject	Enrolment numbers 1992–2012 compared	Participation rate 1992–2012 compared	Participation rate % growth or decline from 1992	Participation rate % growth or decline from 2002
Physics	~39,000>30,877	21%>14%	-33%	-12%
Chemistry	~43,000>39,187	23%>18%	-22%	2%
Biology	~67,000>53,802	35%>24.5%	-31%	-1%
Maths - entry (from 1994)	~67,000>106,900	38%>49%	27%	13%
Maths - intermediate (from 1994)	~60,000>59,144	38%>27%	-29%	-11%
Maths - advanced (from 1994)	~27,000>20,789	16%>9%	-39%	-19%

Note: *Total number of Year 12 enrolments in 1992: 189,041, Total number of Year 12 enrolments in 2012: 219,047.* ***Source:*** *John Kennedy, Terry Lyons and Frances Quinn, The continuing decline of science and mathematics enrolments in Australian high schools, Teaching Science, Vol 60, Number 2, June 2014, page 34–46.*

The cause of the decline in STEM subject participation is diverse and complex. Parental encouragement to choose study and careers in STEM at the high school level is likely to be important. According to a survey performed by Galaxy Research on behalf of Tabcorp, of those survey respondents working in STEM 52 per cent became interested in a STEM career in high school. Parental influence to choose STEM as a career was a factor for about half or survey respondents working in STEM (and even 65 per cent of 20 to 24 year-olds). However, around half of survey respondents currently working in STEM said someone tried to convince them NOT to pursue a career in STEM.

One factor likely to contribute to the slide in the proportion of students choosing Year 12 intermediate and advanced mathematics is that many universities do not require intermediate or advanced maths for entry into science and engineering degrees, with many opting for "assumed knowledge" of mathematics. This affects student perception of the need to step up to the challenge of choosing the harder maths subjects. Table 1.31 summarises maths prerequisites and assumed knowledge to enter Bachelor degrees in science, engineering or commerce across all states in Australia. Only 14 per cent of universities require at least intermediate level maths for entry into a bachelor of science; and only 13 per cent for entry into a bachelor of commerce. Engineering degrees have stricter prerequisites in this regard. However, 41 per cent of engineering degrees do NOT require intermediate level mathematics or higher as a condition of entry. The relaxation of entry requirements in favour of "assumed knowledge" has led to an increasing number of students entering degrees without sufficient knowledge. This is having an adverse impact on both students and universities (King and Cattlin, International Journal of Mathematical Education in Science and Technology 2015). The University of Sydney decided in 2016 to re-introduce maths prerequisites, starting in 2019. (fyimaths.org.au/survey-of-mathematics-entry-requirements-in-australian-universities/).

Table 1.31 Minimum requirements for entry into bachelor degrees

	Science				Engineering				Commerce			
State	No. of unis offering course	Intermed. maths pre-req.	Assumed knowledge of intermed. maths	% with Intermed. maths as pre-req.	No of unis offering course	Intermed. maths pre-req.	Assumed knowledge of Intermed. maths	% with intermed. Maths as pre-req	No of unis offering course	Intermed. maths pre-req.	Assumed knowledge of intermed. maths	% with intermed. maths as pre-req.
TAS	1	0	1	0%	1	1	0	100%	0	0	0	0%
VIC	7	2	0	29%	7	6	1	86%	7	2	0	29%
NSW *	10	0	9	0%	9	0	9	0%	7	0	5	0%
QLD	7	3	3	43%	7	6	1	86%	5	1	0	20%
SA	3	0	1	0%	3	3	0	100%	3	0	0	0%
ACT	2	0	1	0%	2	1	1	50%	2	1	0	50%
WA	4	0	1	0%	4	3	0	75%	4	0	0	0%
NT	1	0	0	0%	1	0	1	0%	1	0	0	0%
National	2	0	0	0%	0	0	0	0%	2	0	0	0%
Total courses	37	5	16	14%	34	20	13	59%	31	4	5	13%

Note: *The following (non-exhaustive) key for basic, intermediate and advanced level mathematics:*
Elementary *- VIC Further Maths, NSW Mathematics General, SA/ACT/NT Mathematics Applications, TAS Maths Applied/ General, QLD Maths A, WA Elementary.*
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.*
Advanced *- VIC/ACT/SA/ NT Specialist maths, NSW Ext 1+2, TAS Specialised maths, QLD Maths C, WA Specialist 3CD.*
Source: *data collected by the FYiMaths network, 2015.*

Another factor may be a belief held by some students that opting for mathematics subjects below their ability will optimise their university entrance scores. A study has shown that for NSW students the study of (elementary) HSC general mathematics leads to higher scaled ATAR scores than the study of more advanced, calculus based HSC mathematics (Pitt, *Australian Journal of Education* 2015). There is no evidence that suggests that this problem extends beyond NSW. However, these and other possible factors certainly warrant further investigation.

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 annual 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-area" (because of a perceived lack of content or methodology training—or both), are considerably less confident and competent in terms of mathematics content, teaching and curriculum documentation than their "in-area" colleagues (Koch and Li, AMSI Choose Maths Research no.1 2017).

AMSI's definition of being qualified in a discipline is to have completed both content and methodology training in the area. The most comprehensive data—gathered in 2013 in the survey "Staff in Australia's Schools"—on qualifications of mathematics teachers in secondary education indicate the following (see Table 1.32):

- 73.9 per cent of Years 7-10 teachers teaching mathematics have completed methodology training in the area, suggesting that 26.1 per cent of these teachers are not fully qualified. This is an improvement on the 2010 data, which indicated only 60.4 per cent of Years 7-10 teachers teaching mathematics had completed methodology training in the area. These numbers still lag behind general science teachers. Data suggests that in Years 7-10, 79.6 per cent of science teachers have completed methodology training in science;
- In Years 11-12, 86.1 per cent of mathematics teachers have completed appropriate methodology training, up from 76.3 per cent in 2010;
- 72.5 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;
- 60.1 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.

Table 1.32 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:** Phillip McKenzie et al., Staff in Australia's Schools 2013: Main Report on the Survey, ACER, April 2014, page 67.*

The ACER data collected in 2013 (Table 1.32) suggests a possible improvement in training levels of mathematics teachers since 2010. This seems to be corroborated by the most recent TIMSS study which also suggests a possible improvement compared to 2011. Where 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—Table 1.12.

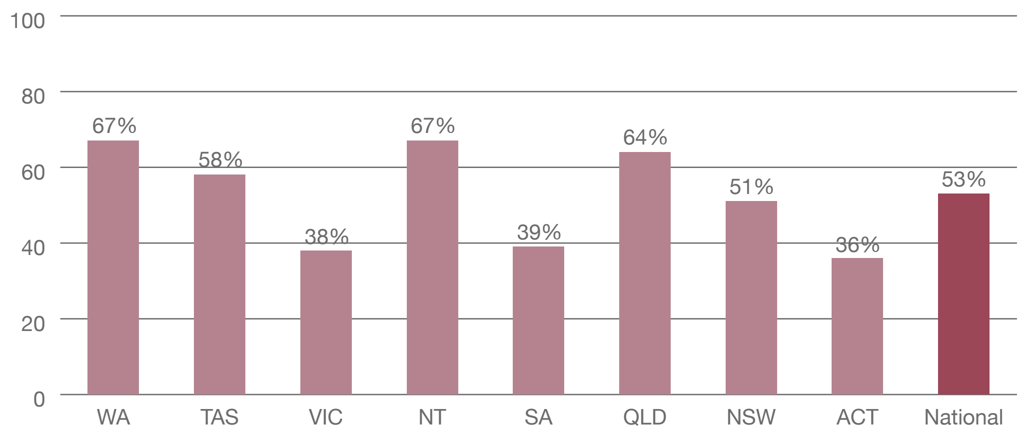
Table 1.33 Teachers in Year 8 majored in education and mathematics 2011–2015

	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	
	% of students	Average achievement	% of students	Average achievement	% of students	Average achievement	% 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 International Results in Mathematics, Exhibit 8.4.*

Two points need to be made here. First of all, despite a possible improvement in recent years, the shortage of qualified mathematics teachers is far from resolved and it remains a well known and persistent problem in the eyes of school principals. A survey by the Australian Education Union among secondary school principals in 2017 showed that 53 per cent of principals reported having maths and science classes taught by not fully qualified teachers (note that the term "not fully qualified" was not further defined). The differences between states were enormous, with no less than 67 per cent of principals from Western Australia, and 64 per cent of principals from Queensland reporting maths and science classes taught by not fully qualified teachers (Figure 1.34).

Figure 1.34 Percentage of maths & science classes taught by not fully qualified teacher



***Source:** Australian Education Union, State of Our Schools 2017 report.*

***Note:** Answers to question "Are there maths and science classes at your school taught by a teacher who is not fully qualified in the subject area?"*

The same ACER data from the survey "Staff in Australia's Schools" 2013 shows that available teaching positions in mathematics are still more likely to remain unfilled than any other teaching positions. In 2007, 10 per cent of secondary schools reported at least one unfilled vacancy for a mathematics teacher at the start of the school year. This decreased to 8.3 per cent in 2010. In 2013, 8.7 per cent of schools reported at least one vacancy in mathematics (even though the absolute number of vacancies decreased by 130). While reported vacancies in most other areas have decreased considerably proportionally, in absolute terms mathematics teaching positions have been, and remain, the most difficult to fill (see Table 1.35).

Source: *Phillip McKenzie et al., Staff in Australia's Schools 2013: Main Report on the Survey, ACER, April 2014, page 127.*

Table 1.35 Unfilled teaching positions in selected areas, at day 1 of the school year, 2007, 2010 and 2013

		Per cent of schools			Total positions		
		2007 %	2010 %	2013 %	2007	2010	2013
Secondary	English	8	7.5	1.7	300	350	60
	LOTE	5	5.4	2.9	150	150	90
	Mathematics	10	8.3	8.7	300	400	270
	Science	8	7.2	5.9	200	190	190
	SOSE	5	3.2	3.2	150	190	90

If principals find certain vacancies difficult to fill, they have a number of options open to them. They might instruct teachers to teach "out-of-field"; hire retired teachers on short-term contracts; or, in acute shortages, recruit teachers not fully qualified in subject areas to teach these subjects. Table 1.36 shows the significant differences between government, Catholic and independent schools in teacher shortages and the strategies to address these. Teaching out-of-field and recruiting not fully qualified teachers are the most prevalent solutions in Catholic schools; principals in government schools mostly opt for teaching out-of-field and recruiting retired teachers on short-term contracts. Over half of independent schools do not report having recent teacher shortages. Of the independent schools who do, the most popular solutions are recruiting retired teachers and combining classes within subject areas. For all schools, compared to 2010, reported teacher shortages have decreased (38.4 per cent in 2013 versus 33.4 per cent in 2010), and teaching out-of-field is less prevalent (33.2 per cent in 2013 versus 42.2 per cent in 2010), which suggests some improvement in staffing shortages overall.

Note: *Principals could indicate >1 strategy.*
Source: *Phillip McKenzie et al., Staff in Australia's Schools 2013: Main Report on the Survey, ACER, April 2014, page 129.*

Table 1.36 Secondary principals' strategies to deal with staffing shortages

Which of the following strategies do you use to deal with teacher shortages at your school?	Secondary			
	Govt	Cath	Ind	All
Reduce the curriculum offered	18.7	7.1	8.9	15.0
Reduce the length of classroom time for a subject	2.2	2.4	0.0	1.7
Combine classes within subject areas	11.6	9.5	7.6	10.4
Combine classes across subject areas	3.6	0.0	2.5	2.9
Combine classes across year levels	14.2	2.4	8.9	11.6
Require teachers to teach outside their field of experience	39.1	35.7	15.2	33.2
Recruit teachers not fully qualified in subject areas with acute shortages	24.4	14.3	7.6	19.4
Recruit retired teachers on short-term contracts	30.2	11.9	6.3	22.5
Share programs with other schools	8.9	9.5	7.6	8.7
Not relevant - no recent teacher shortages	31.6	52.4	50.6	38.4

Secondly, it is necessary to point out that teacher shortages and teaching by not fully qualified staff happen more often at disadvantaged schools and schools in remote locations. Data dating back to 2010 indicated a wide variance of teacher training between metropolitan, provincial and remote areas (see Table 1.37). The proportion of teachers with three years or more tertiary education in mathematics who teach Years 7 to 10 was 45 per cent in metropolitan, 37 per cent in provincial and 40 per cent in remote areas. For Years 11 and 12, 64 per cent of metropolitan teachers had three years or more of tertiary mathematics, compared to 57 per cent and 43 per cent in provincial and remote areas respectively. Table 1.37 shows that only biology boasted a good supply of qualified teachers—unfortunately very few biology teachers are also qualified to teach mathematics.

Table 1.37 Highest year level of tertiary education in field by geolocation: 2010

	None			Year 1			Year 2			Year 3 & higher			Total		
	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote	Metro	Prov.	Remote
Year 7–10	359	223	31	242	119	20	214	116	20	669	266	48	1484	724	119
Maths	24%	31%	26%	16%	6%	17%	14%	16%	17%	45%	37%	40%			
Year 11–12	112	62	7	92	47	9	139	62	13	600	226	22	943	397	51
Maths	12%	16%	14%	10%	12%	18%	15%	16%	25%	64%	57%	43%			
Year 11–12	21	11	2	38	24	4	50	19	1	139	66	4	248	120	11
Physics	8%	9%	18%	15%	20%	36%	20%	16%	9%	56%	55%	36%			
Year 11–12	12	7	0	27	13	2	40	22	3	220	103	1	299	145	6
Chemistry	4%	5%	9%	9%	33%	13%	15%	50%	74%	71%	17%				
Year 11–12	18	17	2	11	9	0	18	7	2	342	147	14	389	180	18
Biology	5%	9%	11%	3%	5%	5%	4%	11%	88%	82%	78%				

Source: *Office of the Chief Scientist, Mathematics, Engineering and Science in the National Interest, May 2012, Appendix F.*

The 2015 PISA survey covered school-related circumstances with regard to scientific literacy performance. Shortage of educational staff (most notably a lack of teaching staff and inadequate or poorly qualified teaching staff) is not the same for all schools. While this part of the 2015 PISA survey was specific not to teaching mathematics but to science, it highlights that finding the right teachers with the right qualifications is a much larger problem for disadvantaged schools than for advantaged schools—Table 1.38.

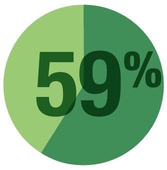
Table 1.38 Shortage of educational staff, by socioeconomic background

	Percentage of students whose principal reported issue is a problem “to some extent” or “a lot”	
	a lack of teaching staff	Inadequate or poorly qualified teaching staff
Socioeconomic background	%	%
Lowest quartile	36	31
Second quartile	29	20
Third quartile	13	15
Highest quartile	6	5
OECD average	29	20

Source: *PISA 2015: Reporting Australia’s results, Table 8.10. page 264.*

HIGHER ED
A FORGOTTEN PATH TO SUCCESS

The number of universities **requiring at least intermediate maths** for entry into science and commerce degrees remains low (page 24)



Only 59% of engineering degrees **include maths as a prerequisite** (page 24)

Small universities often **lack the capability** to offer a major in the mathematical sciences (page 34)

Despite Australia's ageing mathematics workforce, the number of students pursuing a maths degree is not increasing. This points to a **shortage in the future workforce** (Figure 2.17)

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, it seems that the decline in academic staff numbers has come to a halt. Staff numbers however are still very small compared to other disciplines, and heavy at the top, with a comparatively high proportion of staff in the mathematical sciences employed at level D (Associate Professor) and level E (Professor). The academic workforce is predominantly male, with females making up 23 per cent (excluding casual employees).

The majority of the undergraduate student teaching load is taken up by service teaching. Many fields of education at university require basic mathematical and statistical training, which is typically delivered by mathematical sciences departments. The numbers of students completing a Bachelor degree or major in the mathematical sciences are low by international standards. Small universities are often unable to offer a major. Over the last decade, the number of Bachelor degrees in the mathematical sciences has declined to fewer than 400 per year on average. Slight increases in the number of students completing honours and postgraduate degrees have mostly been due to the influx of international students. Even so, this rise is not keeping pace with the overall rise in degree numbers in all fields of education.

2.1 STAFFING AT MATHEMATICAL SCIENCES DEPARTMENTS

Table 2.1 Number of staff employed in participating mathematical sciences departments in FTE (excluding casuals) in 2016

	Teaching only	Research only	Teaching & research	All staff	Average per university
Total Go8 universities (6/8)	22	154	201	377	63
Total ATN universities (3/5)	14	31	61	106	35
Total IRU universities (5/6)	1	7	44	52	10
Total RUN universities (4/6)	1	4	37	42	11
Total unaligned universities (8/14)	11	17	95	124	16
Total all participating universities (26)	49	213	438	701	27

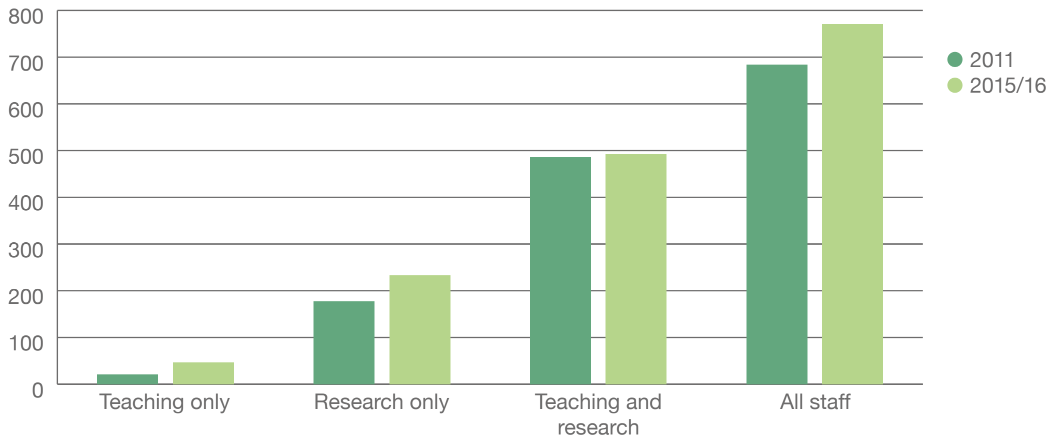
__Note:__ See glossary for an explanation of acronyms Go8, ATN, IRU and RUN. Numbers in brackets indicate the number of respondents out of the total number of members of the university alignment (e.g. 6 out of 8 Go8 universities responded to this question in the survey).
__Source:__ AMSI University Survey 2016, preliminary results.

In 2016, the 26 mathematical sciences departments delivering data on staff numbers to the annual AMSI Survey (AMSI members as well as non-members) reported employing 701 staff (in FTE) (See Table 2.1). The average number of staff in participating mathematics and statistics departments in 2016 was 27—but the average number of staff varies considerably between Group of Eight (Go8) universities and other universities. Note that two of the Go8 universities did not deliver data to the 2016 survey before the deadline of this publication, a major reason for reducing the total and average staff numbers from 789 total staff members and an average of 30 staff members per department reported in 2015.

This does not detract from the overall indication that there has been an increase in staff numbers since 2011. Figures 2.2 and 2.3 below compare the total staff numbers (in EFTSL) from the same 25 mathematical sciences departments at 23 universities in the years 2011 and 2016 (or 2015, if 2016 numbers were unavailable). Of these 25 departments, 16 had higher staff numbers in 2015/16 than in 2011, whereas nine had lower staff numbers.

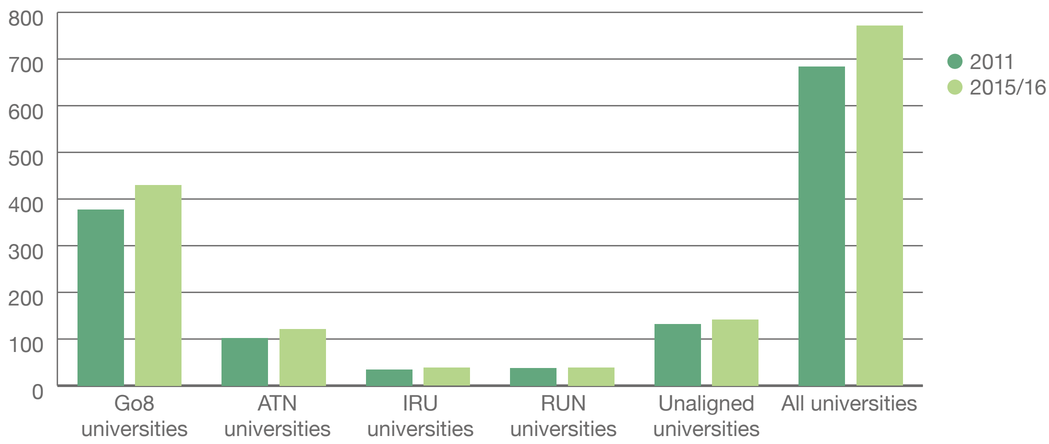
Source: AMSI University Survey 2011–2016.

Figure 2.2 Number of staff at mathematical sciences departments in 2011 and 2015/16 compared by type of employment



Source: AMSI University Survey 2011–2016.

Figure 2.3 Number of staff at mathematical sciences departments in 2011 and 2015/16 compared by university alignment



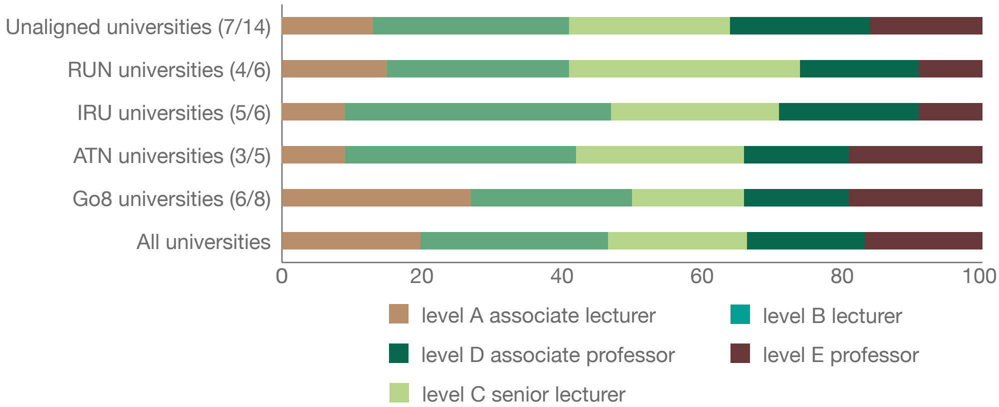
Note: "Other FTE staff" as reported in ERA have not been included here.
Source: ARC, ERA reports 2010, 2012 and 2015.

Table 2.4 Staff reported to ERA 2010–2015 in mathematical sciences 01 by employment level (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
% change 2010–2015	-15%	11%	-2%	11%	21%	5%

Source: AMSI Survey 2016. Data from 25 universities.

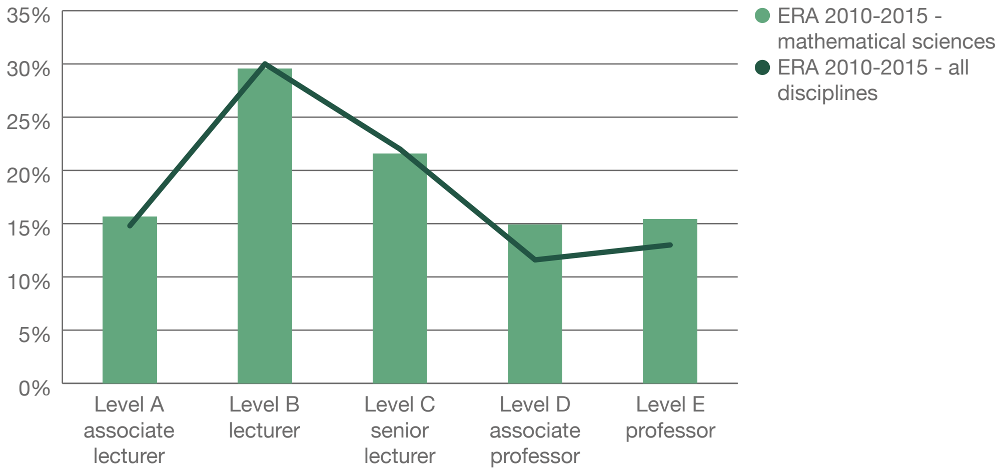
Figure 2.5 Staff in participating mathematical sciences departments by employment level (excluding casual staff) in 2016



The staff data supplied to the ARC for Excellence in Research Australia (ERA) points in the same direction with a 5 per cent staff increase reported from 2012 to 2015. Level B, D and E staff numbers have steadily risen since 2010, whereas staff numbers at level A have dropped—see Table 2.4.

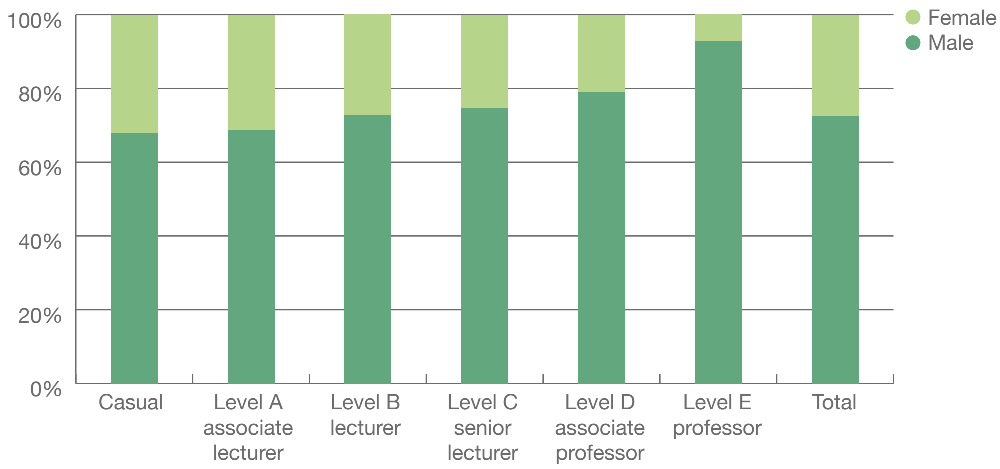
Figure 2.5 indicates a top-heavy staffing profile, with a relatively large number of staff employed at level E (professorial level). Non-Go8 universities tend to employ few staff at entry level A, whereas Go8 universities employ many more junior researchers at this level—a function of the much higher ARC research revenue that they generate. When compared with ERA staffing figures for all disciplines it is clear that while the profile is top-heavy in all disciplines, the staff level at D and E in the mathematical sciences is even higher than in other disciplines (see Figure 2.6). This can be the result of the academic population ageing—if that is the case the mathematical sciences are more deeply impacted than other disciplines.

Figure 2.6 ERA 2010–2015—staffing profile in FTE—percentage distribution by employment level



Source: *ARC, staff data extracted from ERA 2010, 2012 and 2015.*

Figure 2.7 Staff in participating mathematical sciences departments by gender and employment level in 2016



Source: *AMSI Survey 2016. Data from 25 universities.*

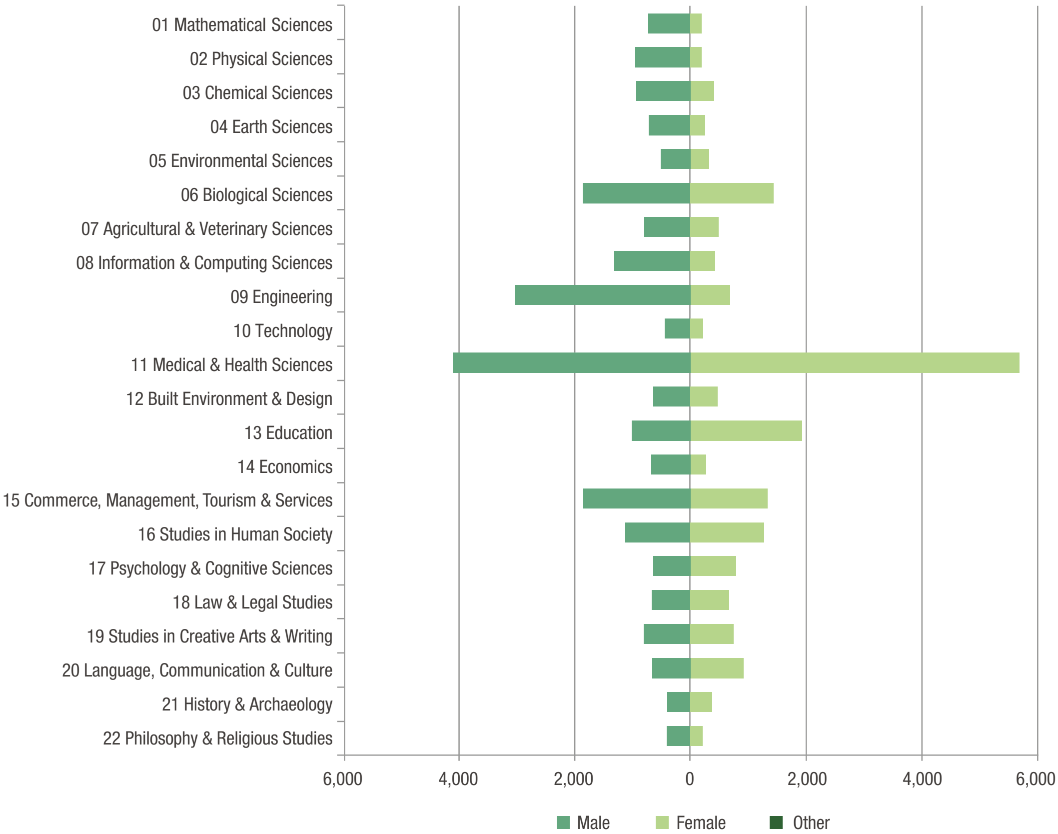
It is clear from the 2016 AMSI survey results (Figure 2.7) that the academic workforce is predominantly male and that the proportion of females reduces with the level of seniority. In 2016, about 32 per cent of reported casuals were female which decreased to 31 per cent at level A, 27 per cent at level B, and 25 per cent at level C. The female proportion of the academic workforce dropped significantly to 21 per cent at level D and 7 per cent at level E. Overall, in 2016 only 27 per cent of the academic workforce in mathematics and statistics was female. If we leave aside casual employees, the overall percentage was only 23 per cent.

It is no surprise that this percentage is lower than almost any other discipline. Figure 2.8 sets out the size and the gender balance of all fields of research disciplines in Australia:

- Only the physical sciences have a lower proportion of female academic staff than mathematical sciences;
- The size of the academic mathematical workforce (level A-E) is very small compared to other disciplines, despite the fact that mathematical sciences departments carry a heavy teaching load, servicing many other fields of education with mathematical and statistical training.

Note: *"Other FTE staff" as reported in ERA have not been included here.*
Source: *ARC, ERA 2015 National report, Section 1, page 80.*

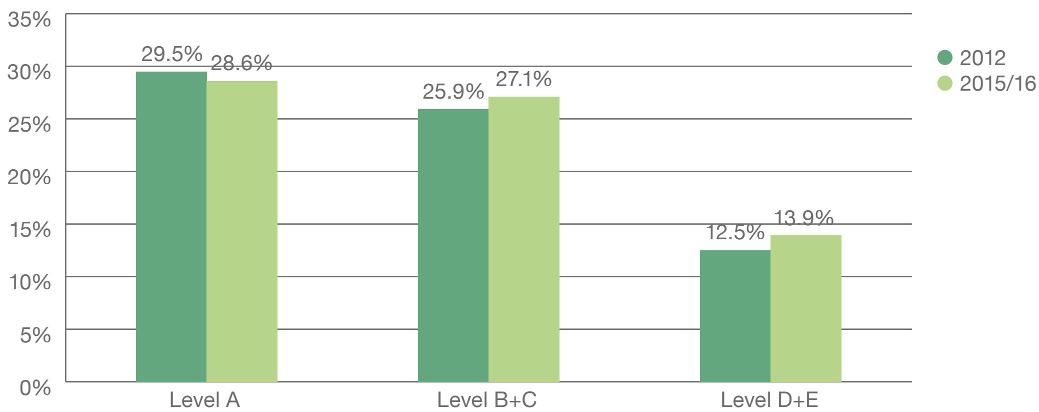
Figure 2.8 Number of FTE staff by gender by two-digit FoR code



Figures 2.7 and 2.8 only provide us with snapshots of the gender balance, and not with any understanding of possible differences in the career trajectory of men and women in academia. Nor do they give us a clear picture of changes to gender balance over time. In the short-term, 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 2.9 below therefore compares the proportion of female academic staff from the same 24 mathematical sciences departments at 22 universities in the years 2012 and 2016 (or 2015 if 2016 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 very slight positive change in B/C and D/E levels. However, it is much too early to tell if this is the reflection of an actual trend, or merely fluctuation. In addition, 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.

Figure 2.9 Proportion of female staff at the same 24 mathematical sciences departments in 2012 and 2015/16 compared

Source: *AMSI University Survey 2011–2016.*

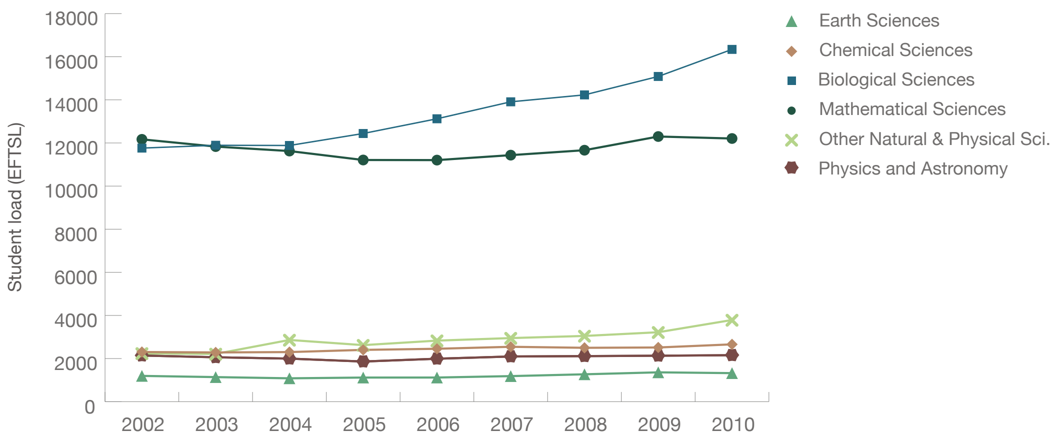


2.2 MATHEMATICS AND STATISTICS TEACHING AT UNIVERSITIES

The mathematical sciences are an essential element of many disciplines, and mathematics and statistics departments supply service teaching to many other departments and faculties. According to Figure 2.10 below, measured in EFTSL the mathematical sciences are the second biggest service discipline after biological sciences (this is a reflection of the enormous increase in popularity of Health Sciences, which receives most of the biological service teaching). Mathematical sciences departments supply teaching to a variety of disciplines such as information technology (IT), engineering, agriculture and environment, society and culture, and health and management.

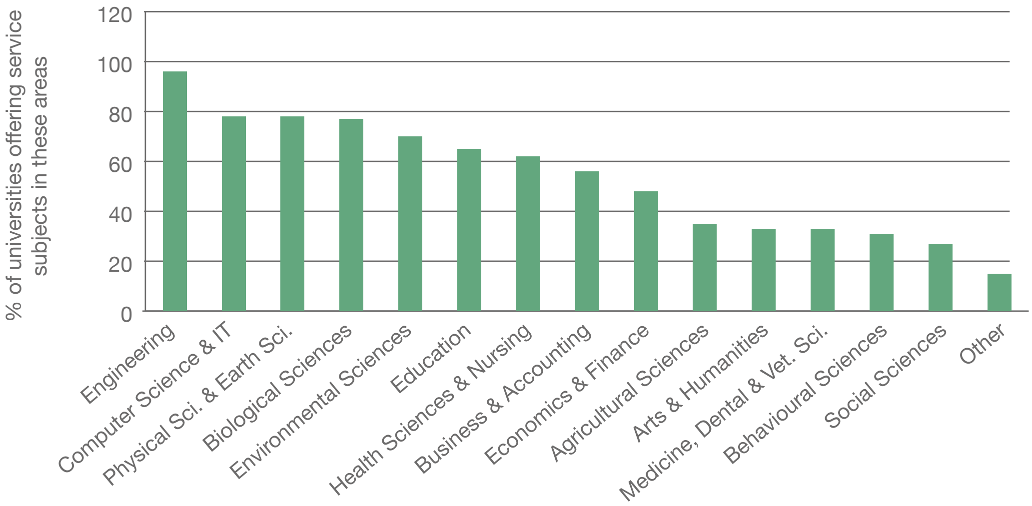
All university departments that responded to this question in the AMSI survey supplied service teaching to other disciplines in 2016 (see Figure 2.11). Most departments supplied teaching to at least three or four other areas, some even offering teaching to twelve separate disciplines. On average mathematical sciences departments serviced around eight other subject areas in 2016. Engineering, computer science and IT, and biological, physical and earth sciences are the most serviced disciplines. The "other" areas mentioned where mathematical sciences departments delivered teaching were general science, biomechanics, wine science, and actuarial studies.

Figure 2.10 Undergraduate science service teaching; narrow disciplines



Source: *Office of the Chief Scientist, Health of Australian Science, May 2012, page 84.*

Figure 2.11 Areas of service teaching in 2016 at participating universities



Source: *AMSI University Survey 2016. Data from 27 departments from 26 universities.*

Table 2.12 Teaching by academic and casual staff at participating universities in 2016: average number of teaching hours per teaching week

(Averages)	Tutorial hours all staff	% of total taught by casuals	Lecture hours all staff	% of total taught by casuals
Go8 universities (5/8)	259	78%	117	5%
ATN and RUN universities (7/11)	90	65%	65	9%
IRU and unaligned universities(11/20)	101	75%	47	11%
all universities (23)	137	75%	70	8%

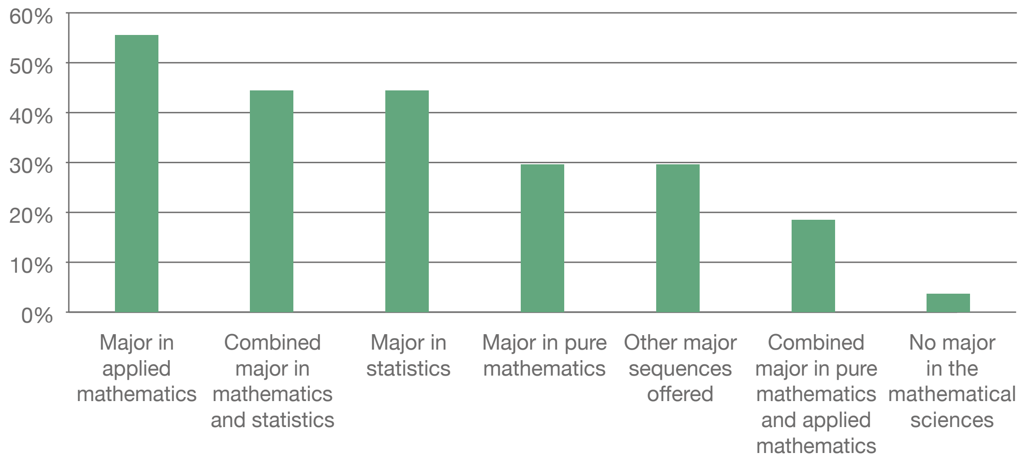
Note: *Numbers in brackets indicate the number of respondents out of the total number of members of the university alignment (e.g. 5 out of 8 Go8 universities responded to this question in the survey).*
**See glossary for an explanation of the meaning of EFTSL.*
Source: *AMSI Survey 2016. Data from 24 departments at 23 universities.*

Given the substantial service teaching load, and the fact that the academic workforce is quite small, a large part of the teaching is left to casual staff. According to the data in Table 2.12, casual staff perform the majority of tutorial teaching. In 2016, around 75 per cent of tutorials were taught by casual staff. The proportion of lecture teaching by casuals is much lower, 8 per cent on average for all universities.

For those students who choose mathematics or statistics as their main field of study, the offering of majors in mathematics and statistics has been stable since 2012. Applied mathematics has consistently remained the 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 27 departments from 26 universities that have provided data for this question in the 2016 survey, all except two reported offering at least one major in the mathematical sciences (see Figure 2.13). Most participating departments offered one to three majors. The number of "other" majors seems to be on the rise, with departments reporting decision science, data science, quantitative data science, financial and insurance mathematics, analytics, information security, actuarial science and oceanography. One department that offered one major in mathematics for teachers in training in 2015 has started offering two "standard" majors in mathematics and applied mathematics in 2016. Two respondents to the 2016 AMSI survey reported not offering a major in the mathematical sciences at all.

Figure 2.13 Majors offered in the mathematical and statistical sciences in 2016

Source: AMSI University Survey 2016. Data from 27 departments at 26 universities.



2.3 STUDENT NUMBERS

Undergraduate enrolments and completions

Table 2.14 Undergraduate enrolments (in EFTSL*) at participating universities in 2016—including service teaching

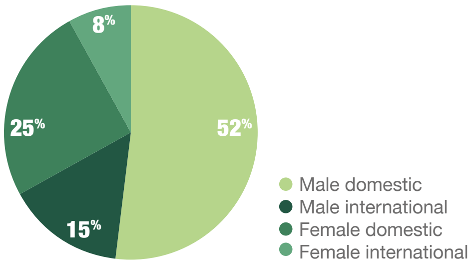
	1st year	2nd year	3rd year	Total
Go8 universities (6/8)	4186	1724	552	6461
ATN/RUN universities (5/11)	1141	441	144	1726
IRU universities (5/7)	1077	196	57	1330
Unaligned universities (7/14)	1763	467	140	2370
Total all universities (23)	8167	2828	892	11887

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). *See glossary for an explanation of the meaning of EFTSL.*
Source: *AMSI Survey 2016. Data from 24 departments at 23 universities.*

In 2016, figures provided by 23 universities showed first year mathematics subjects accounted for about 8167 EFTSL (see Table 2.14). For second year this dropped to around 2828 EFTSL and to approximately 892 in third year subjects. These enrolment numbers include service teaching.

At the 21 universities who were able to report undergraduate student numbers (other than in EFTSL), an estimated 56,000 students enrolled in one or more undergraduate mathematical sciences subjects. Keeping in mind that not all participating universities were able to provide a breakdown of male/female or domestic/international numbers (or both), the estimated male/female distribution among mathematics students was roughly 67:33. The proportion of international students in 2016 was 23 per cent. Figure 2.15 sets out the profile of the undergraduate student cohort in 2016.

Figure 2.15 Undergraduate student profile by gender and domestic/international status in 2016 at participating universities



Source: *AMSI Survey 2016. Data from 21 universities.*

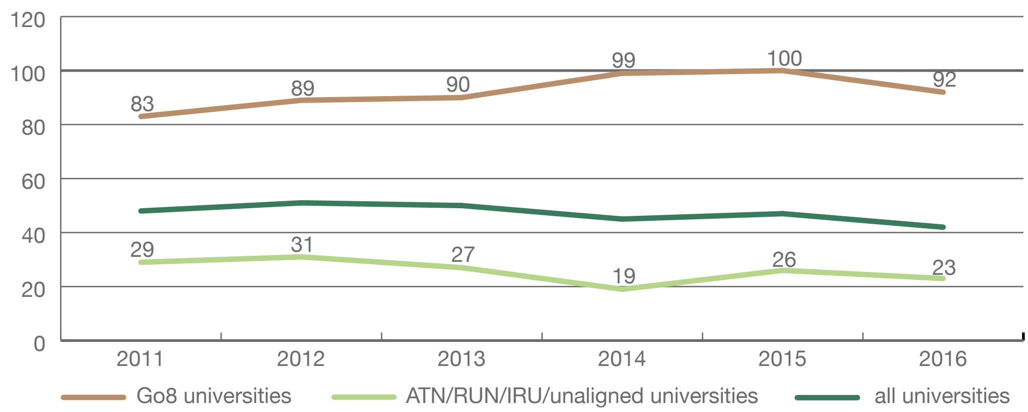
Table 2.16 sets out the average undergraduate enrolment numbers per university. In 2016, universities were asked to deliver enrolment data including service teaching (first column), as well as teaching enrolment data excluding service teaching (if available) in the second column—note that only 11 universities were able to deliver data for the second column. Unsurprisingly, the average number of students who are studying maths as their main field of study (the second column of enrolments "excluding service teaching") is only a fraction of the total student numbers in first and second year, the levels at which most of the service teaching takes place. In third year, it looks like most students enrolled in mathematics or statistics courses are studying mathematical sciences as their main subject, presumably with an eye on completing a bachelor in the mathematical sciences or a maths related major.

Table 2.16 Average number of undergraduate enrolments at participating universities in 2016 (in EFTSL)

		Including service teaching	Excluding service teaching
1st year	Number of universities	21	11
	Go8 universities	698	129
	ATN/RUN/IRU/unaligned universities	261	32
	All universities	387	58
2nd year	Number of universities	21	11
	Go8 universities	287	182
	ATN/RUN/IRU/unaligned universities	71	25
	All universities	133	68
3rd year	Number of universities	21	11
	Go8 universities	92	92
	ATN/RUN/IRU/unaligned universities	23	19
	All universities	42	39

Note: *Due to the small number of respondents to the questions on undergraduate student numbers a breakdown by national alignment other than for Go8 universities is not advisable. See glossary for the meaning of the acronyms EFTSL, G08, ATN, RUN, IRU and the term unaligned..*
Source: *AMSI Survey 2016. Data from 21 universities (first column) and 11 universities (second column).*

Figure 2.17 Average number of third year undergraduate mathematical sciences enrolments at participating universities 2011–2016 (in EFTSL*)—including service teaching



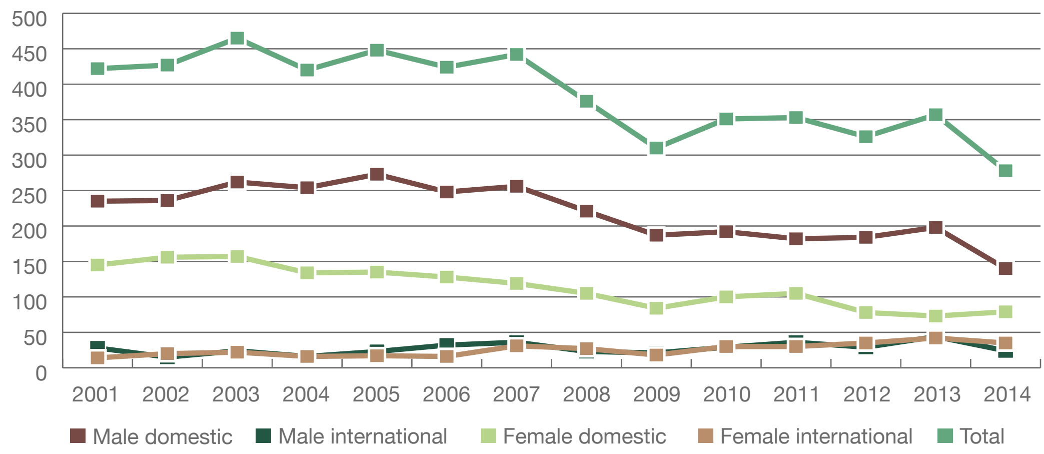
Source: *AMSI Survey 2011–2016.*

In recent years, the average enrolment numbers in third year have slightly declined and the gap in enrolment numbers between Group of Eight and other universities has increased, see Figure 2.17. The number of students taking mathematical sciences in third year is the potential pool of students completing a maths degree or a maths major, or a mathematical sciences teaching degree—in short, the future mathematical workforce. As Chapter 3 of this document shows, the mathematical workforce is ageing, and to combat this these numbers should increase to prevent future shortages.

Instead, according to data from the Department of Education and Training, the number of domestic graduates in mathematical sciences has declined—see Figure 2.18. In the first years of this century the number of bachelor completions in the mathematical sciences easily topped 400 every year, but since 2007 the number of bachelor completions has failed to reach 400, and in 2014 even slipped below 300. A very important limitation of this data is that it does not capture students completing bachelors of science (or similar) with a major in the mathematical sciences. We do not know if the decline is the result of the number of students of mathematics actually shrinking, or a decline in the number of universities offering a bachelor degree in the mathematical sciences (as opposed to general bachelor of Science degrees). However, since the third year enrolment numbers resulting from the AMSI Survey also point in the direction of a possible decline there is cause for concern.

Figure 2.18 Bachelor (pass) completions in the mathematical sciences 2001–2014 by gender and domestic/international status

Source: *Department of Education and Training, data supplied to AMSI.*



Honours and higher degree enrolments and completions

Table 2.19 Reported honours and higher degree enrolments at participating universities in 2016 (in EFTSL)

	Honours	Masters by Coursework	Masters by research	PhD
Go8 universities (6/8)	77	195	19	238
ATN universities (2-3/5)	9	21	11	116
RUN universities (4/6)	5	15	3	32
IRU universities (5/7)	9	20	2	46
Unaligned universities (8/14)	13	13	7	107
Total all universities (26)	113	264	42	539

Note: *See glossary for an explanation of the acronyms Go8, ATN, IRU and RUN. 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 Member Survey 2016. Data from 26 universities.*

The total reported number of enrolments in postgraduate degrees remained fairly static between 2015 and 2016 (see Table 2.20). PhD enrolments were substantially higher than in 2015, but not across the board—and the overall average number of PhD students per university went down slightly. Honours and masters by coursework enrolments were down—masters by research enrolments remained the same. Masters by coursework numbers have slightly increased over the period since 2011, but the reported fluctuations are due to differences in response rates between the years.

Table 2.20 Average honours and higher degree enrolments per university 2011–2016

		2011	2012	2013	2014	2015	2016
Honours	Average Go8 universities	15	14	13	15	15	13
	Average ATN universities	5	5	5	3	10	5
	Average RUN universities	<1	<1	5	1	1	1
	Average IRU universities	5	6	3	3	3	2
	Average unaligned universities	2	3	3	2	3	2
	Average all universities	7	7	6	6	7	5
Masters by Coursework	Average Go8 universities	20	19	16	20	24	33
	Average ATN universities	25	32	53	6	29	10
	Average RUN universities	1	<1	2	4	2	4
	Average IRU universities	2	3	1	2	4	4
	Average unaligned universities	7	6	4	2	10	2
	Average all universities	12	13	14	8	15	11
Masters by Research	Average Go8 universities	5	4	4	6	3	3
	Average ATN universities	2	2	2	2	3	4
	Average RUN universities	0	<1	0	0	1	1
	Average IRU universities	2	2	1	<1	<1	<1
	Average unaligned universities	1	1	1	<1	2	1
	Average all universities	2	2	2	2	2	2
PhD	Average Go8 universities	36	38	37	45	42	40
	Average ATN universities	26	29	24	26	31	39
	Average RUN universities	9	7	6	1	6	8
	Average IRU universities	7	11	10	9	9	9
	Average unaligned universities	15	14	9	8	15	13
	Average all universities	21	23	18	21	23	21

***Note:** Note that between 2011–2012, 27 departments from 25 universities participated; in 2013, 33 departments from 32 universities participated. In 2014 this number dropped to 24 departments from 23 universities, and in 2015 22 departments from 21 universities. In 2016 the number of respondents increased to 26. At the end of 2014 the University of Newcastle ended its membership of the IRU, and it is now an unaligned university.*

***Source:** AMSI Member Survey 2011–2016.*

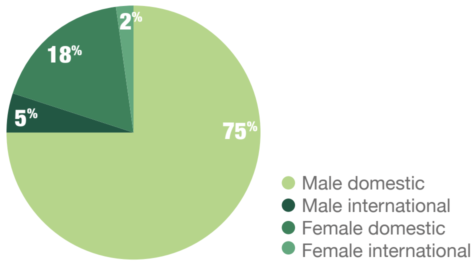
Peter Johnston at Griffith University has, on behalf of the Australian Mathematical Society (AustMS), assembled longitudinal data on honours degree completions in Australia for many years. Despite some spikes and troughs, completions in mathematics and statistics have been rising slightly since 2000. (Note that, for the time being, the two-year coursework masters degree offered at the University of Melbourne has been merged with the honours data). The proportion of females completing honours degrees has not been impressive in the past few years. In the 1980s the average proportion of females completing an honours degree was 26 per cent, in the 1990s this increased to 31 per cent. Unfortunately, in this century the proportion of female honours completions has declined to below 25 per cent—see Figure 2.21.

Figure 2.21 Bachelor (Honours) completions reported by mathematical sciences departments 2001–2015 by gender

***Source:** Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI.*

Figure 2.22 Honours student profile by gender and domestic/international status at participating universities in 2016

Source: *AMSI Survey 2016. Data from 22 universities.*



The 2016 enrolment data shows an even lower female proportion of 20 per cent, see Figure 2.22.

It is also important to note that, even though the total number of honours completions has risen slowly, it has not kept pace with the overall increase in honours completions in other fields of education (see Figure 2.23). The number of bachelor with honours degree completions in Australia has risen steadily in this century. However, the number of honours completions in mathematics and statistics has not kept pace with this trend.

Figure 2.23 Bachelor (Honours) completions in mathematical sciences as a proportion of honours degrees in all fields of education 2003–2015

Source: *Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI; Award course completions 2001–2015, Department of Education and Training document library.*

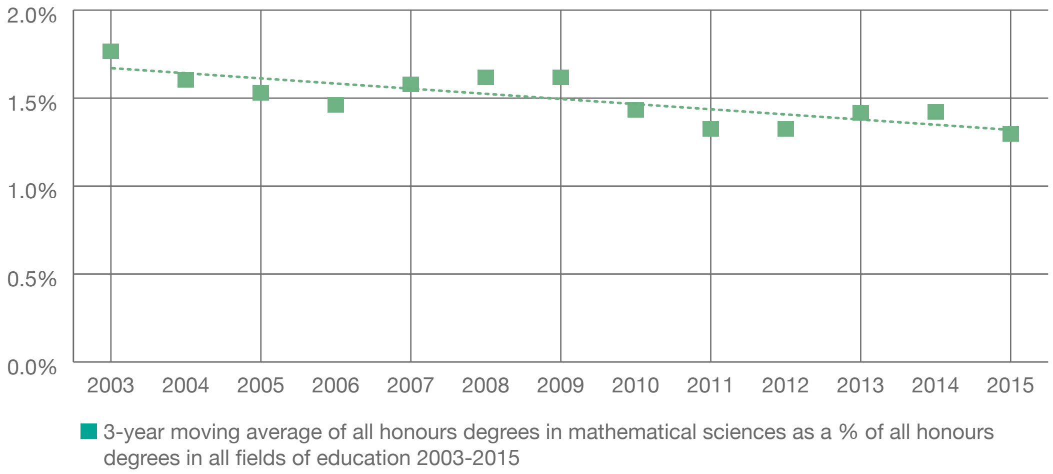
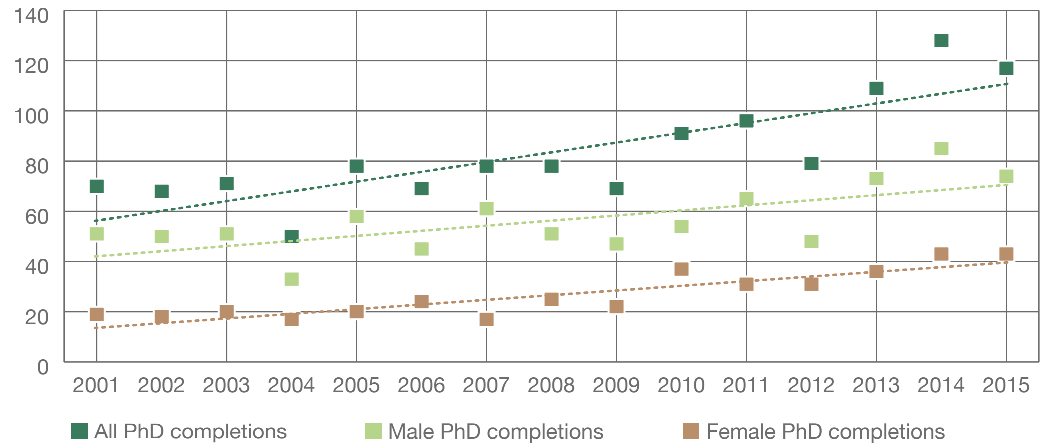


Figure 2.24 PhD completions in the period 2001–2015 by gender

Source: *Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI.*



Over the past 30 years, the number of PhD completions has increased in part due to a rise in the number of females completing a PhD (see Figure 2.24). In the 1980s, the average proportion of females 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. Between 2010–2012 the average female proportion rose to 36 per cent. However, as is shown in Figure 2.25 this was due to the contribution of international female students.

According to data reported to AMSI in its annual survey (see Table 2.26), PhD commencements have remained stable over the past five years. The number of completions fell in 2012, before increasing again in 2013 and 2014.

Figure 2.25 Female proportion of PhD degree completions in the mathematical sciences by domestic/international status 2003–2014

Source: Department of Education and Training, data supplied to AMSI.

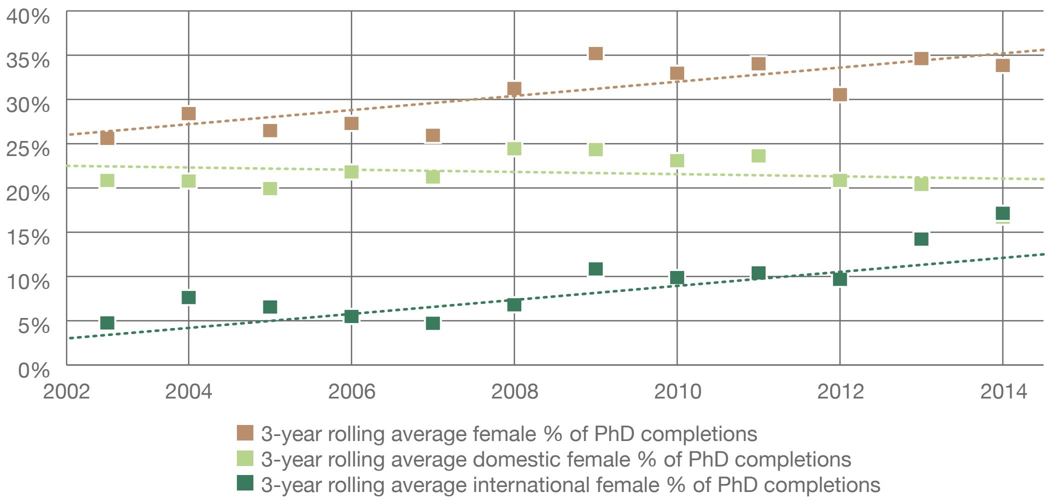


Table 2.26 PhD commencements and completions 2011–2016 (all participating universities)

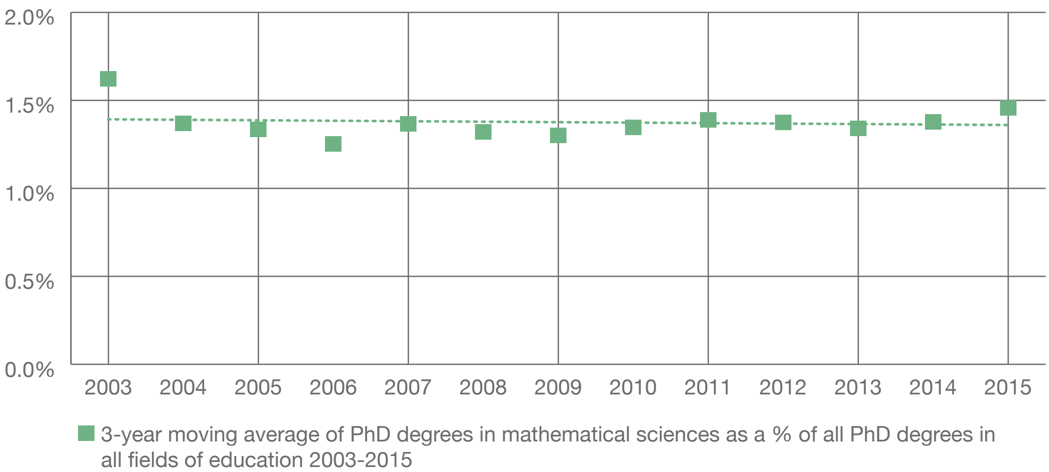
Source: AMSI Member Survey 2011–2016.

	2011	2012	2013	2014	2015	2016
Commencements	153	163	174	175	162	148
Completions	105	88	110	120	120	n/a

Despite a slight trend upward in the number of PhD completions within the mathematical sciences, it should be noted that the number recorded barely keeps pace with increases recorded for PhD degrees in other disciplines. The mathematical sciences hover at less than 1.5 per cent of PhD degrees in all fields of education, see Figure 2.27 below.

Figure 2.27 PhD completions in mathematical sciences as a proportion of PhD degrees in all fields of education 2003–2015

Source: Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI; Award course completions 2001–2015, Department of Education and Training document library.



International comparison of enrolment and completion figures

The entry rate into mathematical sciences degrees is low in Australia in comparison with other countries. Even though these figures need to be read with extreme care, due to the differences in higher education systems in various countries, the Australian figures are consistent with earlier OECD data collections.

The 2012 OECD data again confirmed the low figures (see Table 2.28). In fact, the proportion of entrants into tertiary mathematical degrees in Australia was so low it was deemed negligible: it was less than 0.5 per cent. We do have to take into account that Australia does not have tertiary-type B programs in mathematical sciences, that is tertiary degrees of a practical or vocational nature, such as those taught at TAFE colleges. In Australia, mathematical sciences are taught as theory-based tertiary-type A undergraduate degrees at universities.

Table 2.28 Distribution of tertiary new entrants, by field of education

OECD countries	Note	Engineering, manufacturing & construction	Sciences	Life sciences	Physical sciences	Mathematics & statistics	Computing
Australia	1	9	12	5	3	n	4
Denmark		12	8	1	1	1	5
Finland		25	9	1	3	1	4
Germany		17	13	2	4	2	4
Ireland	2	11	17	5	2	1	7
New Zealand		7	17	5	3	3	7
Sweden		18	11	2	2	2	5
United Kingdom		8	15	5	4	2	4
OECD average		15	10	2	2	1	4
EU21 average		15	11	2	2	1	5

Notes:
1: Exclude tertiary-type B programmes.
2: Exclude advanced research programmes.
n: Magnitude is either negligible or zero.
The numbers are percentages of all new tertiary entrants.
Source: *selected data extracted from Education at a Glance 2014: OECD Indicators, Table C3.3a Distribution of tertiary new entrants, by field of education (2012).*

Looking at gender differences, the data shows the number of males in these fields of study significantly outweighs the number of females. Compared with international figures, the proportion of females awarded a mathematical degree in Australia rose between 2000 and 2012. However, this figure is still lagging behind the OECD average. Note that Table 2.29 shows the percentage of qualifications awarded to women.

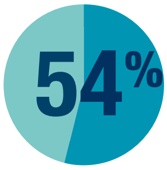
Table 2.29 Percentage of tertiary qualifications awarded to women in tertiary-type A and advanced research programmes, by field of education (2000, 2012)

OECD countries	Note	2012 All fields	2012 Engineering, manufacturing & construction	2012 Sciences	2012 Life sciences	2012 Physical sciences	2012 Mathematics & statistics	2012 Computing	2000 All fields	2000 Engineering, manufacturing & construction	2000 Sciences	2000 Life sciences	2000 Physical sciences	2000 Mathematics & statistics	2000 Computing
Australia	1	58	24	38	55	48	39	20	56	21	41	55	34	37	26
Denmark		59	33	40	65	42	47	27	49	26	42	60	36	41	22
Finland		61	22	43	73	46	47	24	58	19	46	69	42	46	30
Germany		55	22	44	67	42	59	17	45	20	32	55	27	42	11
Ireland		57	21	42	42	42	42	42	57	24	48	61	44	40	41
New Zealand		62	31	43	62	42	43	20	61	33	45	0*	46	56	33
Sweden		62	30	43	60	43	38	29	59	25	47	61	45	30	41
United Kingdom		56	23	38	50	43	42	19	54	20	44	62	39	38	24
United States		58	22	43	58	39	42	21	57	21	44	57	37	45	29
OECD average		58	28	41	63	43	46	20	54	23	40	60	40	42	23
EU21 average		60	29	42	65	44	50	20	55	23	40	61	40	44	21

Note: *1. Year of reference 2011.*
** data included with physical sciences.*
Source: *selected data extracted from Education at a Glance 2014: OECD Indicators, Table A3.3 (Web only). Percentage of tertiary qualifications awarded to women in tertiary-type A and advanced research programmes, by field of education (2000, 2012).*

THE ECONOMICS
OF MATHS & STATS

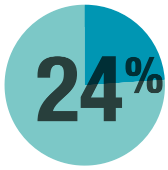
The direct impact of advanced physical and mathematical research is estimated at **$145 billion or 11.2% of the Australian economy annually** (page 51)



54% of Australian adults have only **basic numeracy skills**, only just over the current OECD average (page 43)

The ageing of the mathematical workforce is **worse than in the other STEM workforce sectors** (page 47)

24% of Mathematical Sciences graduates end up working in the **education and training sector**, as teachers and lecturers



This is closely followed by those employed in professional, scientific and technical services (20%), including research and ICT (Figures 3.11 & 3.12)

3 Mathematical Sciences in the Workforce

NUMERACY SKILLS, COMPETENCY AND CHARACTERISTICS OF THE MATHEMATICAL WORKFORCE

First we will look at numeracy skill level across the general adult population. Numeracy is a key cognitive and workplace skill and an indicator of mathematical competency in the workplace and the wider population. More than half of the Australian adult population have only basic numeracy skills. There is also a constant, and significant, gap in mathematical competency between males and females across all age bands between 15 and 74 years of age.

Secondly, we look at the characteristics of members of the Australian workforce with a degree in the mathematical sciences. About 26,000 people in Australia identify as mathematicians or statisticians. They almost exclusively have a university degree in the mathematical sciences. Around 40 per cent of them are women. This already small workforce (to compare: around two and a half million people in Australia have a university degree) is ageing more rapidly than other STEM disciplines due to a lack of younger people entering the mathematical workforce. 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.

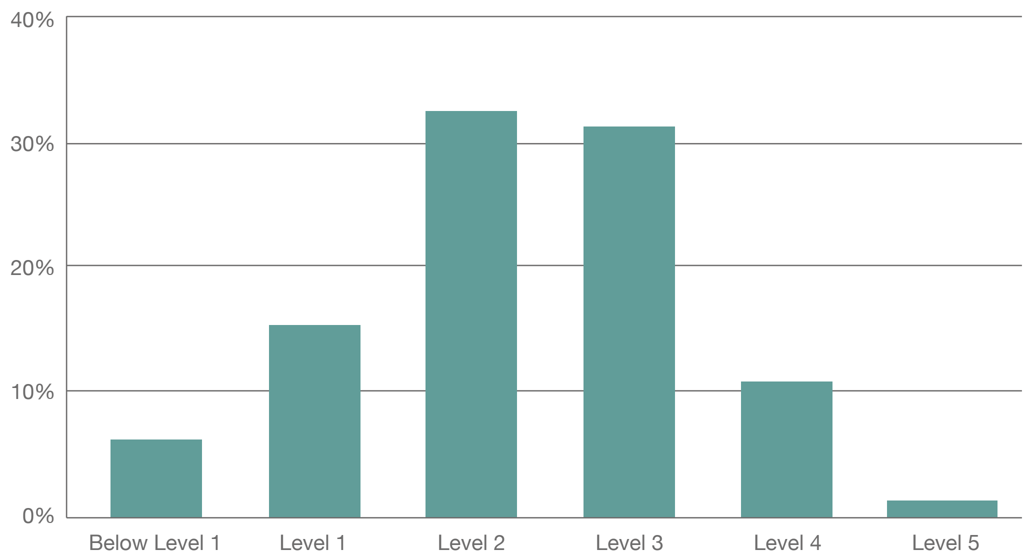
3.1 NUMERACY SKILLS IN THE ADULT POPULATION

The Programme for the International Assessment of Adult Competencies (PIAAC), an international survey into key cognitive and workplace skills, has a scale with six levels to measure numeracy—level five the highest and below level one the lowest. According to PIAAC, 53.5 per cent of the Australian population had numeracy skills at or below level two in 2011—see Figure 3.1.

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.

Shown in Figure 3.1 are the results across Australia's entire population. The 46.7 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. Of the adult population, 31 per cent (5.2 million) fall into level three; with 11 per cent (1.8 million) at level four; and 1.4 per cent (230,000) level five. The average numeracy proficiency in Australia is slightly higher than the current OECD average—see Figure 3.2.

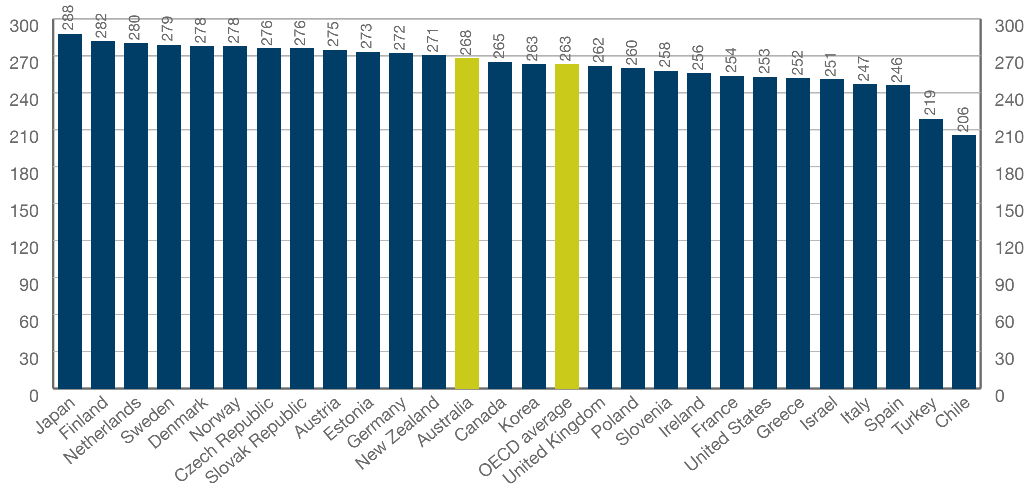
Figure 3.1 Proportion of Australian Adult Population at Each Numeracy Level 2011–12



Source: *ABS, Programme for the International Assessment of Adult Competencies, Australia, 2011–2012.*

Source: *OECD, EducationGPS_Topic_Report on the Survey of Adult Skills (Program for the International Assessment of Adult Competencies) 2015.*

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

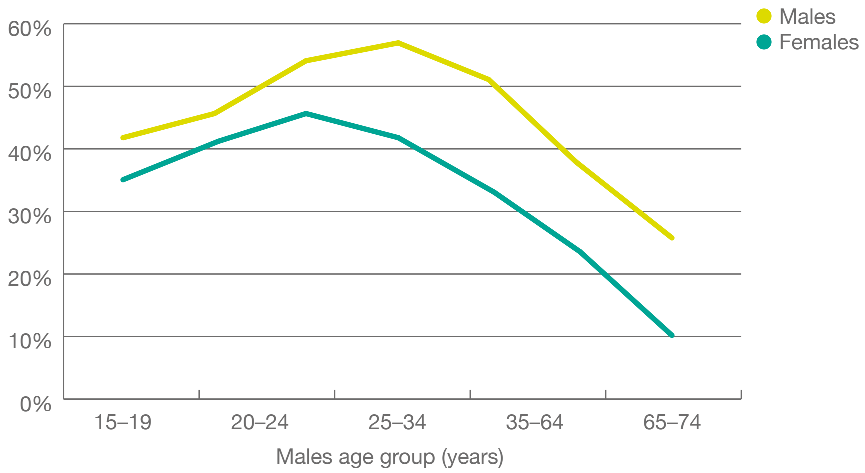


The data shown in Figure 3.3 suggests that numeracy competency is closely related to age and gender. Numeracy skills for both genders tend to drop after peaking between the ages of 35 and 44, and fall to their lowest for people of retirement age (65 years and over).

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.

Source: *ABS, Programme for the International Assessment of Adult Competencies, Australia, 2011–2012.*

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



3.2 EMPLOYMENT OF NEW GRADUATES WITH MATHEMATICAL SCIENCES DEGREES

According to Table 3.4, of the 42 per cent of new bachelor graduates who sought full-time employment, 67 per cent were employed within four months of graduating. This is a relatively low percentage compared to other disciplines. However, compared to other areas of study, a very high percentage of bachelor graduates in the mathematical sciences did not make themselves available for full-time employment straight after completing their degree, but proceeded to further full-time study. They subsequently made themselves available for full-time employment after finishing a postgraduate degree. According to Table 3.4, approximately 44 per cent of bachelor graduates in the mathematical sciences continued with further study. This means that a significant portion of mathematicians entered the mathematical workforce relatively late. Rather than entering the full-time workforce at the median age of 23, they entered after finishing a further degree, around the median age of 30 to 33 (depending on the type of degree).

Employment prospects of those who completed further study, however, increased to approximately

80 per cent for Masters and PhD graduates, and 90 per cent for Graduate Certificate or Diploma graduates. The median starting salary also increased considerably, from A$56,500 for bachelor graduates to A$75,000 for Masters by Coursework graduates, A$80,000 for PhD and Research Masters graduates and A$87,000 for Graduate Certificate or Diploma holders.

Table 3.4 Graduates in mathematics**

What are the characteristics of graduates in mathematics?													
		Bachelor			Masters by coursework			Graduate Certificate/ Diploma			Masters by research/PhD		
		M	F	Total	M	F	Total	M	F	Total	M	F	Total
Survey responses: mathematics		345	145	490	40	38	78	67	52	119	43	18	61
Sex: mathematics (%)		70.4	29.6	100	51.3	48.7	100	56.3	43.7	100	70.5	29.5	100
Sex: all fields of education (%)		37.9	62.1	100	42.3	57.7	100	33.2	66.8	100	44.8	55.1	100
Median age: mathematics (years)		23	23	23	30	37	33	34	32	33	30	29	30
Median age: all fields of education (years)		23	23	23	34	32	33	35	33	34	35	35	35
What are graduates in mathematics doing around four months after graduation?													
		Bachelor			Masters by Coursework			Graduate Certificate/ Diploma			Masters by Research/PhD		
		M	F	Total	M	F	Total	M	F	Total	M	F	Total
Available for full-time employment †	Mathematics (%)	41.7	41.4	41.6	75	71.1	73.1	77.6	76.9	77.3	76.7	72.2	75.4
	Chemistry (%)			37.7			75			50			87.1
	Computer science (%)			76.7			87.4			89.6			76.9
	Accounting (%)			77.5			80.2			80.6			90
	All fields of education (%)			77.7			79.3			69.8			74.6
In further full-time study	Mathematics (%)	43.5	44.1	43.7	20	13.2	16.7	11.9	7.7	10.1	14	0	9.8
	Chemistry (%)			50.5			18.8			33.3			3.4
	Computer science (%)			10.5			2.6			4.8			5.8
	Accounting (%)			9.6			3.2			4.9			0
	All fields of education (%)						4.2			8.2			4.3
Of those available for full-time employment													
In full-time employment †	Mathematics (%)	66.7	68.3	67.2	80	77.8	78.9	90.4	92.5	91.3	78.8	84.6	80.4
	Chemistry (%)			66			66.7			100*			76.2
	Computer science (%)			70.3			79.5			88.2			72
	Accounting (%)			77.4			72.6			88			88.9
	All fields of education (%)	71.3	71.3	71.3	84.1	80.4	82.1	86.7	83.2	84.5	80	77.5	78.7
Median salary													
Median salary: mathematics		58,000	55,000	56,500	75,000	78,000	75,000	95,000	80,600	87,000	80,000	79,000	80,000
Median salary: all fields of education		57,000	53,000	55,000	90,000	75,000	80,000	80,000	69,000	72,000	80,000	78,000	80,000
Most frequently reported occupations													
		1. Business, Human Resource & Marketing Professionals			1. Business, Human Resource & Marketing Professionals			1. Business, Human Resource & Marketing Professionals			1. Business, Human Resource & Marketing Professionals		
		2. Design, Engineering, Science & Transport Professionals			2. Education Professionals			2. Design, Engineering, Science & Transport Professionals			2. Education Professionals		
		3. Education Professionals			3. Specialist Managers			3. Education Professionals			3. Design, Engineering, Science & Transport Professionals		

** Fewer than 10 respondents.*

*** Mathematics: covers mathematical sciences, mathematics, statistics.*

† Includes those in full-time employment.

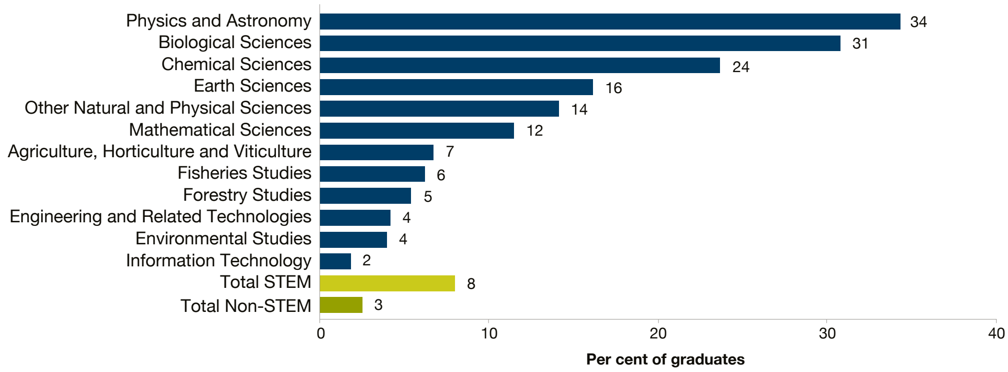
***Source:** Graduate Careers Australia, extract from Grad Jobs and Dollars/Mathematics.*

3.3 MATHEMATICIANS AND STATISTICIANS IN THE WORKFORCE

According to the recent report into pathways of university STEM graduates *Australia's STEM workforce—Science, Technology, Engineering and Mathematics* (using data from the 2011 ABS Census), in 2011 25,667 people identified the main field of study of their highest qualification as mathematics or statistics (the census asked responders to identify their main field of study in an open question). To compare: there were nearly 2.5 million adults in Australia with a university degree, and of those, around 700,000 had a degree in a STEM discipline. The people identifying as mathematicians or statisticians therefore comprise only about four per cent of the STEM university graduates.

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 (96 per cent) university degrees (of course, not all mathematical scientists received their highest qualification in Australia). Most mathematical scientists (70 per cent) had a bachelor degree as their highest level of qualification. About 15 per cent held a Masters degree, and 11 per cent a PhD degree. This is the lowest percentage of doctoral degrees of the "traditional" science disciplines, with the proportion of doctorate degree holders in physics, biology and chemistry much higher—see Figure 3.5.

Figure 3.5 Percentage of graduates in the workforce with doctorates, by field

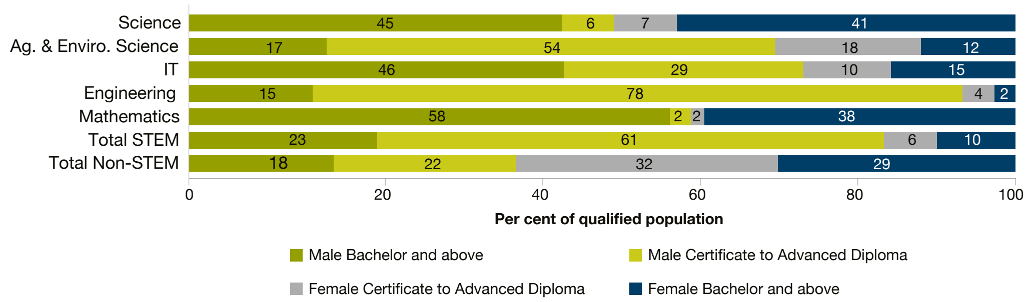


***Source:** Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 43.*

In understanding the gender distribution of those with a mathematical sciences degree we already know from chapter two that the proportion of females is relatively low. We can see in Figure 3.6 below that STEM disciplines in general attract fewer women than men. The figure below includes everyone in the workforce with a post-secondary STEM qualification (not just with university degrees). In mathematics and statistics, the male-female ratio in 2011 was 60:40. A few observations:

- Because the highest qualification of mathematicians and statisticians is almost exclusively at university level, it makes sense to compare them with the ratios of other STEM graduates with university degrees only (represented in the dark-coloured proportions at either end of Figure 3.6). The male-female ratio for STEM university degree holders in general was 70:30. The ratio for university degree holders in Engineering (88:12) and IT (75:25) presented with a deeper gender gap than mathematics, whereas in Science the ratio was more equal (52:48);
- We can see from Table 3.4 in paragraph 3.3 above that the male-female ratio can be slightly different for types of university degrees. For newly graduated bachelors and postdoctoral researchers in the mathematical sciences, the ratio was roughly 70:30, the ratio for Masters by Coursework was 51:49, and for Graduate Certificates and Diplomas 56:44.

Figure 3.6 Gender distribution of post-secondary qualifications, by field and level



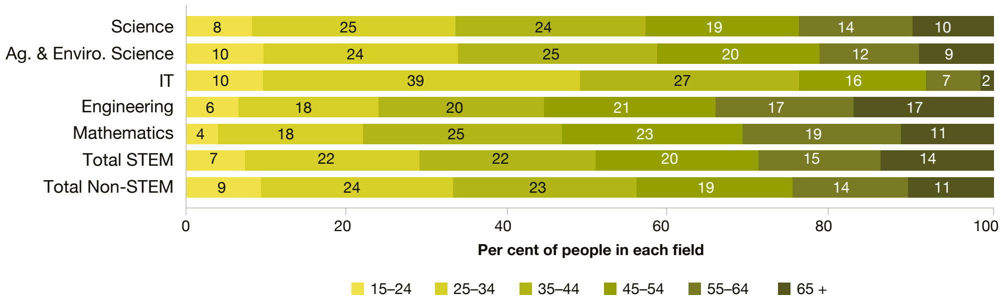
***Source:** Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 13.*

The age distribution data as represented in Figure 3.7 indicates that the mathematical workforce is ageing more rapidly than other STEM disciplines. First of all, this is evident in the low level of new entrants in the younger age bands. In 2011 the proportion of 15–24 year olds was 4 per cent, substantially smaller than in other STEM disciplines.

We have to keep in mind here that mathematical scientists almost exclusively (96 per cent) have university degrees, and this increases the age at which they enter the mathematical sciences workforce (especially considering the fact that 44 per cent of new bachelor graduates—see Table 3.4 on page 45—continued on with further study after

their bachelor degree). We can therefore assume that the 25–34 age band contains many new workforce entrants. It is especially worrying that at 18 per cent, this age band was also smaller than most other STEM disciplines.

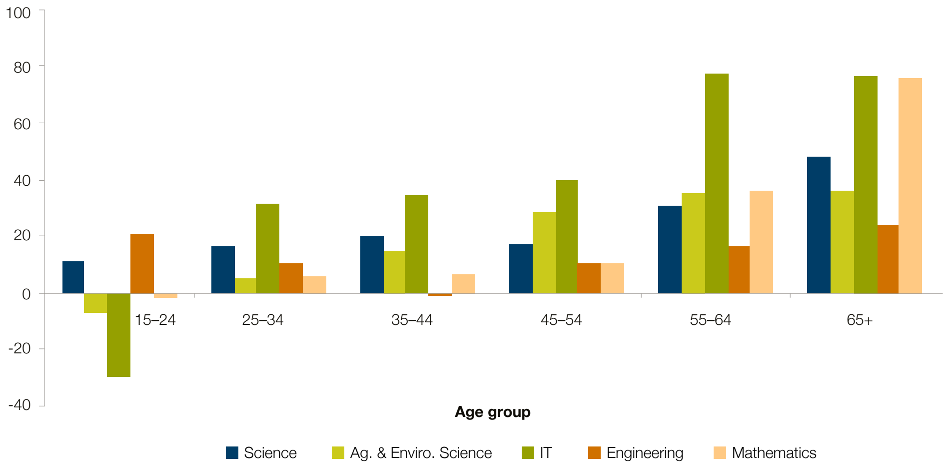
Figure 3.7 Age profile by proportion of people in each age group, by field of highest post-secondary qualification



Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 16.*

Secondly, at 19 per cent the proportion of 55–64 year olds is higher than in the other STEM disciplines. When we look at the changes in age distribution in the STEM workforce between 2006 and 2011 (Figure 3.8 below), the number of mathematicians in the two oldest age brackets 55–64 and 65+ became much larger in that five-year period. This was not compensated by an increase of new entrants in the combined 15–24 and 25–34 age groups (in fact, from 2006 to 2011 we saw a fall in the 15–24 age group). Unless this trend is reversed, we can expect the relatively small workforce in mathematics and statistics to further diminish in the future.

Figure 3.8 Percentage change in STEM-qualified population, by field and age group, 2006 to 2011



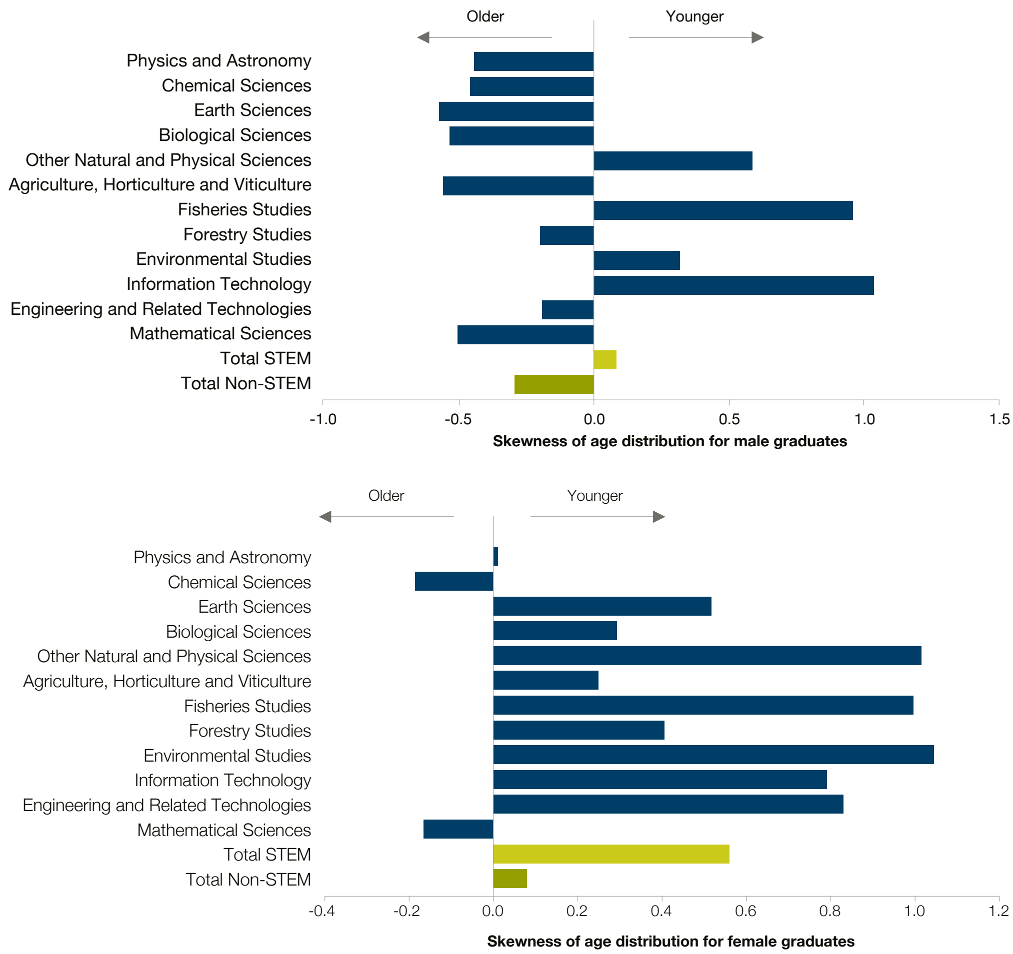
Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 17.*

Age group	Science	Ag. & Enviro. Science	IT	Engineering	Mathematics	Total STEM	Total Non-STEM
15–24	1,983	-1,381	-11,267	16,372	-23	5,684	81,628
25–34	8,692	2,327	25,987	24,773	276	62,055	293,033
35–44	9,735	6,328	19,318	-338	421	35,464	251,032
45–54	6,828	8,706	12,392	30,654	582	59,162	158,966
55–64	7,983	6,280	8,226	36,761	1,399	60,649	214,365
65+	8,632	4,952	2,288	50,598	1,442	67,912	167,692
Total	43,853	27,212	56,944	158,820	4,097	290,926	1,166,716

A third aspect from the STEM workforce report is the combined gender and age distribution used to analyse the skewness (the degree of asymmetry of the distribution around its mean). A positive skewness indicates a higher proportion of younger graduates, and a negative skewness the opposite. In most STEM disciplines, we see a positive skewness of younger female graduates. This means that the female participation in these disciplines is mostly younger. Unfortunately, we see no such skewness in the mathematical workforce. Both the male and female graduates had a higher proportion of older workers than younger workers, although the age distribution of female mathematicians was slightly younger than for males (half the male, versus 44 per cent of female mathematics graduates were aged 45 and over). Part of this effect results from the particularly low proportion of male and female mathematicians aged under 25. As it also means that the entry of young females into the mathematical workforce is not very high—we are unlikely to see a change in gender distribution towards more equality in the near future.

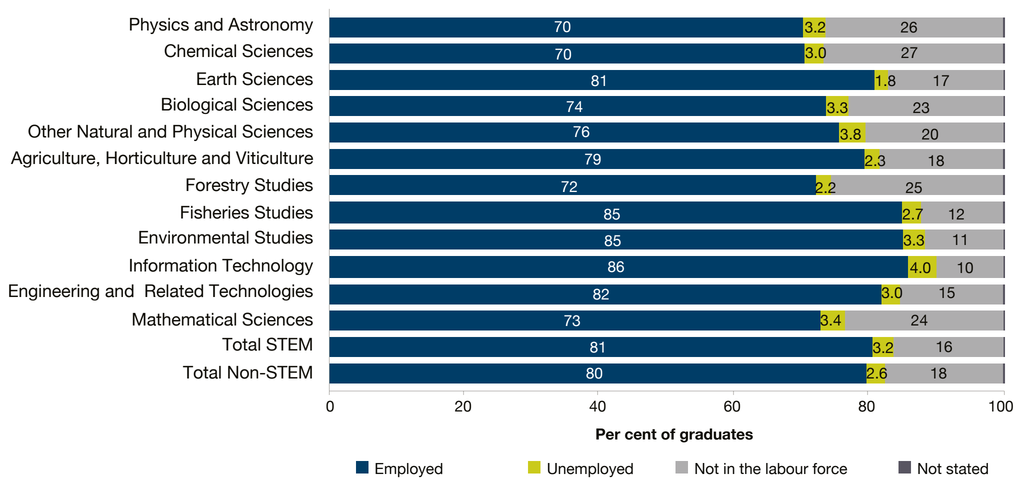
Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 42.*

Figure 3.9 Skewness of the age distribution pattern of male and female STEM graduates, by field



Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 40.*

Figure 3.10 Employment status of STEM graduates, by field

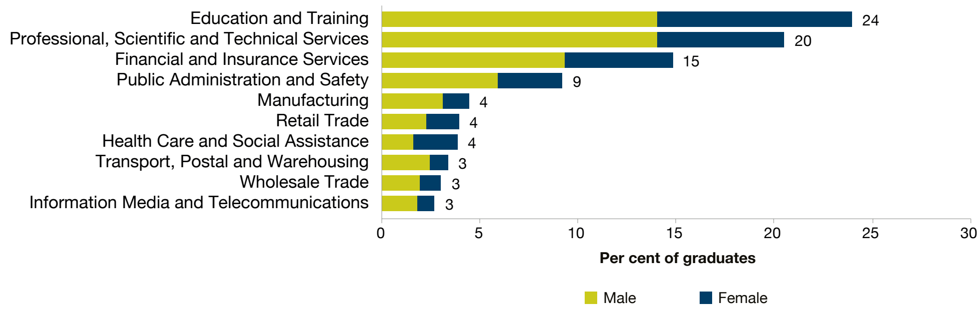


As we can see in Figure 3.10, the employment rate of mathematics and statistics graduates was 73 per cent, lower than the wider STEM population (81 per cent) and the non-STEM workforce (80 per cent). This was mostly due to a high percentage of 24 per cent of mathematical scientists currently outside of the labour force.

Of the mathematical sciences graduates in the labour force, 68 per cent were employed in the private sector (for the STEM workforce as a whole this was 77 per cent). The top ten industry divisions in which mathematicians and statisticians were employed are displayed in Figure 3.11.

Education and training (24 per cent) and professional, scientific and technical services (20 per cent) employed nearly half of all mathematicians and statisticians. It is interesting to note the difference in gender balance across industry divisions. With the exception of health care and social assistance, all industries employed more male than female mathematical scientists. However, in education and training, and financial and insurance services the proportion of females was around 40 per cent, while in professional, scientific and technical services the female proportion was closer to 30 per cent.

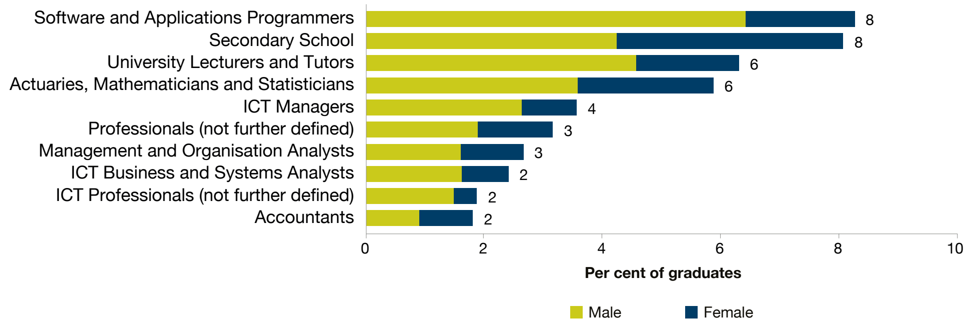
Figure 3.11 Top ten industry divisions of employment for mathematical sciences graduates with qualifications at bachelor level and above, by gender



Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 150.*

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 3.12 sets out the top occupations in more detail.

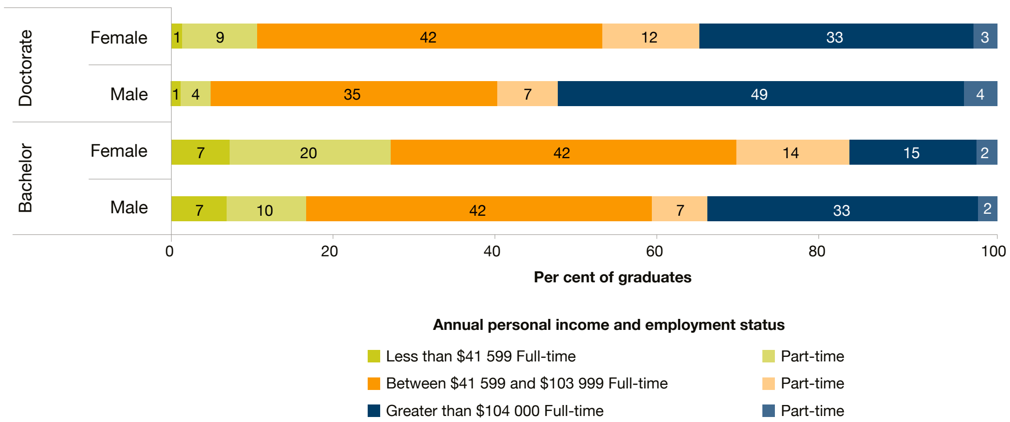
Figure 3.12 Top ten unit group level occupations for mathematical sciences graduates with qualifications at bachelor level and above, by gender



Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 152.*

Among secondary school teachers the gender balance was almost even, whereas for university lecturers and tutors the proportion of females was more like 25 per cent (which is consistent with results from the *AMSI University Survey* as discussed in section 2.1). What is also clear from this graph is that many mathematical scientists ended up in a range of ICT-related occupations. That is, as programmers, managers, business analysts or not-further-defined ICT professionals.

Figure 3.13 Personal annual income of mathematical sciences graduates working full-time and part-time, by gender and level of qualification



Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 154.*

Figure 3.13 highlights how graduate income levels depended on the type of degree, with 53 per cent of male, and 36 per cent of female doctorate degree holders finding themselves 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 females than males worked part-time. The part-time workers were more heavily presented in the lower and middle income brackets.

RESEARCHING OUR WAY TO THE TOP

The mathematical sciences have on average had **a higher success rate** for research grants from the Australian Research Council than other disciplines since 2011 (page 53)

Citation rates of Australian mathematical research in statistics and applied mathematics **outperforming 15 countries** within the European Union

While the mathematical sciences are amongst the smallest areas of research in Australia, internationally it holds its own (pages 57 & 58)

4 Research in the Mathematical and Statistical Sciences

OUTCOMES OF RESEARCH IN THE MATHEMATICAL SCIENCES AND THE AUSTRALIAN ECONOMY

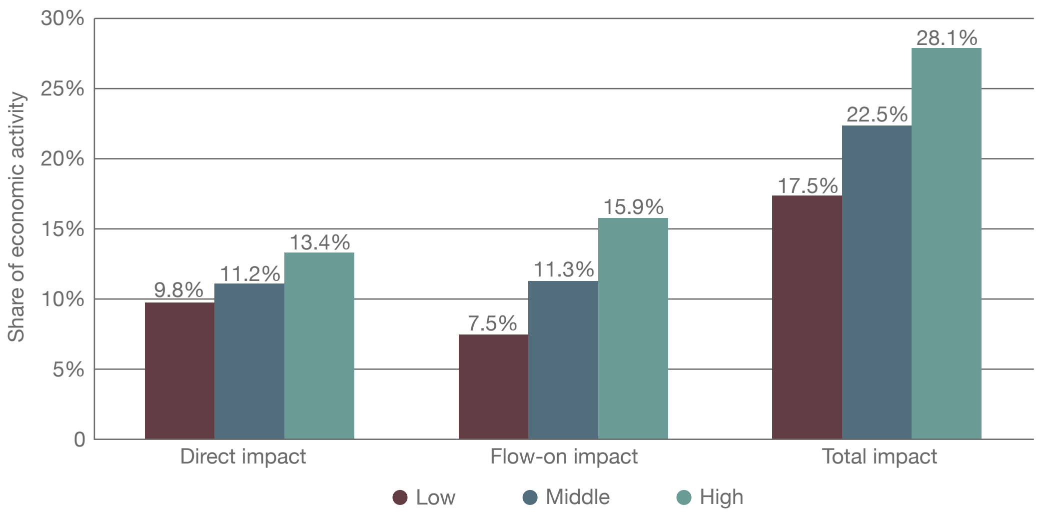
Combined research in the physical and mathematical sciences from the past 20 years contributes an estimated $145 billion annually to the Australian economy, with mathematical research pivotal to many industries, including finance, transport, computing, mining, insurance and telecommunications. Monetary investment is however minimal, with business contributing a minuscule fraction of its Research and Development expenditure on mathematical or statistical research. The two most important sources of funding of mathematical sciences research are Higher Education funding and Commonwealth funding through the Australian Research Council. 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 around 2.15 per cent of the total number of mathematical sciences publications in the world. The fields of Statistics and Applied Mathematics have obtained citation rates above 15 countries of the European Union in the period 2002 to 2012. In the latest Excellence in Research Australia (ERA) evaluation in 2015, 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. The direct impact (productivity improvement) of these combined sciences is estimated to be worth as much as 11.2 per cent of the economy or $145 billion per year. The flow-on cost savings for industries using the output of APM sciences run to an additional 11.3 per cent or $147 billion dollars annually—see Figure 4.1.

Figure 4.1 Direct flow-on and total impacts of the APM sciences on the Australian economy (% share of economic activity, $ billion value added)



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: *Australian Academy of Science, The importance of advanced physical and mathematical sciences to the Australian economy, 2015, Figure 1, page 1.*

Advanced research in the mathematical sciences in particular has been central to a large number of industries. Business sectors based on a single core science discipline (such as finance, transport and computing), as shown in Table 4.2, rely on mathematical sciences research most often. Table 4.3 shows that all dominant industries based on multiple advanced physical and mathematical sciences disciplines (mining, insurance and telecommunications) rely on mathematical or statistical research undertaken within the past 20 years.

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's imputed by the ABS and the industry does not employ any people (it makes up 9% of the total).*
Source: *Australian Academy of Science, The importance of advanced physical and mathematical sciences to the Australian economy, 2015, Table 8.1., page 57.*

Table 4.2 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 (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: *Australian Academy of Science, The importance of advanced physical and mathematical sciences to the Australian economy, 2015, Table 8.2, page 57.*

Table 4.3 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%

4.2 RESEARCH FUNDING

Monetary investment in the advanced mathematical sciences is surprisingly low given its impact on Australia's economy. Table 4.4 shows that between 2011 and 2012 the mathematical sciences received the lowest expenditure in proportion of total spending on research and development. According to data published by the Office of the Chief Scientist (see Table 4.4), higher education expenditure in Research and Development (HERD) contributed the most to mathematical science research ($167 million or 1.7 per cent of STEM funding). This was followed by Commonwealth funding (GOVERD) at $54 million, or 1.5 per cent of STEM funding, mostly through the Australian Research Council (ARC). The business sector spent a minuscule fraction of its R&D expenditure on the mathematical sciences—0.2 per cent or $29 million.

Table 4.4 Australian research expenditure, by sector

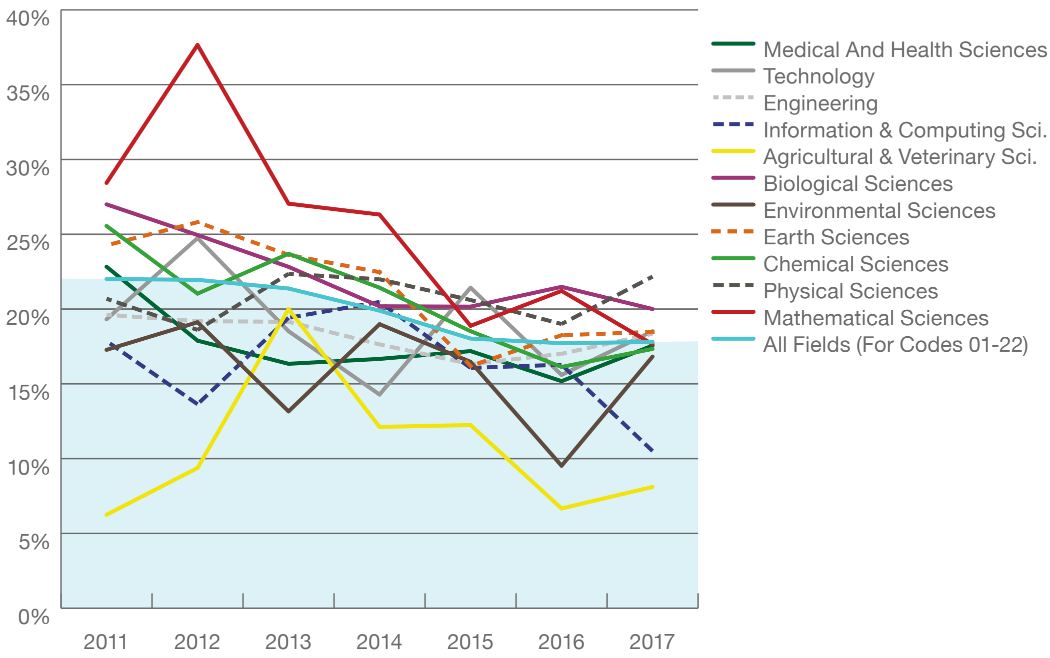
	HERD (2012)		BERD (2011–12)		GOVERD (2011–12)	
Field	$ million	%	$ million	%	$ million	%
Total	9 609	*	18 321	*	3725	*
STEM	6 978	72.6	17 833	97.3	3303	93.5
STEM excluding Medical & Health Sciences	4 156	43.2	16 891	92.2	2820	79.8
Humanities & Social Sciences	2 632	27.4	489	2.7	230	6.5
Breakdown of STEM	$ million	%	$ million	%	$ million	%
Agricultural & Veterinary Sciences	394	4.1	455	2.5	570	16.1
Biological Sciences	841	8.7	113	0.6	364	10.3
Chemical Sciences	358	3.7	426	2.3	165	4.7
Earth Sciences	288	3.0	122	0.7	207	5.9
Engineering	955	9.9	8 686	47.4	536	15.2
Environmental Sciences	342	3.6	281	1.5	247	7.0
Information & Computing Sciences	331	3.4	5 496	30.0	324	9.2
Mathematical Sciences	168	1.7	29	0.2	54	1.5
Medical & Health Sciences	2 823	29.4	941	5.1	483	13.7
Physical Sciences	312	3.2	47	0.3	238	6.7
Technology	168	1.7	1 235	6.7	115	3.2

Note: ** Not applicable.*
Source: *Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, Table 5–1, page 41.*

Mathematical research is therefore highly dependent on university and ARC funding. 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 (ICT) (Source: Australian Research Council, ARC Support for Research in the Mathematical Sciences, a Summary of Trends—Submit Years 2001 to 2011). In fact, Discovery Project proposal success rates in Figure 4.5 show the mathematical sciences outstripped other fields in the four years from 2011 to 2014. However, since 2015 the success rate has fallen substantially to a more modest 17.6 per cent in 2017 (slightly under the overall Discovery Project success rate of 17.8 per cent). At the same time, the ARC success rate for Discovery Projects has declined overall, from 22 per cent in 2011 to 18 per cent or below in the period 2015–2017, as a result of the fact that the ARC has funded considerably fewer projects in all fields of research. For example, the number of ARC Discovery Projects funded in total across all sciences has gradually declined from 931 in 2011 to 630 in 2017.

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, despite a drop to a more modest level against a backdrop of decline in available ARC funding.

Figure 4.5 ARC success rates of Discovery Project proposals 2011–2017 (%)



Source: *AMSI, based on ARC datasets.*

Figure 4.6 Number of ARC projects in the mathematical sciences by year of completion 2005–2017

Source: AMSI, based on ARC datasets.

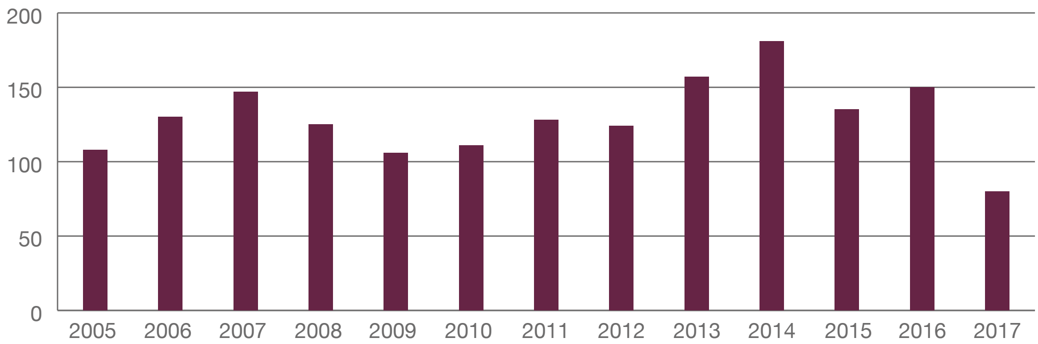


Table 4.7 shows the distribution of ARC funding among universities according to the AMSI Survey. Such funding is largely limited to Group of Eight (Go8) universities. On average, Go8 universities estimated their ARC funding success rate at 33 per cent between 2013 and 2015. Estimates by other universities fluctuate enormously—from very high success rates to no ARC funding success at all.

Table 4.7 Number of ARC grants held by and hosted at participating universities 2012–2016

Source: AMSI University Survey 2012–2016.

	Discovery Projects					Linkage Projects				
	2012	2013	2014	2015	2016	2012	2013	2014	2015	2016
Total Go8 universities	139	159	133	149	132	14	12	15	7	9
Total ATN universities	14	12	14	21	7	6	2	2	7	2
Total RUN universities	3	3	3	4	3	0	0	0	0	0
Total IRU universities	7	8	8	5	2	3	3	3	1	1
Total unaligned universities	16	16	14	9	19	1	1	3	6	4
Total all participating universities	179	198	172	188	163	24	18	23	21	16

ARC research projects can have multiple Chief Investigators, spanning more than one university and more than one discipline or "field of research"—even though there is always one lead university that administers the grant, and one "primary" field of research assigned to every project. Table 4.8 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 with have mathematical sciences as the primary field of research. However, there are also a number of mathematicians and statisticians involved in projects which are primarily related to a different discipline. This result again reinforces the large difference between Go8 universities and others in terms of involvement in ARC-funded research.

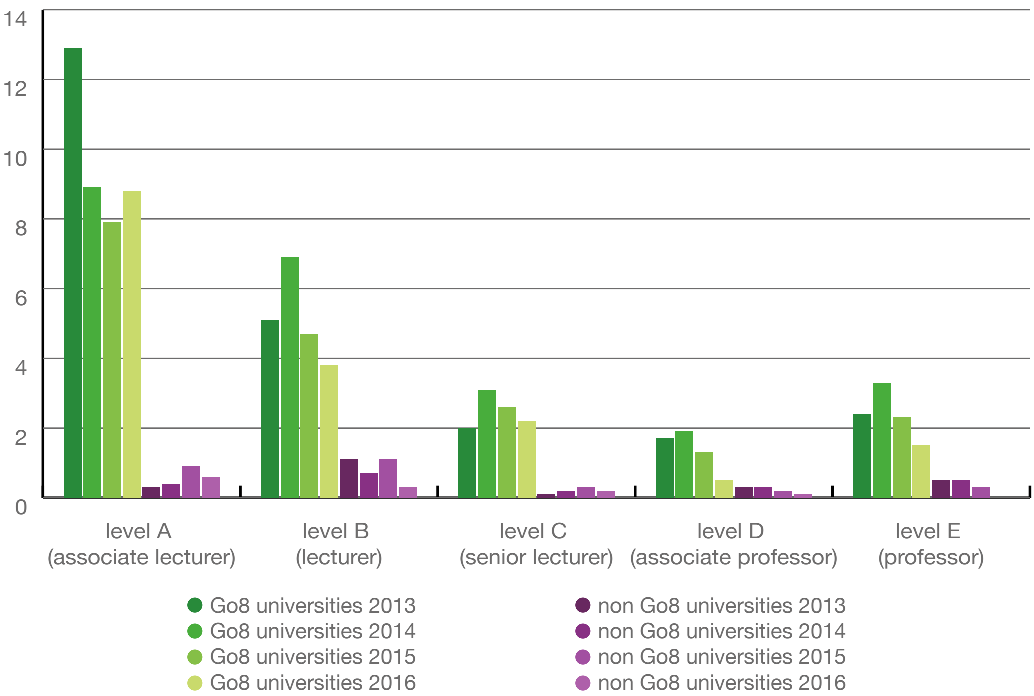
Table 4.8 Number of academic staff in mathematical sciences departments who are Chief Investigators in ARC-funded research projects in 2016

Source: AMSI University Survey 2016.

	with primary field of research code in the mathematical sciences	without primary field of research code in the mathematical sciences
Total Go8 universities (6/8)	176	18
Total non Go8 universities (15/31)	41	11
Total all participating universities	217	29

Figure 4.9 depicts comparative ARC funded staff levels at Go8 universities (in green) and other universities (in purple) for 2013 to 2016 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. However, after reaching a peak in 2013 and 2014, ARC-funded staff numbers have dropped, which is expected given the more moderate ARC success rate in the past few years.

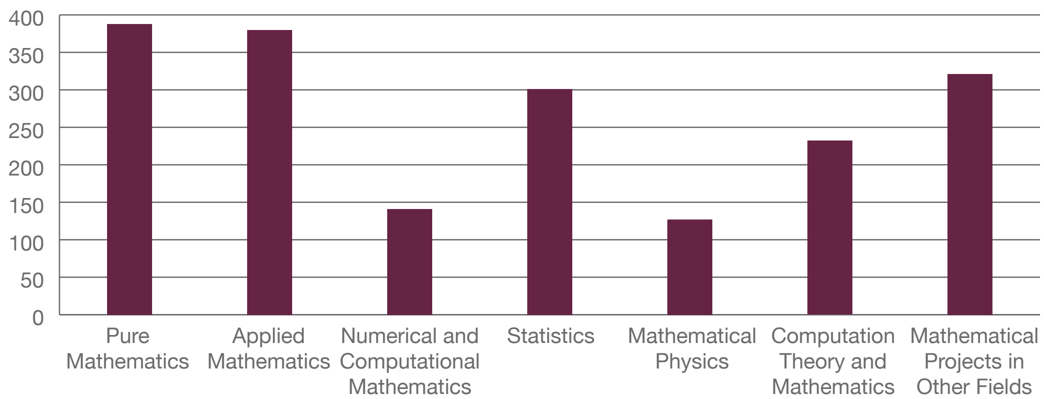
Figure 4.9 Average number of ARC-funded staff at participating universities 2013–2016



Source: *AMSI University Survey 2013–2016.*

Figure 4.10 highlights ARC research grant areas given within mathematics field of research "01" as well as other fields of research given specific funding for their maths component. Further details about these classifications and fields of research (FOR) codes may be found in the 2012 ERA Evaluation Handbook. Areas such as education, engineering, physics, econometrics and computer science can contain research with a mathematical component—as shown by the final bar.

Figure 4.10 ARC projects in the period 2002–2020



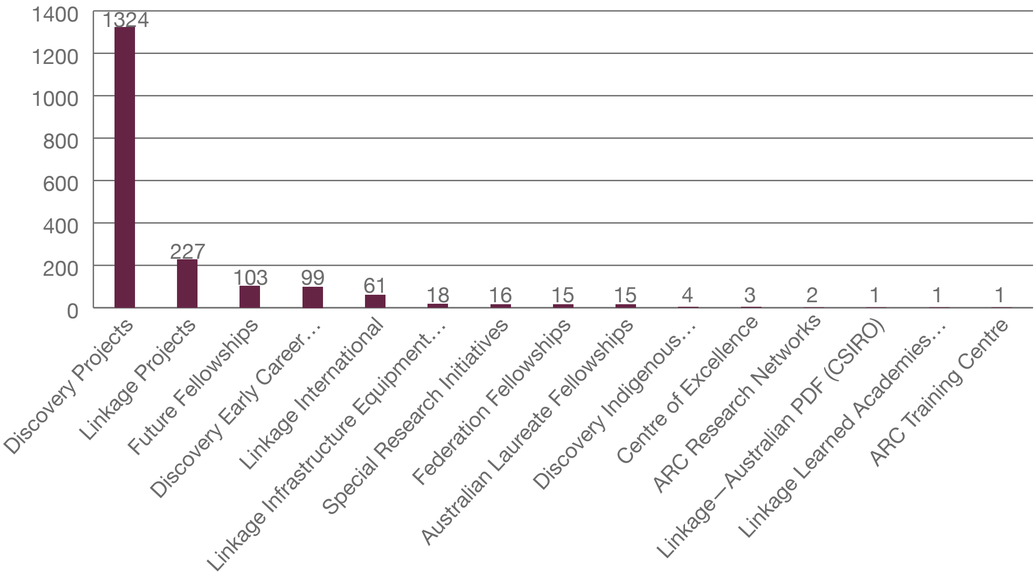
Note: *Included in analysis were projects with primary codes in 0101, 0102, 0103, 0104, 0105 and 0199 as well as projects in 0203, 0802, 0915, 1302 and 1403 with a mathematical component.*

Source: *AMSI, based on ARC datasets.*

Figure 4.11 confirms the majority of ARC research funding in the mathematical sciences comes in the form of Discovery Projects. The number of Linkage Projects (joint research projects with industry and other organisations) in the mathematical sciences is surprising at first glance. However, many of the projects linked with industry and other organisations are in applied areas such as curriculum and pedagogy, engineering or econometrics. Most others are in the fields of applied mathematics, statistics or computation theory; only a few Linkage Projects have a pure mathematics component (see Figure 4.12).

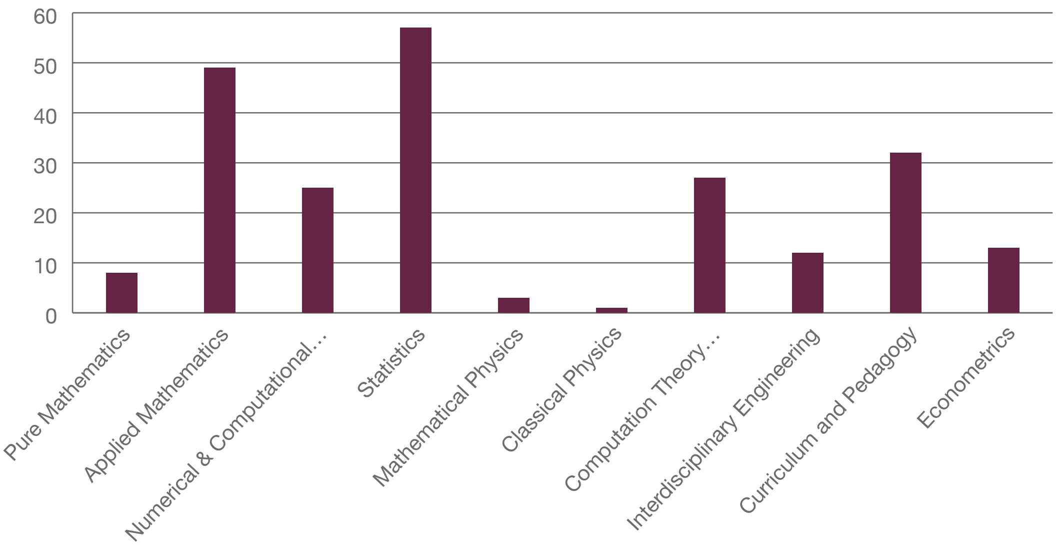
Note: *Included in analysis were projects with primary codes in 0101, 0102, 0103, 0104, 0105 and 0199 as well as projects in 0203, 0802, 0915, 1302 and 1403 with a mathematical component.*
Source: *AMSI, based on ARC datasets.*

Figure 4.11 Number of ARC projects by project type in the years 2002–2020



Note: *Included in analysis were projects with primary codes in 0101, 0102, 0103, 0104, 0105 and 0199 as well as projects in 0203, 0802, 0915, 1302 and 1403 with a mathematical component.*
Source: *AMSI, based on ARC datasets.*

Figure 4.12 ARC Linkage Projects in the period 2002–2020



4.3 RESEARCH OUTPUT AND QUALITY

By share of international output, the Australian mathematical sciences are a small area of research, similar to the chemical and physical sciences.

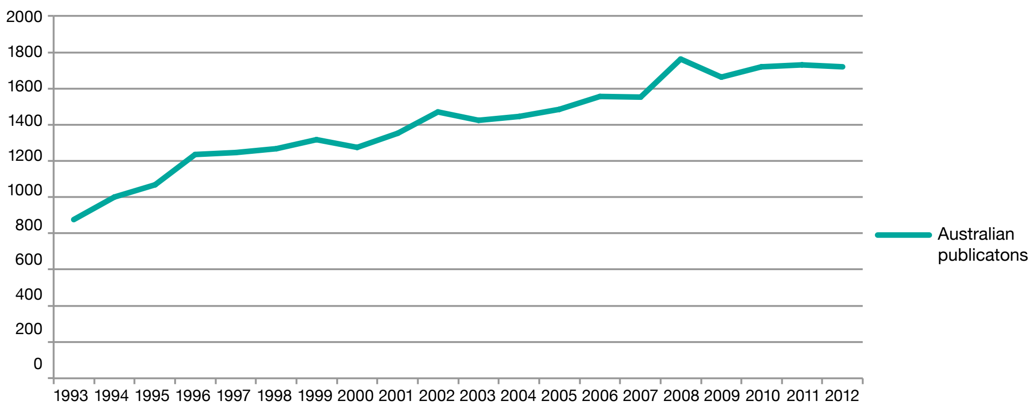
Table 4.13 shows that in the period 2002–2012 the mathematical sciences generated around 20,000 publications—2.15 per cent of the world total.

Table 4.13 STEM publications by field 2002–2012

Field	Australia		World total
	Total	% world	
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: *Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, Table 2–2, page 9.*

Figure 4.14 Australian mathematical publications (MathSciNet) in the period 1993–2012

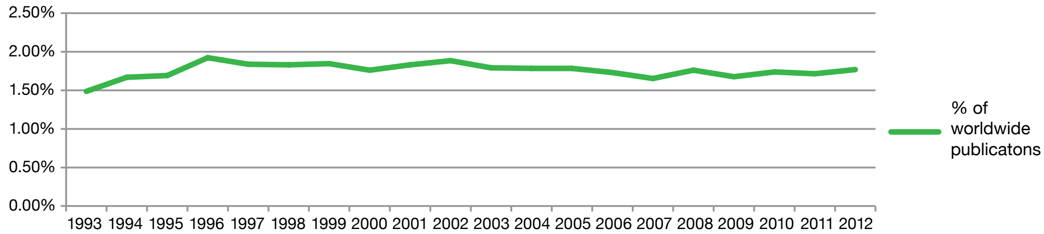


Source: *MathSciNet database on publications in mathematics originating from Australian universities, 1993–2013.*

MathSciNet is the worldwide database of mathematical publications. Figure 4.14 shows that over the last two decades Australian publications have seen a steady rise.

This rise is partly attributable to the MathSciNet database's widening journal coverage. According to Figure 4.15 Australia's contribution as a proportion of worldwide mathematical publications has remained stable at between 1.5 and 2 per cent. When compared to the latter half of the nineties, the overall percentage for the past decade has been slightly lower—less than the 2.15 per cent shown in Table 4.13—but this can be attributed to MatSciNet's partial coverage of scientific papers in statistics and mathematical physics.

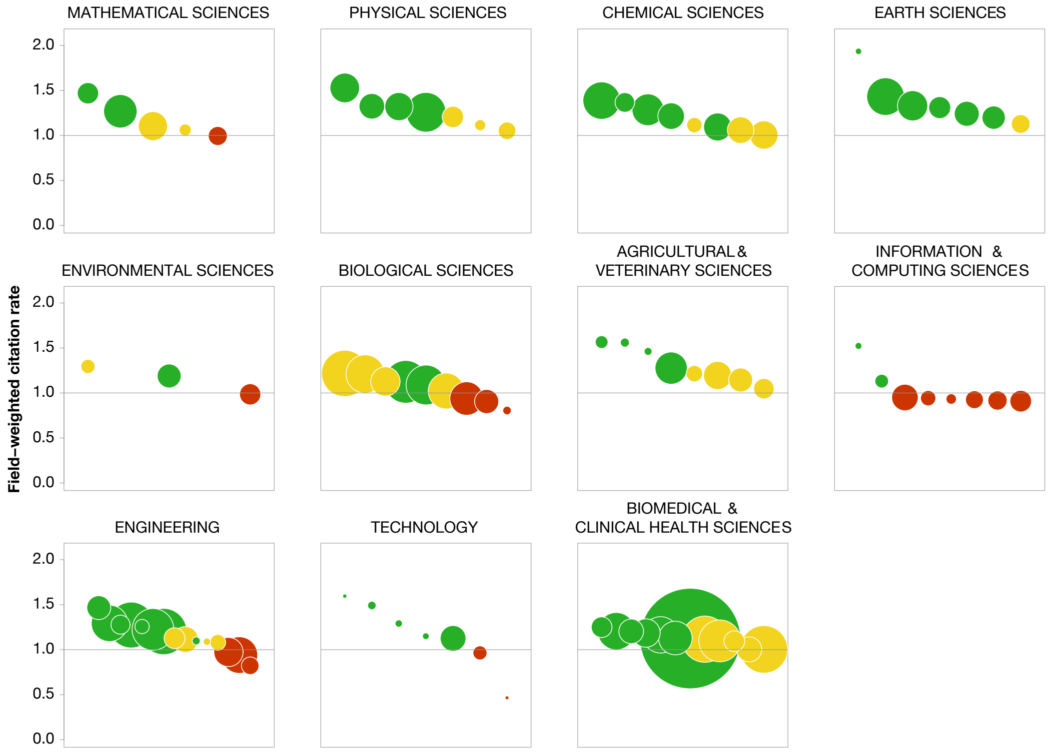
Figure 4.15 Australian publications as a percentage of worldwide mathematical publications in the period 1993–2012



Source: *Data from MathSciNet database on publications in mathematics originating from Australian universities, 1993–2013.*

Looking at the relative quality and impact of Australian mathematical research, it is clear that some areas do very well. Overall, however, Australian mathematical research does not stand out internationally as either particularly strong or weak. Figure 4.16 illustrates the relative position of fields of research measured against the aggregated citation data of 15 countries in the European Union (EU). The fields of statistics and applied mathematics are the only two fields with citation rates above those of the EU countries. Statistics also has higher citation rates than the United States (*Benchmarking*, page 15).

Figure 4.16 Australian STEM research, by sub-field, 2000 to 2012



Notes: *Publication counts are Web of Science documents classified as article, note or review, by year of publication and assigned to a country based on institutional address(es) listed in the publication.*

Each circle represents a STEM subfield of the main discipline (selected using Australia ERA 2012 FoR level 2 categories) ordered by field-weighted citation rate.

Circle area indicates total number of STEM publications, 2002–2012. Green circles show subfields above EU15 countries; yellow circles show subfields above world average (1.0) but below the EU15 countries; red circles show subfields that are below world average.

Source: *Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, Figure 2–4, page 13.*

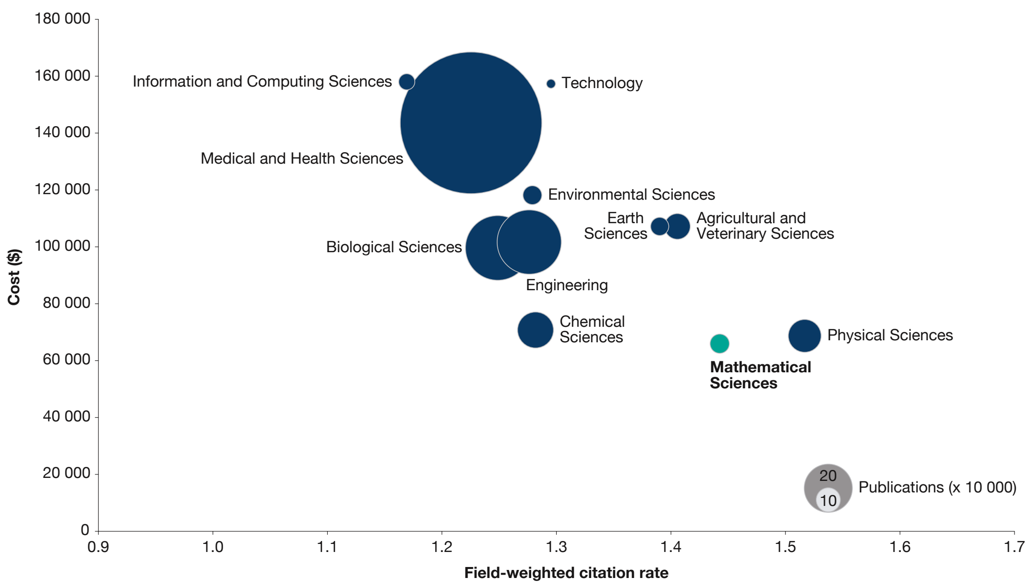
Table 4.17 STEM fields in Australian publications that contribute to the top 1% of global STEM publications, by citation rate, 2002–2012

Field of research	Australian share of top 1 per cent of each field (%)
Earth & Planetary Sciences	8.9
Agricultural & Biological Sciences	7.9
Environmental Science	7.3
Veterinary	6.7
Medicine	5.6
Immunology & Microbiology	5.1
General	5.0
Neuroscience	4.5
Psychology	4.3
Biochemistry, Genetics & Molecular Biology	4.0
Energy	3.8
Computer Science	3.2
Physics & Astronomy	3.2
Mathematics	3.1
Pharmacology, Toxicology & Pharmaceutics	3.1
Chemical Engineering	3.1
Engineering	3.0
Materials Science	2.9
Chemistry	2.5

Source: *Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, Table 3–1, page 23.*

The best Australian mathematical research ranks with the best in the world. In the decade from 2002 to 2012, Australian mathematics and statistics research contributed 3.1 per cent of the "best" world research in science, technology, engineering and mathematics (STEM). Table 4.17 defines the 3.1 per cent as Australia's share of the top 1 per cent of global STEM publications by citation rate.

Figure 4.18 Cost per publication and citation rate, by field



Notes: *Cost per publication is calculated using 2008, 2010 and 2012 HERD and 2009, 2011 and 2013 bibliometric data to account for the lag between funding and publication. Circle size represents number of publications during the period.*
Source: *Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, Figure 5–7, page 40.*

Figure 4.18 offsets the generation costs of Australian research publications against their citation rates. Despite modest funding, the cost per mathematical publication remains low and citation rates relatively high, attesting to the quality and output of mathematical research in Australia.

4.4 EXCELLENCE IN RESEARCH FOR AUSTRALIA (ERA) 2010–2012

The Australian Research Council conducted the Excellence in Research Australia evaluation (ERA) in 2010, 2012 and 2015. 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 sub disciplines), with each UoE receiving a rating from one (low) to five (high). A rating of three indicates “at world standard”. When compared to 2010 and 2012 (Table 4.19) the 2015 ERA results show a higher ranking of Australia’s mathematical sciences performance.

In ERA 2015, mathematical sciences disciplines (01 mathematical sciences) at 26 out of 41 universities were assessed (down from 27 in 2012). At the overall two-digit level, the 26 UoEs were assessed as performing at or above world standard, with seven receiving the highest possible ranking of five. Compared to 2012, all stabilised or increased their rating.

A detailed analysis of the four-digit level (with the discipline split into six sub disciplines) reveals the following:

- 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. In contrast, the number of applied mathematics units of evaluation increased from 17 in 2010, to 22 in 2012 and 23 in 2015. While mathematical physics has remained stable, numerical and computational mathematics has decreased to three (with only three of the four UoEs assessed receiving a rating), and statistics has risen to 12 after a low of 10 in 2012;
- At the four-digit level, the rating for all sub disciplines, with the exception of mathematical physics, has increased. This is especially apparent for statistics, which has increased to a rating of five—well above world standard—for all but one of the evaluated units;
- All sub disciplines at the four-digit level attracted a rating at or above world standard (against 62 per cent of UoEs in all research disciplines), with 39 per cent of the evaluated units receiving the highest rating of five (against 32 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 4.21.

Table 4.19 ERA Mathematical Sciences Institution Report (2010 and 2012)

01 MATHEMATICAL SCIENCES	2010							2012						
Institution	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	0199 Other Mathematical Sciences	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	0199 Other Mathematical Sciences
Australian Catholic University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The Australian National University	4	5	4	n/a	3	5	n/a	5	5	4	n/a	n/a	4	n/a
Batchelor Institute of Indigenous Tertiary Education	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bond University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Central Queensland University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5	n/a	5	n/a	n/a	n/a	n/a
Charles Darwin University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Charles Sturt University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Curtin University of Technology	3	n/a	3	3	2	n/a	n/a	3	n/a	3	3	n/a	n/a	n/a
Deakin University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Edith Cowan University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Flinders University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a
Griffith University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
James Cook University	2	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	3	n/a	n/a	n/a	n/a
La Trobe University	2	2	3	n/a	n/a	n/a	n/a	2	2	2	n/a	n/a	n/a	n/a
Macquarie University	2	3	n/a	n/a	2	n/a	n/a	2	3	n/a	n/a	2	n/a	n/a
University of Divinity	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Monash University	3	3	4	n/a	2	n/a	n/a	3	3	4	n/a	3	n/a	n/a
Murdoch University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a
Queensland University of Technology	4	n/a	4	3	3	n/a	n/a	4	n/a	3	4	4	n/a	n/a
RMIT University	2	n/a	3	n/a	n/a	n/a	n/a	3	n/a	4	n/a	n/a	n/a	n/a
Southern Cross University	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Swinburne University of Technology	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
University of Adelaide	3	4	3	n/a	3	n/a	n/a	4	4	4	n/a	4	n/a	n/a
University of Ballarat	2	2	n/a	n/a	n/a	n/a	n/a	2	2	2	n/a	n/a	n/a	n/a
University of Canberra	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Melbourne	5	4	4	n/a	4	5	n/a	4	5	4	n/a	4	4	n/a
The University of New England	4	4	n/a	n/a	n/a	n/a	n/a	3	4	n/a	n/a	n/a	n/a	n/a
University of New South Wales	4	3	4	5	3	4	n/a	4	4	4	3	3	3	n/a
The University of Newcastle	3	3	5	n/a	n/a	n/a	n/a	3	3	5	n/a	4	n/a	n/a
University of Notre Dame Australia	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Queensland	4	3	4	5	5	4	n/a	4	4	4	5	5	3	n/a
University of South Australia	3	3	3	n/a	n/a	n/a	n/a	4	3	3	n/a	n/a	n/a	n/a
University of Southern Queensland	3	n/a	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	n/a	n/a	n/a	n/a
The University of Sydney	5	4	4	3	3	5	n/a	5	4	3	3	4	4	n/a
University of Tasmania (inc. Australian Maritime College)	3	2	n/a	n/a	n/a	n/a	n/a	3	n/a	3	n/a	n/a	n/a	n/a
University of Technology, Sydney	3	n/a	3	n/a	n/a	4	n/a	3	n/a	4	n/a	n/a	3	n/a
University of the Sunshine Coast	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Western Australia	4	5	4	n/a	3	n/a	n/a	3	4	3	n/a	n/a	n/a	n/a
University of Western Sydney	3	3	n/a	n/a	n/a	n/a	n/a	4	3	4	n/a	n/a	n/a	n/a
University of Wollongong	3	3	3	n/a	2	n/a	n/a	4	3	4	n/a	4	n/a	n/a
Victoria University	2	1	3	n/a	n/a	n/a	n/a	3	1	4	n/a	n/a	n/a	n/a
Total UoEs evaluated	**24**	**18**	**17**	**5**	**12**	**6**	**0**	**27**	**17**	**22**	**5**	**10**	**6**	**0**

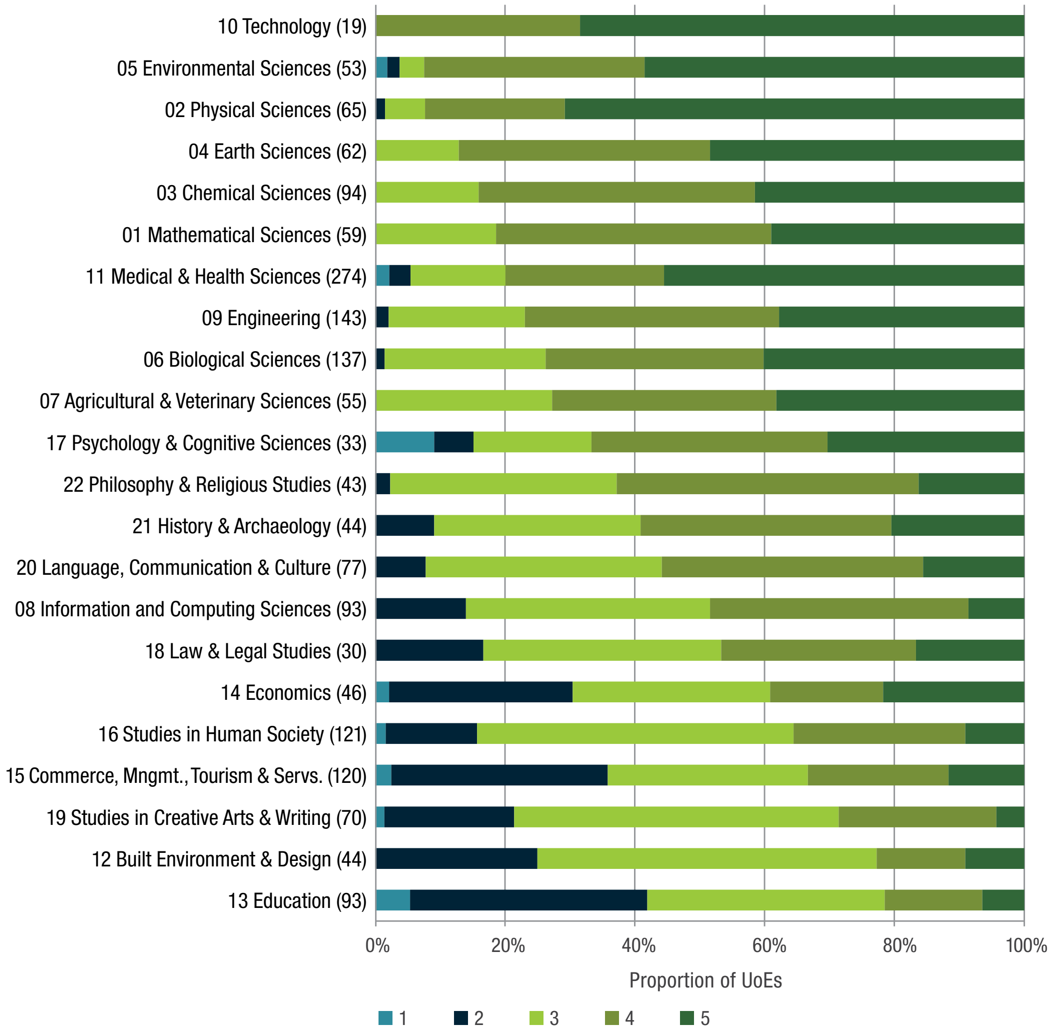
Source: *ARC/ERA, Section 4, ERA 2010 Institution Report, page 264 and ARC/ERA, Section 4, ERA 2012 Institution report, page 309.*

Source: *ARC/ERA, Section 5, ERA 2015 Institution Report, page 364–365.*

Table 4.20 ERA Mathematical Sciences Institution Report (2015)

01 MATHEMATICAL SCIENCES							
Institution	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical & Computational Mathematics	0104 Statistics	0105 Mathematical Physics	0199 Other Mathematical Sciences
Australian Catholic University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The Australian National University	5	5	4	n/a	n/a	3	n/a
Batchelor Institute of Indigenous Tertiary Education	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bond University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Central Queensland University	5	n/a	5	n/a	n/a	n/a	n/a
Charles Darwin University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Charles Sturt University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Curtin University of Technology	3	n/a	4	4	n/a	n/a	n/a
Deakin University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Edith Cowan University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Federation University Australia	3	3	3	n/a	n/a	n/a	n/a
Flinders University	3	n/a	4	n/a	n/a	n/a	n/a
Griffith University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
James Cook University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
La Trobe University	4	4	3	n/a	5	n/a	n/a
Macquarie University	4	5	n/a	n/a	4	n/a	n/a
Monash University	4	4	4	n/a	5	n/a	n/a
Murdoch University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Queensland University of Technology	4	n/a	4	5	5	n/a	n/a
RMIT University	3	n/a	5	n/a	n/a	n/a	n/a
Southern Cross University	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Swinburne University of Technology	3	n/a	3	n/a	n/a	n/a	n/a
University of Adelaide	5	5	4	n/a	5	n/a	n/a
University of Canberra	n/a	n/a	n/a	n/a	n/a	n/a	n/a
University of Divinity	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Melbourne	5	5	4	n/a	5	3	n/a
The University of New England	4	4	n/a	n/a	n/a	n/a	n/a
University of New South Wales	5	5	4	n/a	5	n/a	n/a
The University of Newcastle	4	4	4	n/a	5	n/a	n/a
University of Notre Dame Australia	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Queensland	4	4	4	n/a	5	3	n/a
University of South Australia	5	n/a	5	n/a	n/a	n/a	n/a
University of Southern Queensland	3	n/a	n/a	4	n/a	n/a	n/a
The University of Sydney	5	5	4	n/a	5	3	n/a
University of Tasmania (inc. Australian Maritime College)	3	n/a	4	n/a	n/a	n/a	n/a
University of Technology, Sydney	4	n/a	4	n/a	5	3	n/a
University of the Sunshine Coast	n/a	n/a	n/a	n/a	n/a	n/a	n/a
The University of Western Australia	3	4	4	n/a	n/a	3	n/a
University of Western Sydney	4	3	5	n/a	n/a	n/a	n/a
University of Wollongong	4	4	5	n/a	5	n/a	n/a
Victoria University	4	n/a	4	n/r	n/a	n/a	n/a
Total UoEs evaluated	**26**	**15**	**23**	**4**	**12**	**6**	**0**

Figure 4.21 Distribution of ratings for four-digit UoEs (aggregated four-digit results, grouped by two-digit FoR code)



Notes: *FoRs are ordered by the proportion of four-digit UoEs that received a rating of 4 or 5. The numbers in the brackets following the FoR name show the total number of four-digit UoEs that were rated in that two-digit FoR.*

Source: *ARC/ERA, Section 1, ERA 2015 National Overview, page 14.*

GLOSSARY

AAS: Australian Academy of Sciences
ABS: Australian Bureau of Statistics
ACER: Australian Council for Educational Research
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 Queensland University of Technology, Curtin University, University of South Australia, RMIT University, and University of Technology Sydney
BERD: Business Expenditure Research & Development
CIE: Centre of International Economics
EFTSL: Equivalent Full Time Student Load
ERA: Excellence in Research for Australia
FoR: Fields of Research classification
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
ICT: Information and communications technology
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 University of Newcastle
MathSciNet: Mathematical Reviews Database, maintained by the American Mathematical Society
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
PIAAC: The Programme for the International Assessment of Adult Competencies
PISA: Programme for International Student Assessment
RUN: Regional Universities Network, alignment of universities consisting of Central Queensland University, Southern Cross University, Federation University, University of New England, University of Southern Queensland, and University of the Sunshine Coast
STEM: Science, Technology, Engineering and Mathematics
TIMSS: Trends in International Mathematics and Science Study
UoE: Unit of Evaluation (ERA)

ABOUT THE 2016 AMSI UNIVERSITY SURVEY

Every year university departments and schools teaching and performing research in the mathematical sciences (members and non-members of AMSI) are sent a comprehensive survey questionnaire with enquiries about their staffing situation, teaching, student numbers and a host of other data. In 2016, 27 universities provided data in response to the annual survey. This *Discipline Profile* contains the preliminary results.

A final report of the AMSI Member Survey 2016 will be published on the AMSI website later in 2017.

AMSI wishes to thank all respondents to the 2016 survey for their cooperation:

The Australian National University
Charles Darwin University
Curtin University
Deakin University
Edith Cowan University
Federation University
Flinders University
James Cook University
La Trobe University
Macquarie University
Monash University
Murdoch University
Queensland University of Technology
RMIT University
Swinburne University of Technology
The University of Melbourne
The University of New England
The University of New South Wales
The University of New South Wales Canberra (ADFA)
The University of Newcastle
The University of Queensland
University of Southern Queensland
University of Tasmania
University of Technology Sydney
University of the Sunshine Coast
University of Wollongong
Victoria University
Western Sydney University

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MathSciNet, Data on publications in mathematics originating from Australian universities, 1993–2013.

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