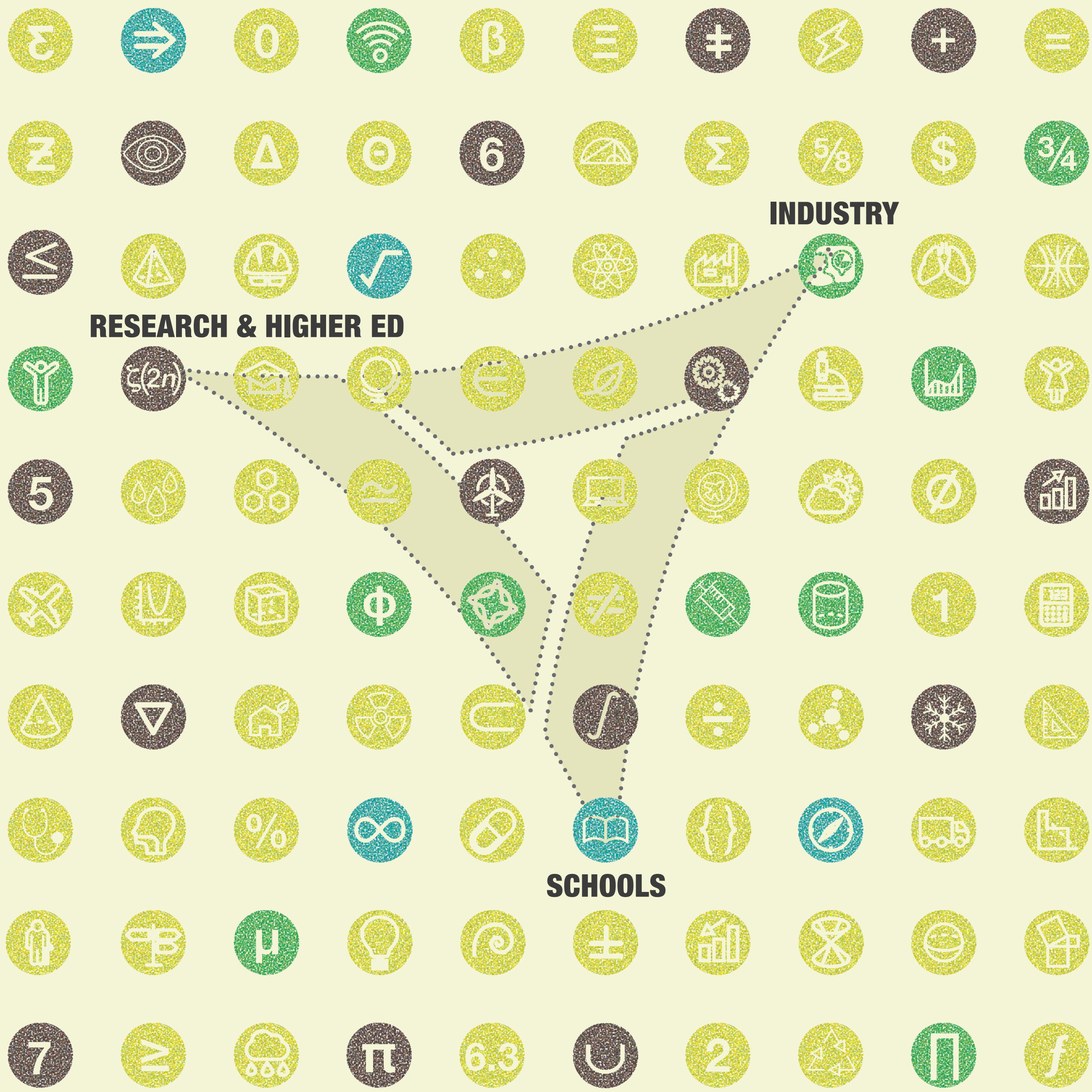
DISCIPLINE PROFILE
OF THE MATHEMATICAL SCIENCES



2016

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 lead innovation and technological development globally.

In its fifth 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.

This year's profile includes preliminary data from AMSI's 2015 survey of Australian university mathematical sciences departments, as well as the recent ERA report on research performance in Australia and new mathematical sciences workforce data.

As always, we include the latest NAPLAN data, as well as the Grattan Institute's current analysis outlined in their report Widening Gaps: what NAPLAN tells us about student progress.

Australia's deepening mathematics deficit should 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 decline 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 updated version of AMSI's policy document ***Securing Australia's mathematical workforce***.
www.amsi.org.au/mathsworkforce

FROM CLASSROOM TO INDUSTRY

EDUCATION NEEDS TO **CHOOSE MATHS**

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

26%

At least 26% of Years 7–10 maths classes **do not** have a qualified maths teacher, roughly twice the international average

(pages 15 & 16)

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 10 & 11)

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 2015

(page 12)

HIGHER ED A FORGOTTEN **PATH TO SUCCESS**

Australia's entry into university mathematical sciences degrees is **half the OECD average**

(pages 30 & 31)

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

(page 15)

59%

Only 59% of engineering degrees include **maths as a prerequisite**

(page 15)

Small universities often **lack the capability** to offer a major in the mathematical sciences

(page 22)

The mathematical sciences have **a higher sustained success rate** for research grants from the Australian Research Council than other disciplines
(page 43)

Citation rates of Australian mathematical research in statistics and applied mathematics **outperform 15 countries** within the European Union
(pages 46 & 47)

RESEARCHING OUR WAY TO THE TOP

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 41)

54%

54% of Australian adults have only **basic numeracy skills**, only just over the current OECD average
(page 33)

The ageing of the mathematical workforce is **worse than in the other STEM workforce sectors**
(page 37)

AT RISK

the prospects of creating a scientifically literate population

EDUCATION NEEDS TO CHOOSE MATHS

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(page 12)

1 School Education

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

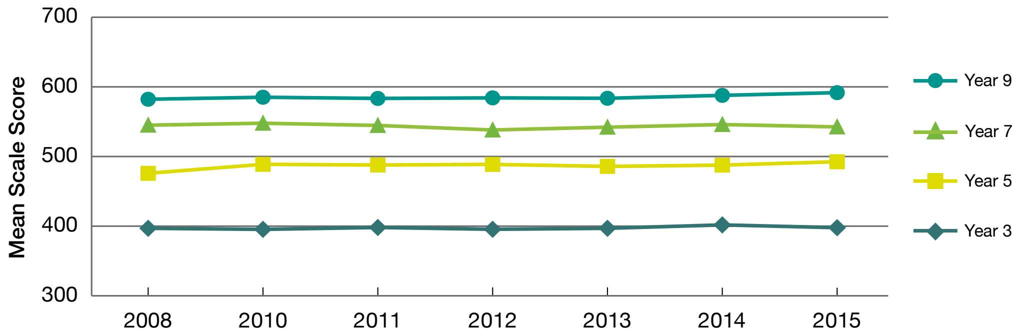
In Australia, the mathematical performance of students overall has remained static for some time. When compared to other countries, Australia's ranking has been in long-standing decline according to both the PISA and TIMSS surveys. Within the school population, the inequality between low-performing and high-performing students has increased. Most students who start off at a disadvantage never catch up, falling further behind during their schooling years.

By international standards, a high proportion of secondary school teachers, particularly in Years 7–10, have no methodology training in mathematics. Vacancies for maths teachers remain difficult to fill, making out-of-field-teaching a necessity for many schools. In Year 12, most students still choose to take some mathematics, but the proportion of students choosing advanced or intermediate maths as their highest level mathematics subject has declined over the past two decades. Many universities no longer require intermediate or advanced maths as an entry requirement for science, business or engineering degrees. The proportion of girls taking advanced maths in Year 12 is about seven 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 eight 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 2015 most scores show no significant difference. The Year 5 results indicate a modest increase in both the mean numeracy achievement, as well as the percentage of children working at or above the national minimum standard. Year 9 results show an increased percentage of students at or above the national minimum standard in 2014 and 2015. This follows after a moderate decline in the percentage of students scoring at or above the national minimum standard in 2013.

Figure 1.1 NAPLAN Achievement of Students in Numeracy, 2008, 2010–2015



Students		2008	2010	2011	2012	2013	2014	2015	Nature of the difference: 2008 vs. 2015	Nature of the difference: 2014 vs. 2015
Year 9	Mean / (S.D.)	582.2 (70.2)	585.1 (70.4)	583.4 (72.1)	584.2 (72.4)	583.6 (82.2)	587.8 (70.9)	591.7 (67.8)	■	■
	% at or above NMS	93.6	93.1	93.0	93.7	90.6	94.1	95.7	△	△
Year 7	Mean / (S.D.)	545.0 (73.2)	547.8 (72.4)	544.6 (73.7)	538.1 (73.9)	542.1 (71.4)	545.9 (73.0)	542.5 (68.6)	■	■
	% at or above NMS	95.4	95.1	94.5	93.8	95.0	95.1	95.9	■	■
Year 5	Mean / (S.D.)	475.9 (68.8)	488.8 (69.9)	487.8 (68.2)	488.7 (70.9)	485.8 (71.5)	487.6 (69.0)	492.5 (68.0)	△	■
	% at or above NMS	92.7	93.7	94.4	93.3	93.4	93.5	95.1	△	■
Year 3	Mean / (S.D.)	396.9 (70.4)	395.4 (71.8)	398.1 (70.6)	395.5 (72.6)	396.9 (65.8)	401.8 (73.0)	397.8 (74.3)	■	■
	% at or above NMS	95.0	94.3	95.6	93.9	95.7	94.6	94.4	■	■

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:** NAPLAN, 2015 National Report, page 279.*

Source: Selected data from TIMSS 1995, 2003, 2007 and 2011; Sue Thomson et al., Highlights from TIMSS and PRLS from Australia's perspective, ACER 2012.

Table 1.2 International student achievement in mathematics: Selection of data from TIMSS 1995–2011

4th grade						
	Girls	Boys	Australia overall	Int. (scaling) Average	Number of countries outperforming Australia	Countries outperforming Australia
1995			495			
2003	497	500	499	495	13	Singapore, Hong Kong SAR, Japan, Chinese Taipei, Belgium (Fl), Netherlands, Latvia, Lithuania, Russian Federation, England, Hungary, United States, Cyprus
2007	513	519	516	500	12	Hong Kong SAR, Singapore, Chinese Taipei, Japan, Kazakhstan, Russian Federation, England, Latvia, Netherlands, Lithuania, United States, Germany
2011	513	519	516	500	17	Singapore, Republic of Korea, Hong Kong SAR, Chinese Taipei, Japan, Northern Ireland, Belgium (Fl), Finland, England, Russian Federation, United States, Netherlands, Denmark, Lithuania, Portugal, Germany, Ireland
8th grade						
	Girls	Boys	Australia overall	Int. (scaling) Average	Number of countries outperforming Australia	Countries outperforming Australia
1995			509			
2003	499	511	505	467	9	Singapore, Republic of Korea, Hong Kong SAR, Chinese Taipei, Japan, Belgium (Fl), Netherlands, Estonia, Hungary
2007	488	504	496	500	10	Chinese Taipei, Republic of Korea, Singapore, Hong Kong SAR, Japan, Hungary, England, Russian Federation, United States, Lithuania
2011	500	509	505	500	6	Republic of Korea, Singapore, Chinese Taipei, Hong Kong SAR, Japan, Russian Federation

Source: Selected data from PISA 2000, 2003, 2006, 2009 and 2012; Sue Thomson et al., PISA 2012: How Australia measures up, ACER 2013.

Table 1.3 Student performance in the mathematical sciences among 15-year olds: Selection of data from OECD PISA reports in the period 2000–2012

	Australia score	Comparison to int. average	No of countries significantly outperforming Australia	Countries significantly outperforming Australia
2000	533	Above average	1	Japan
2003	524	Above average	4	Hong Kong-China, Finland, Korea, Netherlands
2006	520	Above average	8	Chinese Taipei, Finland, Hong Kong-China, Korea, Netherlands, Switzerland, Canada, Macao-China
2009	514	Above average	12	Shanghai-China, Singapore, Hong Kong-China, Korea, Chinese Taipei, Finland, Liechtenstein, Switzerland, Japan, Canada, Netherlands, Macao-China
2012	504	Above average	16	Shanghai-China, Singapore, Hong Kong-China, Chinese Taipei, Korea, Macao-China, Japan, Liechtenstein, Switzerland, Netherlands, Estonia, Finland, Canada, Poland, Belgium, Germany

The international surveys TIMSS (table 1.2) and PISA (table 1.3) indicate a decline in the average mathematical performance of Australian teenagers. At the same time, however, other countries, particularly in the Asia-Pacific region, have managed to significantly improve students' mathematical proficiency. Both PISA and TIMSS have completed new surveys in 2015 with release of results expected at the end of 2016. These will be included in next year's Discipline Profile.

1.2 DISTRIBUTION OF MATHEMATICAL ACHIEVEMENT

The deepening issue of performance inequality amongst Australian students is of significant concern. In particular, we see significant discrepancies when comparing student performance in metropolitan and rural areas, states and territories and top and low performers. The 2012 PISA survey showed that while the number of students performing very well in mathematics has fallen since 2003, the number of low performers has been rising. The percentage of Australian students reaching the two highest levels of proficiency is slightly under 15 per cent compared to the OECD average of 12.6 per cent. In 2003, this was approximately 20 per cent, equating to a 5 per cent drop over nine years. In comparison there has been a 5.3 per cent increase in our low performing (below proficiency level 2) students. In 2003, only 15 per cent of Australian students were considered as underperforming, in 2012 this figure rose to 20 per cent (source: PISA 2012, Volume I, page 70).

Given the possible influence of different factors on achievement levels, the annual NAPLAN reports include a breakdown of success according to gender, geolocation, language background other than English (LBOTE), state and territory, and parental education and occupation. Below is an extract from the 2015 NAPLAN report summarising Year 9 numeracy achievement by these variables.

Table 1.4 NAPLAN Year 9 Numeracy in 2015

	Below national minimum standard (%)		At national minimum standard (%)	Above national minimum standard (%)				At or above national minimum standard (%)
NAPLAN Year 9 Numeracy in 2015	Exempt	Band 5 & below	Band 6	Band 7	Band 8	Band 9	Band 10	
Achievement of Year 9 Students by Sex, 2015								
Male	2.3	2.3	14.0	28.3	26.7	16.0	10.5	95.4
Female	1.3	2.8	15.7	31.2	27.5	14.2	7.2	95.9
Achievement of Year 9 Students by LBOTE Status, 2015								
LBOTE*	2.2	2.5	12.9	25.2	24.1	16.4	16.6	95.3
Non-LBOTE*	1.7	2.5	15.2	30.9	28.1	14.8	6.9	95.9
Achievement of Year 9 Students by Parental Education, 2015								
Bachelor degree or above	1.0	0.4	5.2	19.5	30.7	24.4	18.9	98.6
Advanced Diploma/Diploma	1.4	1.5	12.9	32.5	30.4	14.8	6.6	97.2
Certificate I to IV	1.6	2.9	19.3	36.8	26.3	9.8	3.3	95.5
Year 12 or equivalent	2.2	2.7	17.8	34.2	26.0	11.7	5.5	95.1
Year 11 or equivalent or below	3.8	6.8	28.4	35.2	17.8	6.0	2.0	89.4
Not stated (8%)	2.8	5.5	18.6	28.5	24.1	13.5	7.0	91.7
Achievement of Year 9 Students by Parental Occupation, 2015								
Senior Management/qualified professionals	0.8	0.5	5.7	20.3	30.9	24.0	17.7	98.7
Other business managers & associate professionals	1.0	1.1	10.5	29.0	31.5	17.5	9.5	97.9
Tradespeople, clerks, skilled office, sales & service staff	1.5	2.2	16.6	35.5	27.5	11.7	5.0	96.4
Machine operators, hospitality staff, assistants, labourers	2.3	3.9	22.9	36.1	21.9	8.5	4.4	93.8
Not in paid work in the previous 12 months	5.4	7.5	28.0	32.8	16.7	6.5	3.2	87.1
Not stated (11%)	2.8	5.7	20.8	30.4	22.8	11.5	6.0	91.5
Achievement of Year 9 Students by Indigenous Status, 2015								
Indigenous	2.9	14.3	34.9	31.0	12.8	3.4	0.8	82.8
Non-Indigenous	1.7	1.9	13.7	29.6	27.9	15.8	9.5	96.4
Achievement of Year 9 Students by Geolocation, 2015								
Metro	1.8	2.0	13.2	28.3	27.5	16.5	10.7	96.2
Provincial	1.7	3.2	18.9	34.1	26.4	11.5	4.1	95.1
Remote	1.8	7.6	24.9	32.5	22.2	8.7	2.3	90.6
Very Remote	1.0	32.0	32.5	20.6	10.3	3.0	0.5	67.0
Achievement of Year 9 Non-Indigenous students by Geolocation, 2015								
Metro	1.8	1.7	12.5	28.2	27.9	16.9	11.1	96.5
Provincial	1.6	2.4	17.1	34.1	27.9	12.4	4.5	96.0
Remote	1.3	2.3	18.2	35.8	27.9	11.3	3.2	96.4
Very Remote	1.3	2.1	20.9	38.5	26.4	8.6	2.0	96.5
Achievement of Year 9 Indigenous Students by Geolocation, 2015								
Metro	3.0	9.7	32.5	33.3	15.6	4.6	1.2	87.2
Provincial	3.1	11.2	36.1	33.6	12.6	2.9	0.5	85.7
Remote	3.2	21.1	41.5	24.5	7.2	2.2	0.3	75.7
Very Remote	1.0	44.3	37.1	13.0	3.8	0.7	0.0	54.7

**LBOTE: Language Background Other Than English.*

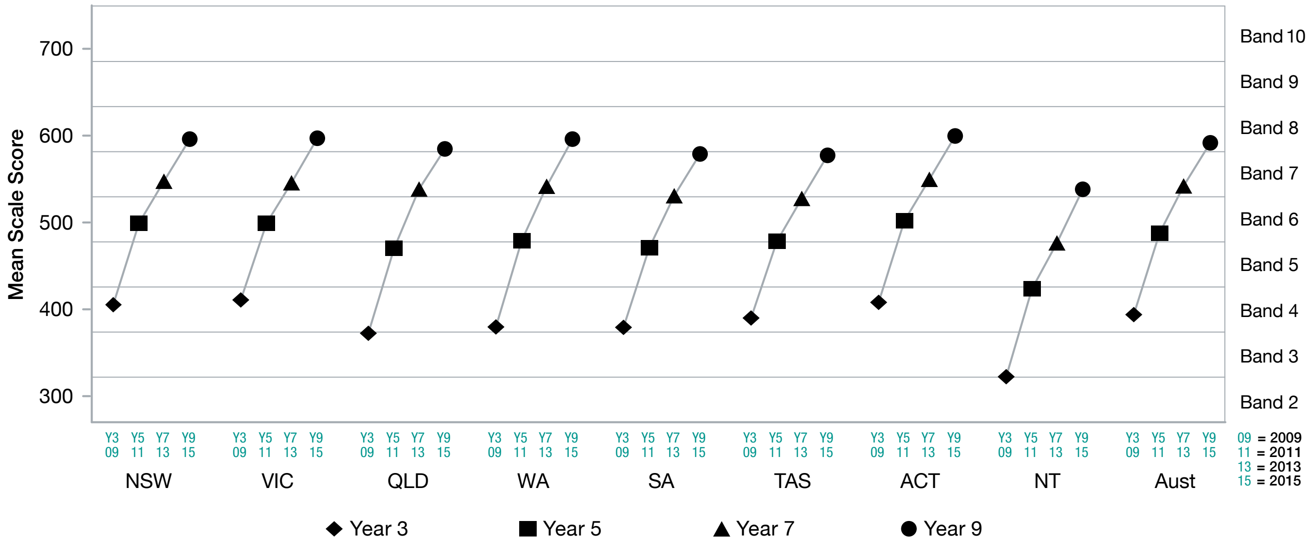
Source: *NAPLAN, 2015 National Report, extracts from tables 9.N2-N9, pages 239–248.*

Table 1.4 shows very little difference between male and female students when it comes to attaining minimum standards. Males are, however, represented significantly more in the highest achievement bands. This difference warrants close examination, especially to see if there is a relation with the lower percentage of girls choosing advanced mathematics in Year 12—see page 12.

Language background does not appear to be a strong disadvantage with students from non-English backgrounds dominating the highest bands of achievement. Parental education and occupation, however, are important factors in numeracy achievement, this effect is especially pronounced in the highest achievement bands. Geolocation also plays a significant role with students in metropolitan and provincial outperforming those in remote and very remote areas. This appears to be intimately linked to indigenous status. In a comparison of non-indigenous students across all areas (remote, very remote, metropolitan and provincial) minimum standard achievement rates are not dramatically different. Results for Indigenous students in remote and very remote areas, however, are well below the rest of Australia.

Another way of looking at inequalities in numeracy is to observe the progress of students over time. Figure 1.5 depicts the gains in numeracy skills over a six-year period of the cohort who attended Year 9 in 2015. This cohort sat their first NAPLAN tests in 2009 (Year 3), completing subsequent testing in 2011 (Year 5), 2013 (Year 7) and 2015 (Year 9). In this cohort the highest achievement gain took place between Years 3 and 5, and the lowest between Years 7 and 9. This is consistent with the numeracy gains of the cohort who completed Year 9 in 2014. Significantly, students in Western Australia and Queensland are shown to have gained the most numeracy skills in their schooling years—they did, however, start from a lower base. Despite starting with a higher proficiency, the results show smaller gains for students in NSW and Victoria.

Figure 1.5 NAPLAN Cohort Achievement—Students in Numeracy



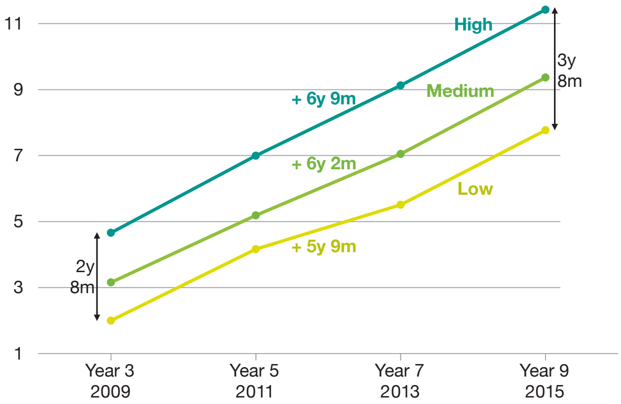
Source: *NAPLAN, 2015 National Report, page 354.*

From the raw NAPLAN data described above we cannot immediately determine the actual level of disparity between low and high achievers. The Grattan Institute has therefore proposed a new time-based measure, "equivalent year levels". Converting the NAPLAN scores into "years of progress" allows comparison of different student groups within the same cohort. When applied to the NAPLAN numeracy data from the state of Victoria for the 2009–2015 cohort, these are some of the troubling disparities coming to light in this approach:

- Low achievers in numeracy never catch up with their peers, but fall even further behind by Year 9 (Figure 1.6)
- 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 1.7)
- 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 1.8)
- 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 1.9)

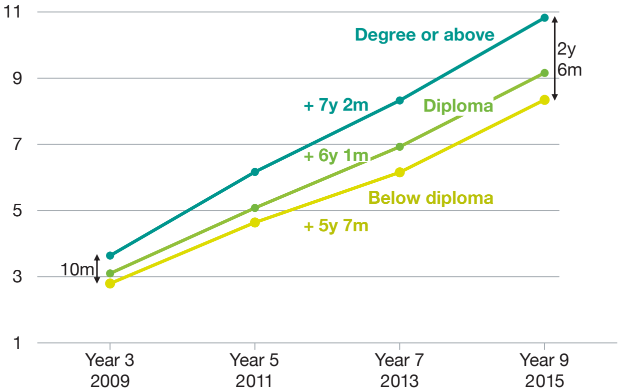
This last result in particular highlights how the Australian education system further entrenches numeracy performance inequality, as it is not the students' innate capabilities which determine their educational outcome in numeracy, but which school they have attended.

Figure 1.6 Growth of disadvantage—Estimated progress of low, medium and high achievers



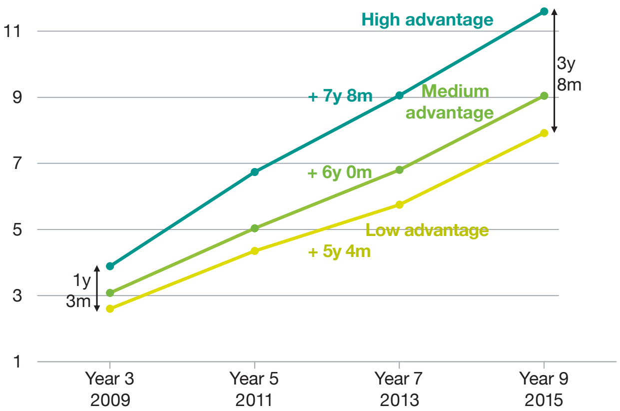
Notes: *Results show the estimated progress of low, medium and high achievers (students who scored at the 20th, 50th and 80th percentiles in Year 3) between Years 3–9. Black values indicate the gap between highest and lowest groups. Coloured values are the years of progress gained over the six-year period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

Figure 1.7 Growth of disadvantage—Estimated progress of students grouped by their parents' education



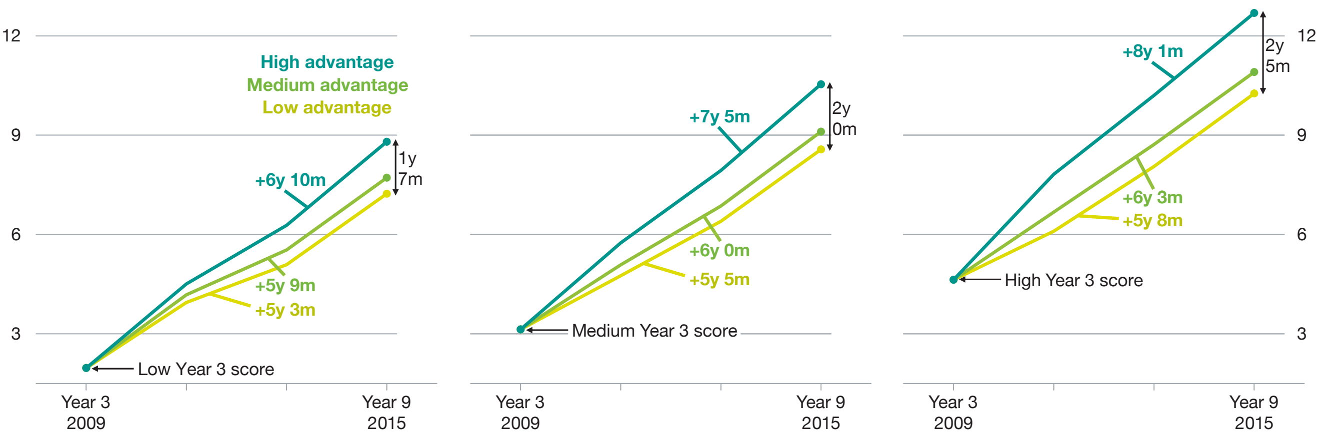
Notes: *Equivalent year level, numeracy, median, Victoria, 2009–15. Results show the estimated progress of students grouped by their parents' highest level of education as a proxy for socio-economic status. Black values are the gap between highest and lowest groups. Coloured values are the years of progress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

Figure 1.8 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).*

Figure 1.9 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).*

SCHOOLS

1.3 STUDENT NUMBERS AND PARTICIPATION RATES

Year 12 mathematics participation rates have been tracked since 1995. Figure 1.10 clearly illustrates that the proportion of students choosing intermediate and advanced mathematics subjects has been in steady decline for some time, although this decline seems to have stabilised in the past two years.

Source: *Michael Evans and Frank Barrington, Year 12 Mathematics Participation Rates in Australia 1996–2015, data collection commissioned by AMSI.*

Figure 1.10 Australian Year 12 mathematics students

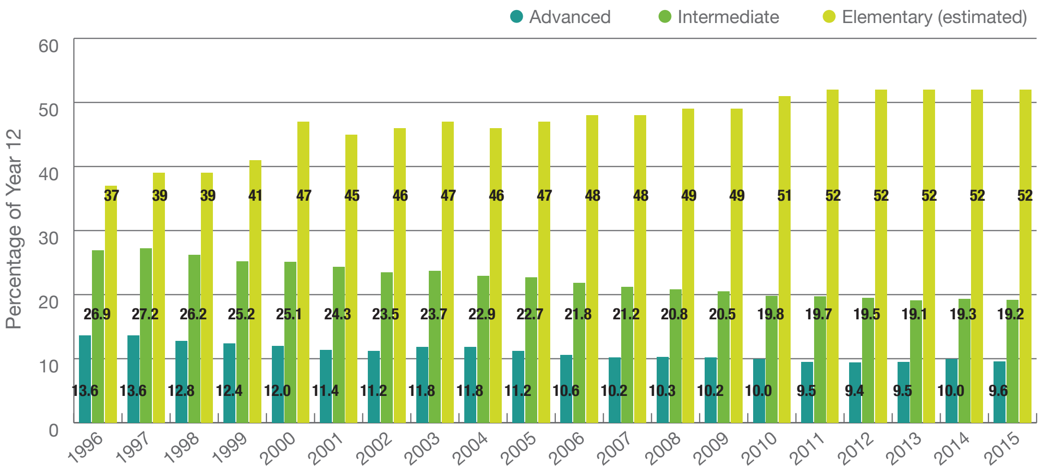


Figure 1.10 includes data for all Year 12 mathematics students enrolled through the secondary boards of studies and the Australian International Baccalaureate (IB) in all states and territories, for years 1996–2015.

The number of Australian Year 12 students studying advanced mathematics rose from 21,189 in 2013 to 21,507 in 2014. The 2014 advanced mathematics percentage participation rate of 10 per cent was also slightly up for the second year in a row, from 9.4 per cent in 2012 and 9.6 per cent in 2013. The number of intermediate students (those enrolled in an intermediate mathematics subject but not enrolled in an advanced mathematics subject) decreased, from 42,232 in 2013 to approximately 41,750 in 2014. When measured against the ever-increasing Australian Year 12 population, there has been a persistent and ongoing decline in the percentages of Year 12 students taking advanced and intermediate mathematics. 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 students enrolled in elementary mathematics (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 since 2011. The proportion of Australian students studying some mathematics in Year 12 has remained at 80 per cent over the past two decades. It is, however, the level of mathematics studied that has dropped considerably. Despite a slight increase in numbers and participation rate in the 2013 and 2014, the proportion of Year 12 students taking advanced mathematics in 2015 was 20 per cent lower than it was in 2000 and 32 per cent lower than in 1996—see figure 1.11.

While the percentages of boys and girls taking elementary mathematics was virtually the same in 2014, the intermediate mathematics participation rate (that is, the percentage of students taking intermediate mathematics but not taking advanced mathematics) was 18.2 per cent for girls compared with 20.6 per cent of boys. The gender gap widens in advanced mathematics, with only 6.8 per cent of girls taking advanced mathematics in 2014, compared with 13.4 per cent of boys—see figure 1.12 on the next page.

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

Figure 1.11 Percentage decline proportion of advanced mathematics students

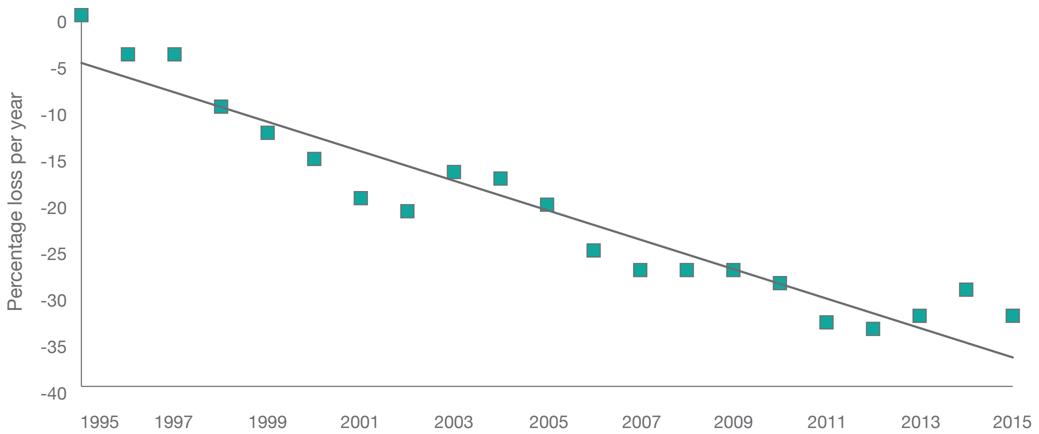
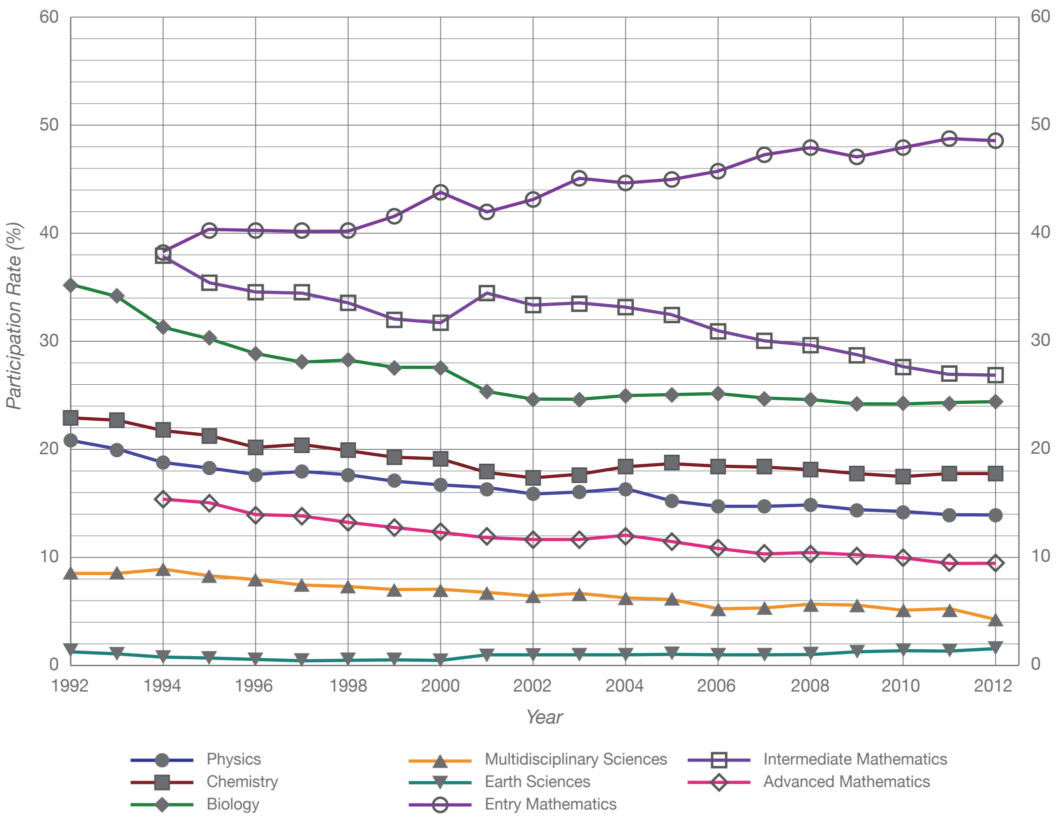


Figure 1.12 Year 12 advanced mathematics students in Australia

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

The field of mathematics is not the only field where participation has been declining; other STEM fields have also been affected. Figure 1.13 below shows that other STEM subjects such as Chemistry, Biology and Physics have also seen a decline in participation over the past two decades.

Figure 1.13 Participation rates in science and mathematics subjects 1992–2012



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.*

Table 1.14 on the next page sets out enrolment numbers and participation rates in Biology, Chemistry and Physics since 1992 alongside those for Mathematics since 1994. It is 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 1992–2002, 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 per cent—it's just that students are opting to do the "easier" mathematics subjects
- Since 2012 the fall in intermediate and advanced mathematics 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 to three years

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.

Table 1.14 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%

The cause of this decline in STEM subject participation is complex. In exploring trends for mathematics, it is possible to identify a few contributing factors, including cultural attitudes towards the study of mathematics. Achievement in mathematics is certainly related to student self-confidence and learning attitudes. Table 1.15 below sets out student attitudes towards mathematics and science in Year 8. According to the TIMSS 2011 results for Australia, students' self-confidence and the value they place on mathematics learning, lie close to the international average. However, 45 per cent of Australian Year 8 students do not like mathematics, compared with 31 per cent internationally. Science in general is not doing much better, with 44 per cent of Year 8 students indicating they "do not value" science.

Source: TIMSS 2011, selected data from Exhibits 8.1 to 8.5; Sue Thomson et al., Monitoring Australian Year 8 student achievement internationally: TIMSS 2011.

Table 1.15 Student attitudes towards mathematics: selection of data from TIMSS 2011

% of students who like science & mathematics						
	Like		Somewhat like		Do not like	
	Science	Mathematics	Science	Mathematics	Science	Mathematics
Australia	25	16	42	40	33	**45**
International average	35	26	44	42	21	31
% of students who are confident in science & mathematics						
	Confident		Somewhat confident		Not confident	
	Science	Mathematics	Science	Mathematics	Science	Mathematics
Australia	16	17	49	46	35	37
International average	20	14	49	45	31	41
% of students who value science & mathematics						
	Value		Somewhat value		Do not value	
	Science	Mathematics	Science	Mathematics	Science	Mathematics
Australia	25	**46**	31	40	44	14
International average	41	46	33	39	26	15

A second factor likely to contribute to the slide in the proportion of students choosing Year 12 intermediate and advanced mathematics is that many universities have dropped intermediate or advanced mathematics as prerequisites for entry into science and engineering degrees, with many moving to "assumed knowledge" of mathematics. This affects student perception of the need to step up to the challenge of choosing the harder mathematics subjects. Table 1.16 on the next page summarises mathematics 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 has recently decided to re-introduce maths prerequisites starting in 2019. (http://fyimaths.org.au/survey-of-mathematics-entry-requirements-in-australian-universities/).

A third factor may be a belief held by some students that opting for maths subjects below their ability will optimise their university entrance scores.

A recent 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 to suggest that this problem extends beyond NSW. However, all these, and other, possible factors certainly warrant further investigation.

Table 1.16 Minimum requirements for entry into Bachelor Degrees

State	Science: No of Unis offering course	Science: Intermed. Maths PreReq	Science: Assumed Knowledge of Intermed. Maths	Science: % with Intermed. Maths as pre req	Engineering: No of Unis offering course	Engineering: Intermed. Maths PreReq	Engineering: Assumed Knowledge of Intermed. Maths	Engineering: % with Intermed. Maths as pre req	Commerce: No of Unis offering course	Commerce: Intermed. Maths PreReq	Commerce: Assumed Knowledge of Intermed. Maths	Commerce: % 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: ** NSW Mathematics Extension 1 for majority of majors in BSc.*
Some degrees may list advanced mathematics as a prerequisite or assumed knowledge for entry into certain majors, e.g. mathematics or physics majors.
Source: *data collected by the FYiMaths network, 2015.*

1.4 TEACHER PROFILES AND QUALIFICATIONS

Research consistently shows there are not enough mathematically qualified teachers in Australian secondary schools. The commonly accepted definition of being qualified in a discipline is to have completed methodology training in the area. The most recent data—gathered in 2013—on qualifications of maths teachers in secondary education indicate the following (see table 1.17):

- 73.9 per cent of Years 7–10 teachers teaching maths 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 maths 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 the science
- In Years 11–12, 86.1 per cent of maths teachers have completed methodology training, up from 76.3 per cent in 2010
- 72.5 per cent of Years 11 and 12 maths 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 maths teachers had at least three years tertiary education, up from 54.8 per cent in 2010 and 53 per cent in 2007

Table 1.17 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 1.17) suggests an important improvement in training levels of maths teachers since 2010. It is not clear what has caused this shift, and close scrutiny of this issue remains necessary.

For instance, data from a 2013 Queensland Audit Office report indicated the shortage of qualified maths teachers was much more serious than the shortage of science teachers—see table 1.18 over page. According to this report, in Years 8–10, 36.5 per cent of maths teachers had no specialist qualification, against 20.3 per cent of teachers teaching science.

Table 1.18 Out-of-field Teachers teaching Mathematics and Science Subjects in 2010

Source: *Queensland Audit Office, Supply of specialist subject teachers in secondary schools, Report to Parliament 2: 2013–2014, page 19.*

	Subject & level	Teachers with no specialist subject area qualification & teaching %	Teachers with specialist subject area qualification & not teaching (underuse) %
Maths	All maths subjects	33.3	28.6
	Years 8–10	36.5	33.0
	Mathematics A	32.5	46.3
	Mathematics B	12.5	53.7
	Mathematics C	8.8	72.6
Science	All science subjects	14.5	41.5
	Years 8–10	20.3	43.8
	Chemistry	9.80	58.4
	Physics	17.0	51.5
	Biology	7.8	62.7

From an international perspective the Australian situation only recently looked significantly worse than the international average. Compared to the international average of 12 per cent, a staggering 34 per cent of Australian Year 8 students were being taught mathematics by a teacher without a solid mathematical background, according to the 2011 TIMSS survey—see table 1.19.

Furthermore, lack of teacher training in mathematics had a negative effect on student performance. The average achievement of students in classes with a teacher without a major in either mathematics or mathematics education in 2011 was 500—five points lower than the national average achievement of 505 points—see table 1.2 in this chapter for the nationwide average achievement scores. In comparison the achievement of students with a teacher with a mathematical background was the same or higher than the national average.

Data dating back to 2010 also indicated a wide variance of teacher training between metropolitan, provincial and remote areas—see table 1.20. The proportion of teachers with three years or more tertiary education in mathematics who teach Years 7 to 10 is 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 have three years or more tertiary mathematics, compared to 57 per cent and 43 per cent in provincial and remote areas respectively. Table 1.20 shows that only biology shows a good supply of qualified teachers—unfortunately very few biology teachers are also qualified to teach mathematics.

Table 1.19 Teachers Majored in Education and Mathematics (8th Grade): extract from TIMSS

Source: *TIMSS 2011 Exhibit 7.4: Teachers Majored in Education and Mathematics.*

	Major in Mathematics & Maths Education		Major in Maths Education but no Major in Mathematics		Major in Mathematics but no Major in Maths Education		All Other Majors	
	% of students	Average Achievement	% of students	Average Achievement	% of students	Average Achievement	% of students	Average Achievement
Australia	37	505	9	522	21	519	**34**	500
International Average	32	471	12	470	41	468	12	462

Table 1.20 Highest Year level of Tertiary Education in Field by Geolocation: 2010

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

	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%				

Despite the encouraging new ACER data from 2013, 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 maths 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 and in absolute terms mathematics teaching positions have been, and remain the most difficult to fill—see table 1.21.

Table 1.21 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

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

Difficulty in filling vacancies leads to teachers teaching "out-of-field'; retired teachers being hired on short-term contracts; or, in acute shortages, teachers not fully qualified in subject areas being recruited to teach these subjects. Table 1.22 shows the significant differences between government, catholic and independent schools in teacher shortages and their 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 versus 33.4 per cent in 2010), and teaching out-of-field is less prevalent (33.2 per cent versus 42.2 per cent in 2010) which suggests some improvement in staffing shortages overall.

Table 1.22 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

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.*

HIGHER ED A FORGOTTEN **PATH TO SUCCESS**

Australia's entry into university mathematical sciences degrees is **half the OECD average**
(pages 30 & 31)

The number of universities **requiring at least intermediate maths** for entry into science and commerce degrees remains low
(page 15)

59%

Only 59% of engineering degrees include **maths as a prerequisite**
(page 15)

Small universities often **lack the capability** to offer a major in the mathematical sciences
(page 22)

2 Higher Education

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

Overall, the mathematical sciences are a small discipline within 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 been halted. 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 less than 25 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 past decade, the number of Bachelor degrees completed 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 an increase in international students. Even so, this rise isn't really keeping up with the overall rise in degree numbers across 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 2015

	Teaching only	Research only	Teaching & Research	All staff	Average per university
Total Go8 universities (7/8)	43	156	238	437	62
Total ATN universities (4/5)	27	22	83	133	33
Total IRU universities (5/6)	5	6	45	56	11
Total RUN universities (4/6)	3	5	32	40	10
Total unaligned universities (6/14)	16	20	89	124	18
Total all participating universities (26)	93	208	488	789	30

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. 7 out of 8 Go8 universities responded to this question in the survey).*
Source: *AMSI University Survey 2015, preliminary results.*

In 2015, mathematical sciences departments in Australia participating in the *AMSI university survey* reported employing 789 staff in (FTE)—see table 2.1. The average number of staff in participating mathematics and statistics departments in 2015 was 30 (same as in 2014)—but the average number of staff differs greatly between Group of Eight universities and other universities.

This doesn't detract from the overall indication that there's been a small increase in staff numbers over the past five years. If we look at the staff numbers across the 14 universities who have participated in all AMSI surveys so far (see figure 2.3), there has been an overall increase in staff levels between 2011 and 2014 which has levelled off in 2015. In the period 2011–2015, 9 of these 14 universities increased staff numbers, while 4 decreased staff numbers. The rise stemmed mostly from an increase in research-only staff until 2014, and a rise in staff in Teaching and Research positions in 2015.

The staff data supplied to the ARC for Excellence in Research Australia (ERA) points in the same direction with a five per cent staff increase reported from 2012 to 2015—see table 2.2. Level B, D and E staff numbers have steadily risen since 2010, whereas staff numbers at level A have dropped.

Table 2.2 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%

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

Source: AMSI Member Survey 2012–2014, and preliminary results 2015.

Figure 2.3 Number of staff at mathematical sciences departments participating in AMSI Surveys 2011–2015 (in FTE)

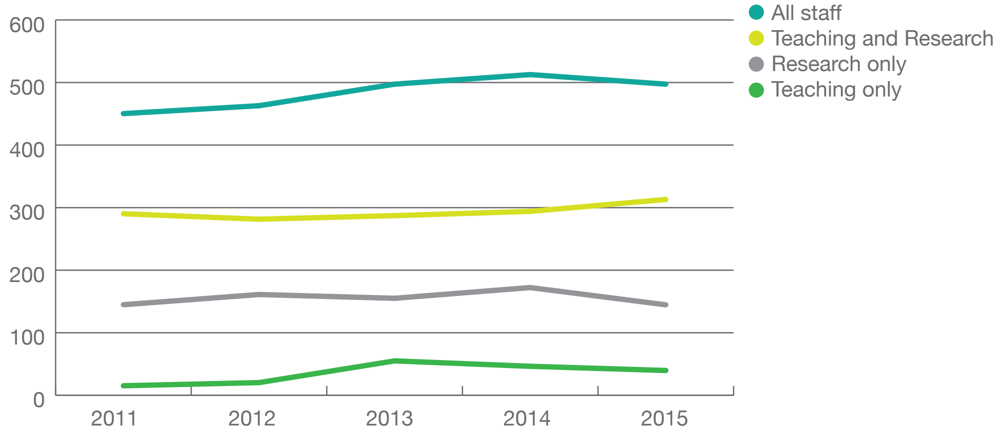
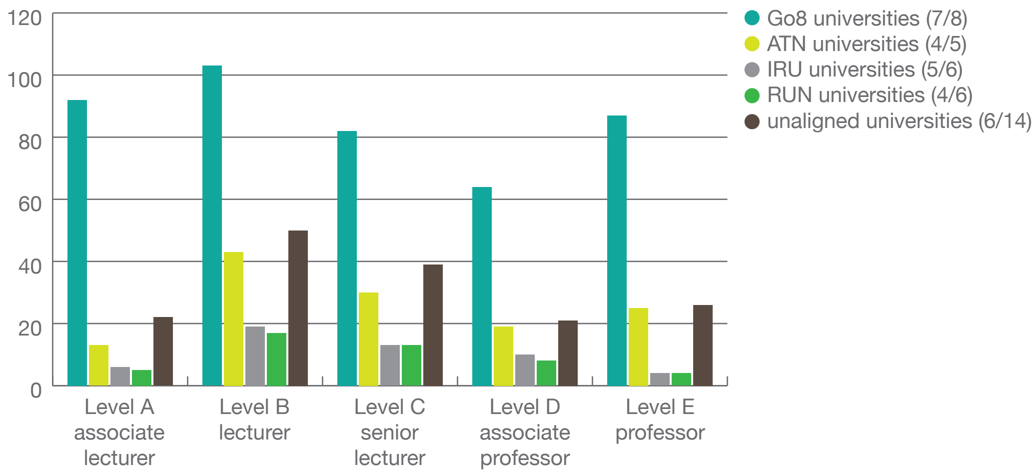


Figure 2.4 indicates a top-heavy staffing profile, with a relatively large number of staff employed at level E (professorial level). Non-Go8 universities tend to employ few staff at entry level A, whereas Go8 universities employ many more junior researchers at this level—a function of the much higher ARC research revenue that they generate. When compared with ERA staffing figures for all disciplines it's 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 2.5. This can be the result of the academic population ageing—if that's the case the mathematical sciences are more deeply impacted than other disciplines.

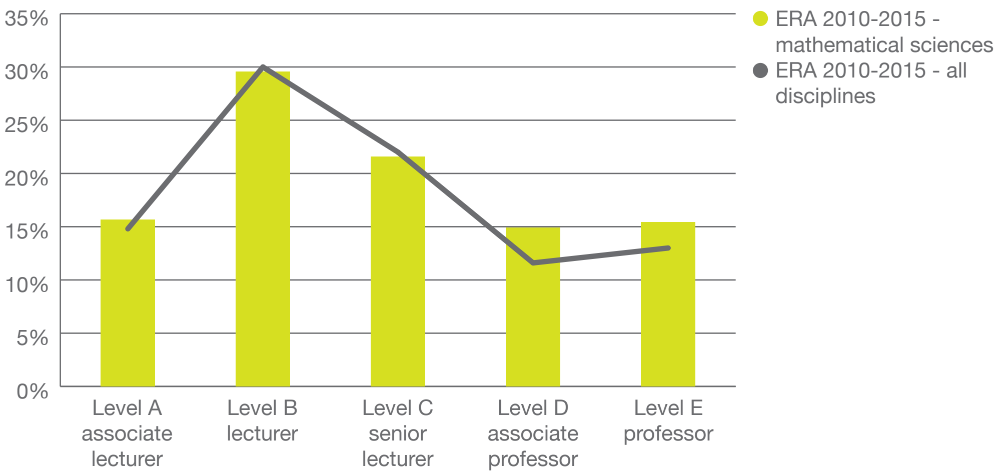
Note: See glossary for acronyms Go8, ATN, IRU and RUN. Numbers in brackets indicate the number of respondents out of the total number of members of the university alignment (e.g. 7 out of 8 Go8 universities responded to this question in the survey).
***Source:** AMSI Survey 2015, preliminary results. Data from 26 universities.*

Figure 2.4 Staff in participating mathematical sciences departments by employment level (excluding casual staff) in 2015



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

Figure 2.5 ERA 2010–2015 - staffing profile in FTE - percentage distribution by employment level

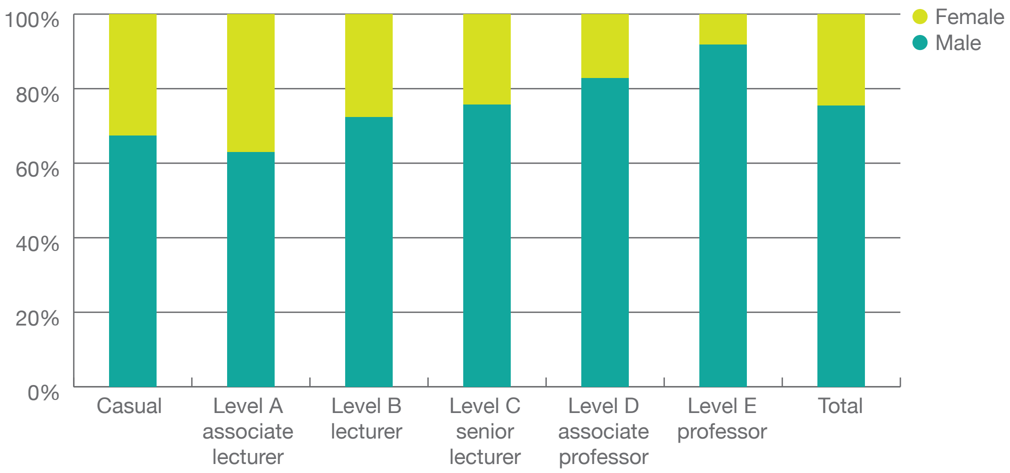


It's clear from the 2015 AMSI survey results (figure 2.6) that the academic workforce is predominantly male and the proportion of females reduces with seniority. In 2015, about 33 per cent of reported casuals were female increasing to 37 per cent at level A (29 per cent in 2014), 28 per cent at level B (down from 31 per cent in 2014), and 24 per cent at level C. This drops significantly to 17 per cent at level D and 8 per cent at level E. Overall, in 2015 only 28 per cent of the academic workforce in mathematics and statistics was female. If we leave aside casual employees the overall figure was only 23 per cent.

It can be no surprise that this percentage is lower than almost any other discipline. Figure 2.7 sets out the size and the gender balance of all fields of research disciplines in Australia:

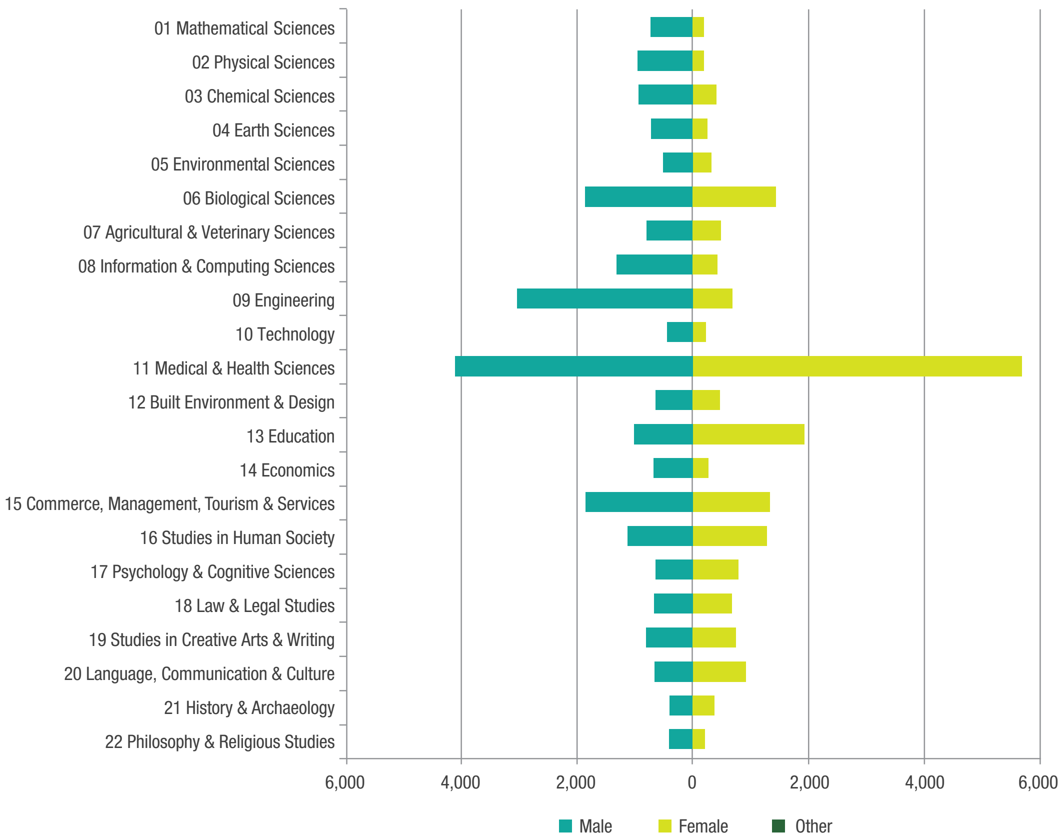
- Only the Physical Sciences have a lower proportion of female academic staff than Mathematical Sciences.
- The size of the academic mathematical workforce is very small compared to other disciplines.

Figure 2.6 Staff in participating mathematical sciences departments by gender and employment level in 2015



Source: *AMSI Survey 2015, preliminary results. Data from 26 universities.*

Figure 2.7 Number of FTE staff by gender by two-digit FoR code



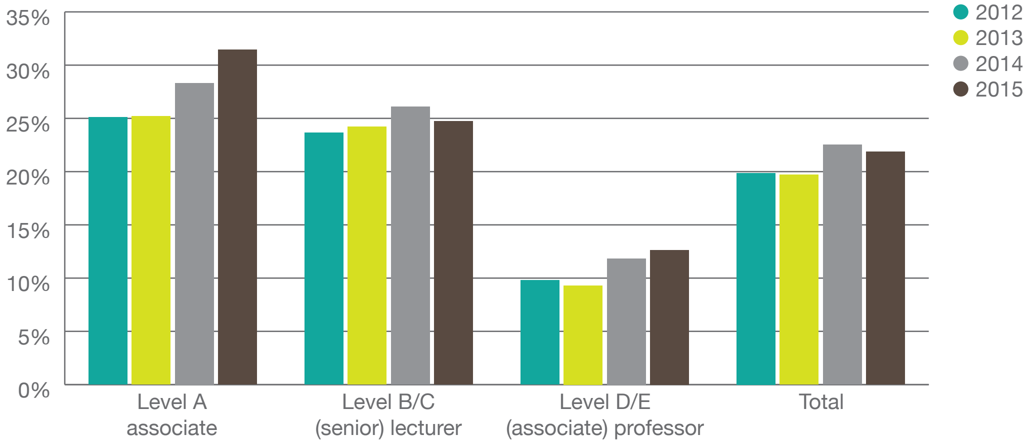
Note: *"Other FTE staff" as reported in ERA have not been included here.*

Source: *ARC, ERA 2015 National report, Section 1, page 80.*

Figures 2.6 and 2.7 only provide snapshots, but no understanding of possible differences in the career trajectory of men and women in academia such as retention and promotion pathways. Nor does it give us a clear picture of changes to gender balance over time. In the short-term, the year-to-year differences in gender balance tracked by AMSI are heavily influenced by the mix and number of respondents to each survey. We isolated the departments which have participated in all AMSI surveys to date to see if any change in gender balance occurred at these 14 universities—see figure 2.8 on the next page.

Among these universities, level A positions were the only area where the **proportion** of females substantially increased. Unfortunately, this is not attributable to an increase in female staff numbers, but rather a drop in the **number** of level A positions filled by male staff members. Academic participation in levels D and E is nudging upwards, but only very slightly. Further insight into hiring patterns at level A and B (which are entry levels for academic careers) and promotion to higher levels would be very useful to understand what is happening.

Figure 2.8 Proportion of female staff by gender and employment level 2012–2015 (among respondents to all surveys)



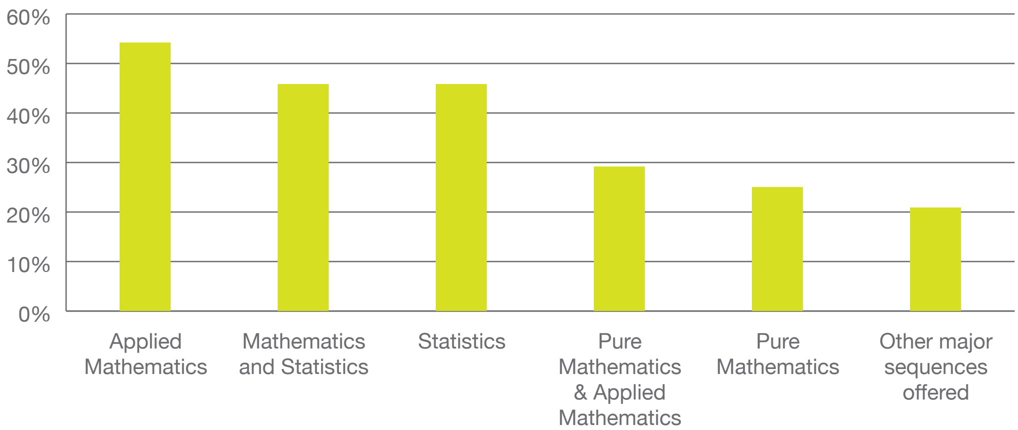
Source: *AMSI University Survey 2012–2014 and preliminary results 2015. Data from 14 universities.*

2.2 MATHEMATICS AND STATISTICS TEACHING AT UNIVERSITIES

In 2015, applied mathematics remained the most prevalent major offered to mathematics and statistics students, followed by combined major streams in mathematics and statistics, and majors in statistics. Of the 24 departments who have so far provided data for this question in the 2015 survey, all reported offering at least one major in the mathematical sciences. Most participating departments offer one to three majors. In addition, under “other” majors, maths departments reported decision science, actuarial science, quantitative risk, and oceanography. One department offers a general major in mathematics structured for those training to become school teachers.

Data from earlier annual surveys indicate that some departments within smaller universities, many of whom have not responded to the 2015 survey, are not in a position to offer a major. A web search revealed seven, and possibly nine, universities do not have a major in the mathematical sciences.

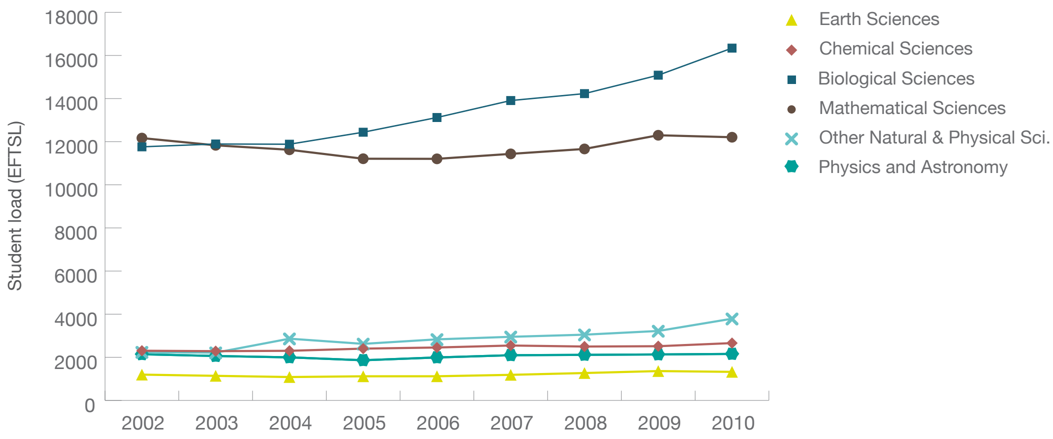
Figure 2.9 Majors offered in the mathematical and statistical sciences in 2015



Source: *AMSI University Survey 2015, preliminary results. Data from 24 universities.*

Mathematics is an essential element of many disciplines and mathematics departments supply service teaching to many other departments and faculties. According to figure 2.10 on the next page, 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 and Medical Sciences which receives most of the biological service teaching). Mathematical science departments supply teaching to a variety of disciplines such as information technology (IT), engineering, agriculture and environment, society and culture, and health and management.

Figure 2.10 Undergraduate science service teaching; narrow disciplines

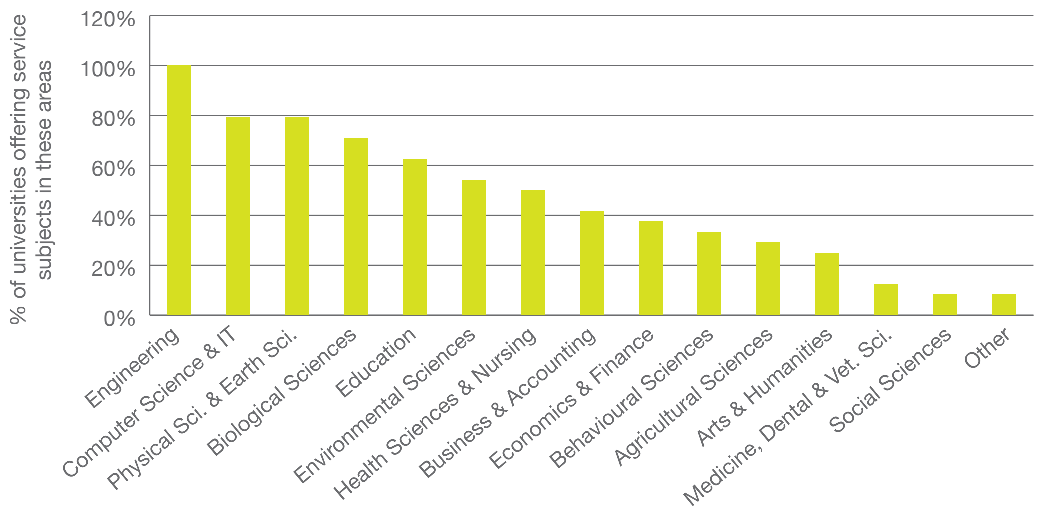


Source: *Office of the Chief Scientist, Health of Australian Science, May 2012, page 84.*

All university departments who responded to this question in the AMSI survey supplied service teaching to other disciplines in 2015—see figure 2.11. Most departments supplied teaching to at least three or four other areas, some even offer teaching to up to twelve. On average mathematics departments serviced seven other subject areas in 2015. Engineering, computer science, IT and biological, physical and earth sciences are the most serviced disciplines. The "other" areas mentioned where mathematics departments delivered teaching were to general first year Science, and to Design.

According to the data in table 2.12, casual staff perform the majority of tutorial teaching. In 2015, around 73 per cent of tutorials were taught by casual staff. The proportion of lecture teaching by casuals is much lower, 9 per cent on average for all universities.

Figure 2.11 Areas of service teaching in 2015 at participating universities



Source: *AMSI University Survey 2015, preliminary results. Data from 24 universities.*

Table 2.12 Teaching by academic and casual staff at participating universities in 2015

(Averages)	tutorial hours all staff	tutorial hours casual staff	% of total taught by casuals
Go8 universities (6/8)	203	160	79%
ATN & RUN universities (6/11)	91	65	72%
IRU & unaligned universities (9/20)	108	71	66%
All universities (21)	130	95	73%
(Averages)	**lecture hours all staff**	**lecture hours casual staff**	**% of total taught by casuals**
Go8 universities (6/8)	123	10	8%
ATN & RUN universities (6/11)	60	5	8%
IRU & unaligned universities (9/20)	50	5	10%
All universities (21)	129	11	9%

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 Survey 2015, preliminary results.*

2.3 STUDENT NUMBERS

Undergraduate enrolments and completions

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 2015, preliminary results.

Table 2.13 Undergraduate enrolments (in EFTSL*) at participating universities in 2015

	1st year	2nd year	3rd year	Total
Go8 universities (6/8)	5354	1645	601	7600
ATN universities (3/5)	447	241	197	885
RUN universities (4/6)	757	277	63	1096
IRU universities (4/7)	668	98	60	825
Unaligned universities (4/14)	1730	271	72	2074
Total all universities (21)	8956	2532	993	12480

In 2015, figures provided by 21 universities showed first year mathematics subjects accounted for about 8,956 EFTSL. For second year this dropped to around 2,532 EFTSL and to approximately 993 in third year subjects. Table 2.14 below sets out the average undergraduate enrolment numbers in the past five years. Between 2011 and 2015, average first year enrolments increased across all universities. Second year enrolments increased between 2011 and 2013 but dropped off in 2015. Third year enrolments have been fairly constant. However, since the mix of universities providing undergraduate enrolment data is quite different from year to year both the total and average numbers are not very comparable. Any conclusions about trends in undergraduate enrolments should be treated very cautiously. However, the jump in first and second year undergraduate students at Go8 universities was accompanied by a higher reported undergraduate student load—see table 2.15.

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 2012, 2013, 2014 and 2015, preliminary results.

Table 2.14 Average number of undergraduate enrolments at participating universities 2011–2015 (in EFTSL)

		2011	2012	2013	2014	2015
1st year	Average Go8 universities	573	562	594	754	892
	Average ATN/RUN/IRU/unaligned universities	192	176	225	178	240
	Average all universities	308	303	361	370	426
2nd year	Average Go8 universities	246	265	261	254	274
	Average ATN/RUN/IRU/unaligned universities	71	90	78	77	59
	Average all universities	126	147	146	133	121
3rd year	Average Go8 universities	83	89	90	99	100
	Average ATN/RUN/IRU/unaligned universities	29	31	27	19	26
	Average all universities	48	51	50	45	47

Note: Due to the lower number of respondents to this question, the data from ATN/RUN/IRU and unaligned universities have been combined. In the 2015 University Survey 16 universities provided data to this question.
Source: AMSI Survey 2012, 2013, 2014 and 2015, preliminary results.

Table 2.15 Staff-student ratios in EFTSL per EFT teaching staff (excluding casuals) 2011–2015 at participating universities

	2011	2012	2013	2014	2015
Average Go8 universities	25	27	27	29	32
Average ATN/RUN/IRU unaligned universities	27	27	24	26	26
Average all universities	27	27	25	27	28

A significant number of universities reported difficulties in obtaining reliable undergraduate enrolment numbers (other than in EFTSL). At the 19 universities who were able to report undergraduate student numbers, an estimated 45,000 students enrolled in one or more undergraduate mathematics 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 66:34. The proportion of international students in 2015 was 24 per cent.

Figure 2.16 Undergraduate student profile by gender and domestic/international status in 2015 at participating universities

Source: AMSI Survey 2015, preliminary results. Data from 19 universities.

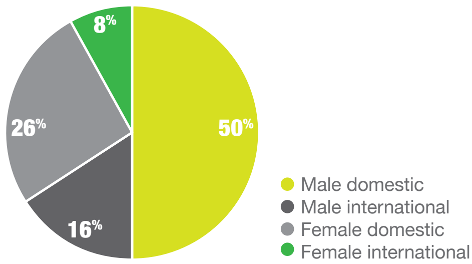
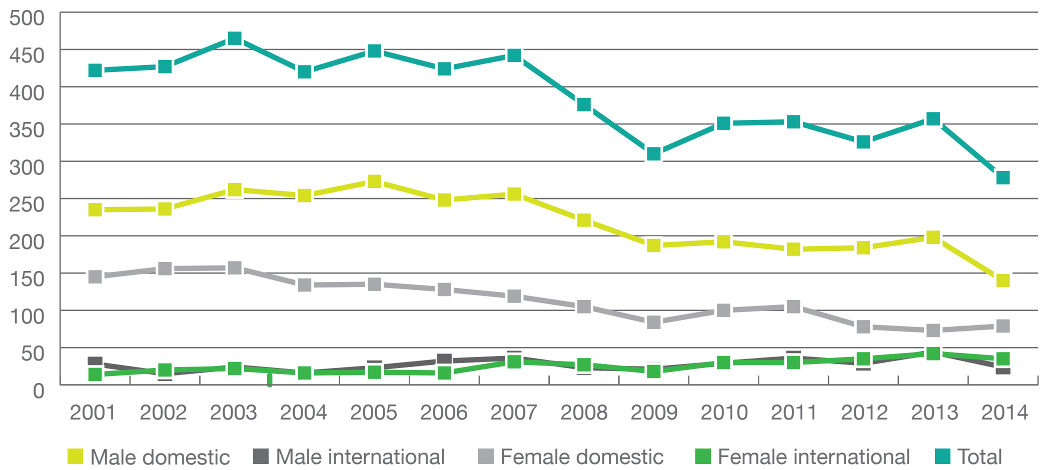


Figure 2.17 Bachelor (pass) completions in the mathematical sciences 2001–2014 by gender and domestic/international status

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



Due to the important part played by service teaching in the mathematical sciences, it is clear that a large number of Australian students complete at least some mathematics and statistics subjects during their studies. However, the number of students who complete a Bachelor degree in mathematical sciences is substantially lower. According to data from the Department of Education and Training the number of domestic graduates in mathematical sciences has declined—see figure 2.17. A very important limitation of these data is that they do not capture students completing Bachelors of Science (or similar) with a major in the mathematical sciences, so these figures do not deliver a complete picture. Some of the universities with the largest numbers of Bachelor graduates are not represented in figure 2.17. However, if the decline in the number of Bachelor graduates in the mathematical sciences is mirrored amongst Bachelor of Science and similar degrees, it identifies a worrying trend. In the first years of this century the number of Bachelor degrees 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.

Honours and Higher Degree enrolments and completions

Table 2.18 Reported Honours and Higher Degree enrolments at participating universities in 2015 (in EFTSL)

	Honours	Masters by Coursework	Masters by research	PhD
Go8 universities (6/8)	89	169	18	296
ATN universities (3/5)	29	87	9	94
RUN universities (4/6)	4	6	3	23
IRU universities (4/7)	13	13	1	34
Unaligned universities (4/14)	2	43	9	38
Total all universities (21)	137	317	40	483

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 2015, preliminary results.

The reported number of enrolments in postgraduate degrees remained fairly static between 2014 and 2015. Honours and PhD enrolments were higher than last year, however, Masters by Research enrolments continued their long-term decline. 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.

GENDER
ACROSS THE PIPELINE

ENGAGEMENT OF WOMEN AND GIRLS IN MATHEMATICS REMAINS A KEY POLICY priority across all AMSI programs, as we seek to secure Australia's mathematical capability and capacity as a foundation for future prosperity. A key challenge across all STEM disciplines, this divide appears to be deepening across the mathematical pipeline.

Evidenced across the overall adult population, the most significant gender divides in numeracy fall between 15 years and 74 years. 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.

The following snapshot highlights the current status of female mathematics participation from the classroom and higher education to research engagement and the mathematical workforce. Linkages to fuller reporting in key sections of the Discipline Profile are provided.

CLASSROOM BEGINNINGS

TIMSS: GAP WIDENING

Trends in International Mathematics and Science (TIMSS) show, while initially narrow, the mathematical gender divide begins from early primary. 2003 data for Year 4 shows girls tracking approximately 3 points below their male counterparts, figures for 2007 and 2012 show this gap widening to 6 points. According to TIMSS data this gap is significantly wider in high-school with the Year eight gap at 12 points in 2003, 16 points in 2007 and 9 points in 2011. **See page 4**

NAPLAN: A DIFFERENT TRUTH

Interestingly, NAPLAN offers a different perspective that doesn't support the wider high-school gender divide narrative provided by TIMSS. 2015 NAPLAN data showed little difference in Year 9 numeracy achievement with 95.9 per cent of girls at or above NMS against 95.4 per cent of boys.

The gap widens, however in the higher bands. Representation at band 9 was just 14.4 per cent for girls and 16 per cent for boys, with representation in band 10 falling to 10.5 per cent for boys and just 7.2 per cent for girls. Further analysis of NAPLAN data shows girls are behind in the highest available band in every year level—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 6**

MISSING THE MARK FOR A STEM FUTURE

The recent Year 12 high-level mathematic participation report card is particularly concerning as we seek to build a STEM workforce for the future. In 2014 only 6.8 per cent of female Year 12 students took advanced maths compared with 13.4 per cent of male students. The number of Year 12 students studying intermediate mathematics as their highest level of maths also remains low at only 20.6 per cent for males and 18.2 per cent for females. **See page 13**

WOMEN
UNREALISED POTENTIAL

HIGHER EDUCATION

GENDER DIVIDE DEEPENS AT UNIVERSITY

In 2015 female students accounted for only 34 per cent of undergraduate mathematics students, 26 per cent domestic and 8 per cent international. **See figure 2.16**

Annual bachelor (pass) in mathematical science completions for female domestic students have remained below 100 since 2012. **See figure 2.17**

This century has seen a decline in the number of females completing bachelor (honours) with the proportion of female compeltions dropping below 25 per cent. **See figure 2.20**

The proportion of domestic female students enrolled in honours in 2015 was 20 per cent, with international females accounting for 4 per cent of all enrolments. **See figure 2.21**

POSTGRADUATES

AN INTERNATIONAL BOOST

We have seen some growth in the number of PhDs completed by females over the past 15 years, with the proportion of females completing a PhD increasing from nearly 25 per cent at the start of this century to almost 35 per cent. However, this is largely due to a rising influx of international students—domestic female participation in PhD degrees has remained stagnant. **See figure 2.23 and 2.24**

Overall between 2000 and 2012 we have seen a rise in the proportion of females awarded university mathematics graduate and postgraduate degrees in Australia from 37 per cent to 39 per cent. Despite this, Australia continues 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) 2000 and 7 points (OECD) and 11 points (EU) 2012. **See table 2.18**

WORKFORCE

RECORDS BEST LEFT UNBROKEN

The academic workforce in mathematics remains predominantly male, with only 23 per cent of reported staff (excluding casuals) female. This is one of the lowest percentages of females in any academic discipline. **See figures 2.6, 2.7 and 2.8**

A WORKFORCE DEFICIT

Women account for about 40 per cent of Australia's mathematically qualified workforce. A low influx of younger females into the mathematical workforce 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**

SOME SECTORS MORE EQUAL THAN OTHERS

Gender distribution differs between employment divisions and occupations. Female mathematical scientists outnumber males within the Healthcare and Social Assistance sectors. The percentage of females in the Education and Training, and Finance and Insurance industries is around 40 percent, 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 amongst university lecturers and tutors is closer to 25 per cent. **See figures 3.11 and 3.12**

PART-TIME VERSUS FULL-TIME

Employment structure also differs with approximately 36 per cent of female mathematical bachelor degree holders working part time compared to 19 per cent of males. At the doctorate level, 24 per cent of female PhDs work part time against 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 male bachelor degree holders versus 15 per cent of female bachelor degree holders earn in the highest income bracket. Of the doctorate degree holders 49 per cent of males and 33 per cent of females are represented in the highest income brackets. **See figure 3.13**

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 Member Survey 2012–2014 and 2015, preliminary results.*

Table 2.19 Average Honours and Higher degree enrolments per university 2011–2015

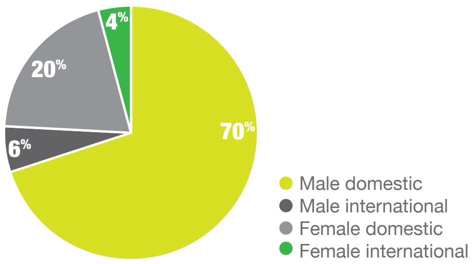
		2011	2012	2013	2014	2015
Honours	Average Go8 universities	15	14	13	15	13
	Average ATN universities	5	5	5	3	10
	Average RUN universities	<1	<1	5	1	1
	Average IRU universities	5	6	3	3	3
	Average unaligned universities	2	3	3	2	<1
	Average all universities	7	7	6	6	7
Masters by Coursework	Average Go8 universities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

For many years Griffith University's Peter Johnston at has assembled longitudinal data on Honours degree completions in Australia on behalf of the Australian Mathematical Society (AustMS). 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. The 2015 enrolment data shows a male/female ratio of 76:24—see figure 2.21.

Figure 2.20 Bachelor (Honours) completions reported by mathematical sciences departments 2001–2014 by gender—Johnston's data

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

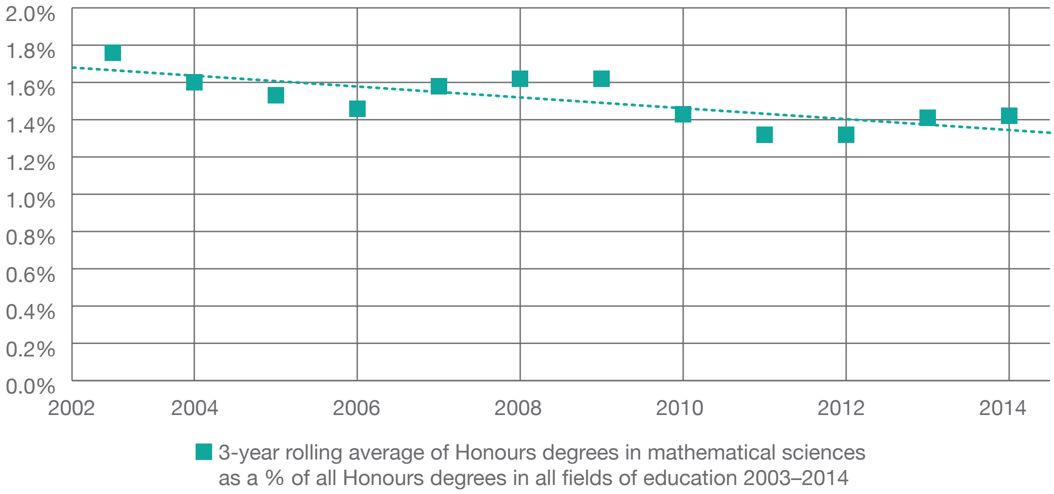
Figure 2.21 Honours student profile by gender and domestic/international status at participating universities in 2015



Source: AMSI Survey 2015, preliminary results. Data from 19 universities.

It's important to note that, even though the total number of Honours completions has risen slowly, it hasn't kept pace with the overall increase in Honours completions in other fields—see figure 2.22. The number of Bachelor of Honours degree completions in Australia has risen steadily in this century, however, the number of Honours completions in mathematics and statistics hasn't kept pace with this trend.

Figure 2.22 Bachelor (Honours) degrees in mathematical sciences as a proportion of Honours degrees in all fields of education 2003–2014

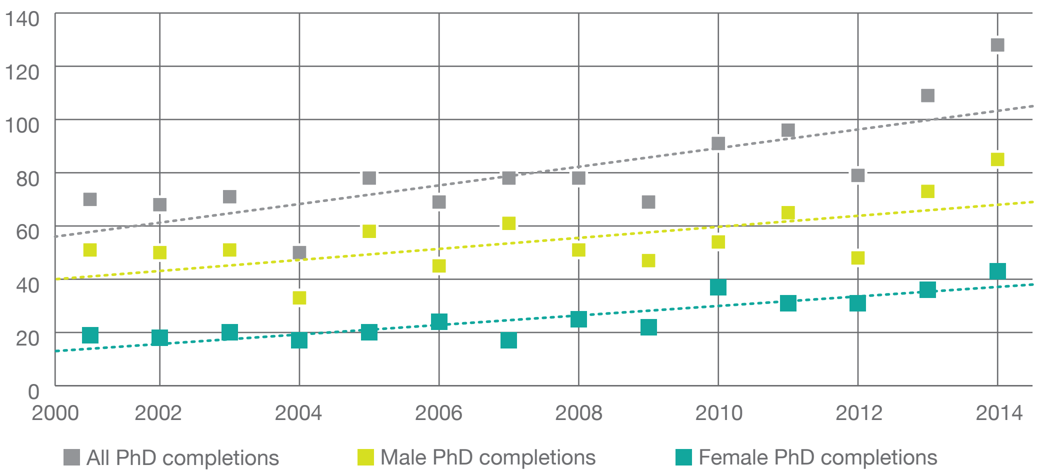


Source: Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI; Award course completions 2001–2014, Department of Education and Training document library.

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 2.23. 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. In the first decade of this century 29 per cent of PhD graduates were female. From 2010–2012 the average female proportion rose to 36 per cent. However, as is shown in figure 2.24 on the next page this was due in large part to the contribution of international female students.

According to data reported to AMSI in its annual survey (see table 2.25), PhD commencements have remained stable over the past five years. The number of completions fell in 2012, before increasing again in 2013 and 2014. 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 2.26 on the next page.

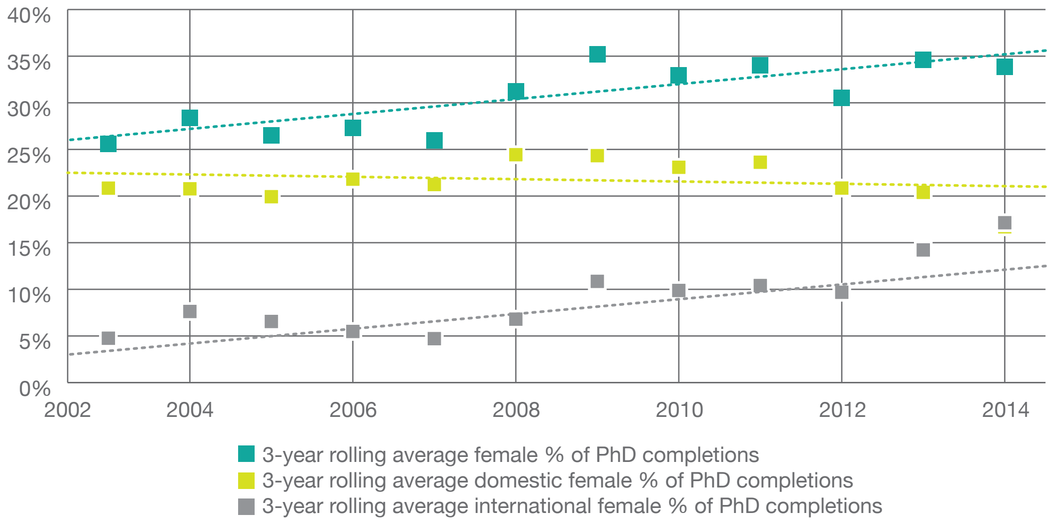
Figure 2.23 PhD completions in the period 2001–2014



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

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

Figure 2.24 Female proportion of PhD degree completions in the mathematical sciences by domestic/international status 2003–2014



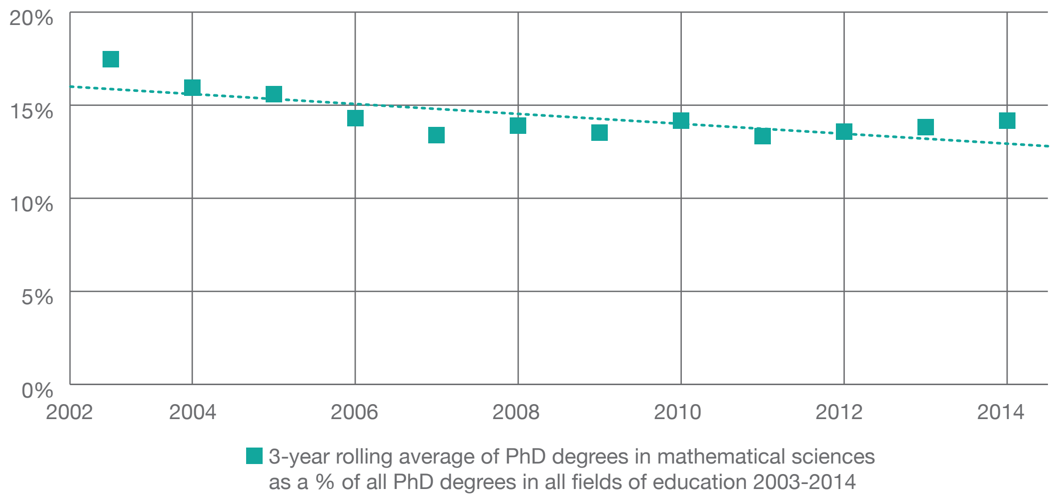
** Partly based on projected figures provided by departments for the current year. Final commencement & completion figures will replace projected figures if provided.*
*** based on projections for 2015.*
Source: *AMSI Member Survey 2012, 2013, 2014 and 2015 preliminary results.*

Table 2.25 PhD commencements and completions 2011–2015 (all participating universities)

	2011	2012	2013*	2014*	2015**
Commencements	153	163	174	160	162
Completions	105	88	110	118	102

Source: *Peter Johnston, Higher Degrees and Honours Bachelor Degrees in mathematics and statistics, data collection provided to AMSI; Award course completions 2001–2014, Department of Education and Training document library.*

Figure 2.26 PhD degrees in mathematical sciences as a proportion of PhD degrees in all fields of education 2003–2014



International comparison of enrolment and completion figures

The entry rate into mathematical sciences degrees remains low in Australia. 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 2.27. 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 taught at TAFE colleges. In Australia, mathematical sciences are taught as theory-based tertiary type A undergraduate degrees at universities.

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 2.28 shows the percentage of qualifications awarded to women.

Table 2.27 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).*

Table 2.28 Percentage of tertiary qualifications awarded to women in tertiary-type A and advanced research programmes, by field of education (2000, 2012)

		2012							2000						
OECD countries	Note	All fields	Engineering, manufacturing & construction	Sciences	Life sciences	Physical sciences	Mathematics & statistics	Computing	All fields	Engineering, manufacturing & construction	Sciences	Life sciences	Physical sciences	Mathematics & statistics	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**

The flow-on impact runs to an additional 11.3% or $147 billion dollars annually (Source: Office of the Chief Scientist/ Australian Academy of Science)

(page 41)

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

(page 33)

The ageing of the mathematical workforce is **worse than in the other STEM workforce sectors**

(page 37)

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.

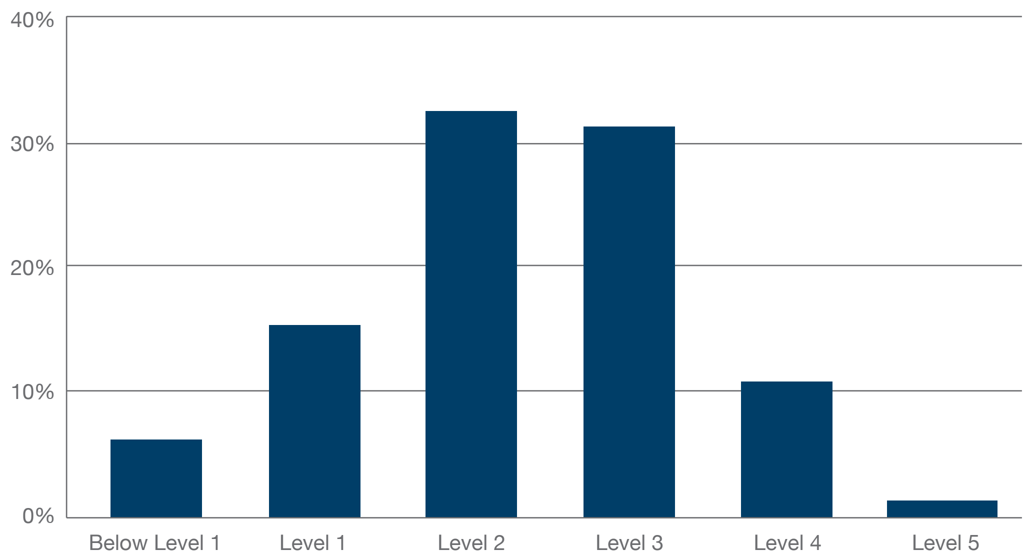
3.1 NUMERACY SKILLS IN THE ADULT POPULATION

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.

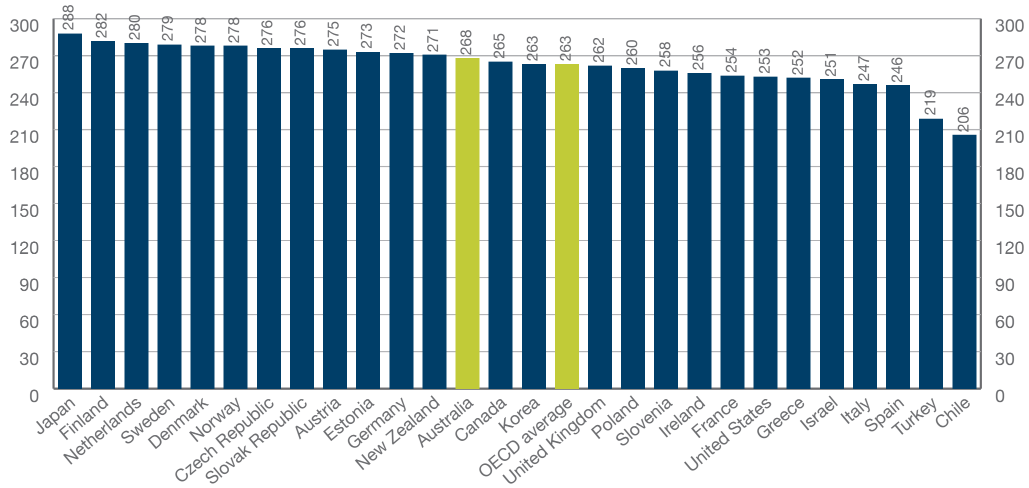
Figure 3.1 Proportion of Australian Adult Population at Each Numeracy Level 2011–12



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

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

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

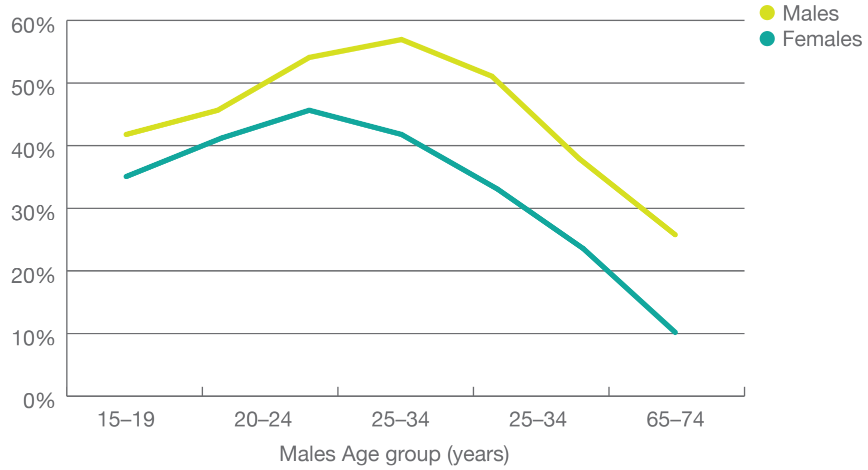


The data shown in figure 3.3 suggests that numeracy competency is closely related to age and gender. Numeracy skills for both genders tend to drop after peaking between the ages of 35 and 44. And fall to their lowest for people of retirement age (65 years and over).

The data also illustrates the consequences of the under-representation of girls and young women in school and university level mathematical education. There is a significant, and constant, gap in the mathematical skills between Australian men and women.

Figure 3.3 Proportion of Australian Adult Population at Numeracy level 3 or Above, by Sex and Age group 2011–2012

Source: ABS, Programme for the International Assessment of Adult Competencies, Australia, 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**

		Bachelor			Masters by Coursework			Graduate Certificate/ Diploma			Masters by Research/PhD		
		M	F	Total	M	F	Total	M	F	Total	M	F	Total
What are the characteristics of graduates in mathematics?													
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?													
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.*

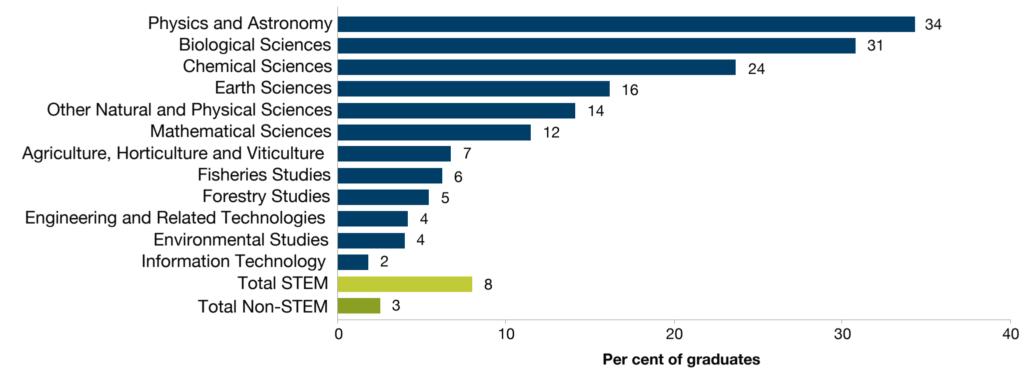
3.3 MATHEMATICIANS AND STATISTICIANS IN THE WORKFORCE

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.*

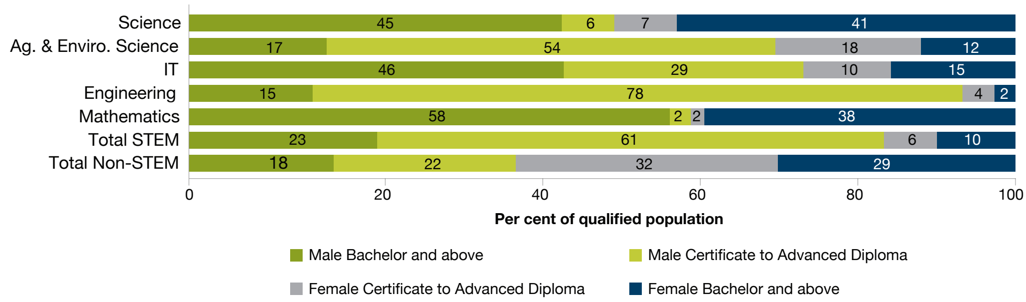


In understanding the gender distribution of those with a mathematical sciences degree we already know from chapter two that the proportion of females is relatively low. We can see in figure 3.6 below that STEM disciplines in general attract fewer women than men. The figure below includes everyone in 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

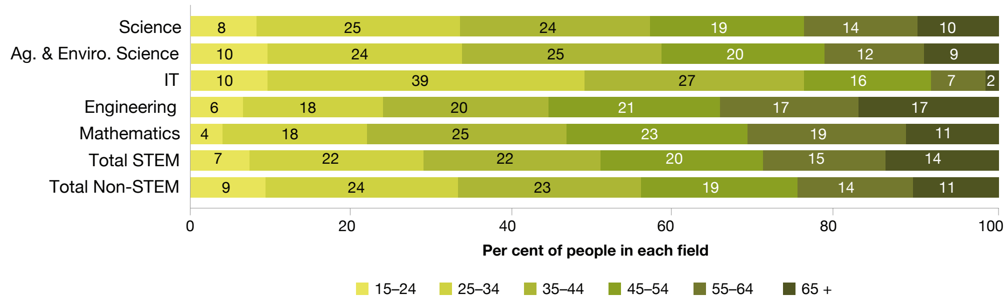
Source: *Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 13.*



The age distribution data as represented in figure 3.7 indicate 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 four 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 35—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.

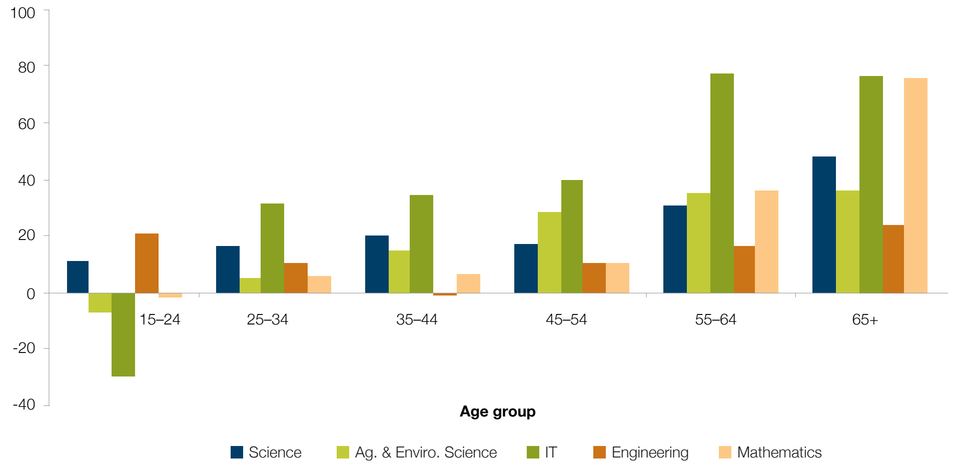
Figure 3.7 Age profile by proportion of people in each age group, by field of highest post-secondary qualification



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



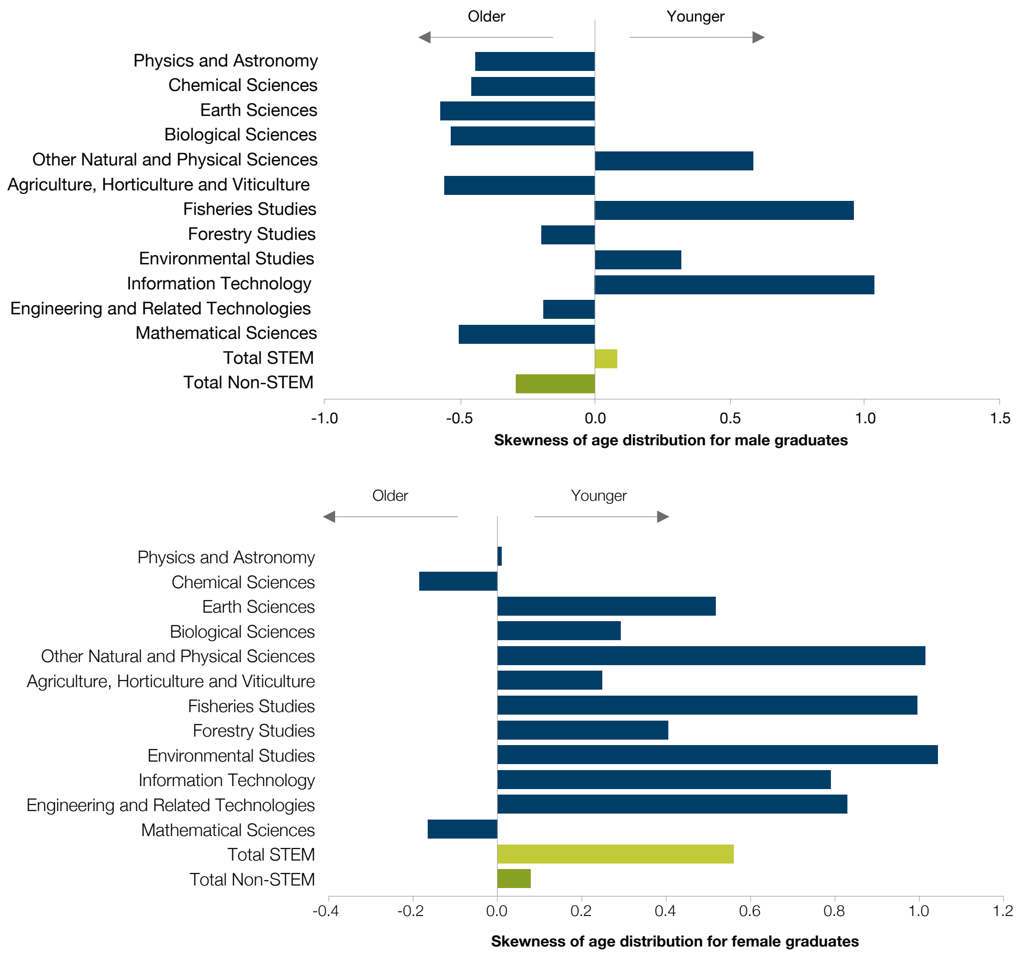
Age group	Science	Ag. & Enviro. Science	IT	Engineering	Mathematics	Total STEM	Total Non-STEM
15–24	1,983	-1,381	-11,267	16,372	-23	5,684	81,628
25–34	8,692	2,327	25,987	24,773	276	62,055	293,033
35–44	9,735	6,328	19,318	-338	421	35,464	251,032
45–54	6,828	8,706	12,392	30,654	582	59,162	158,966
55–64	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

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

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.

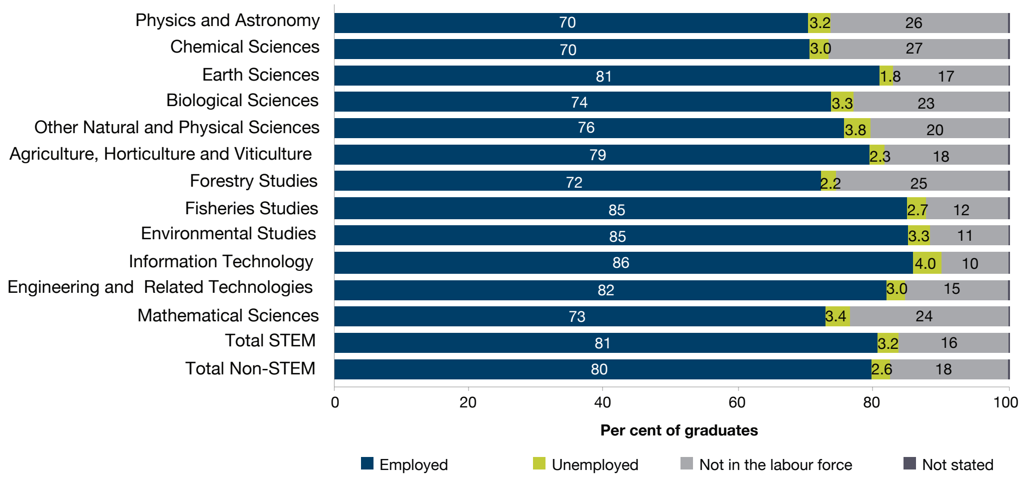
Source: Office of the Chief Scientist, Australia's STEM Workforce, March 2016, page 42.

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.

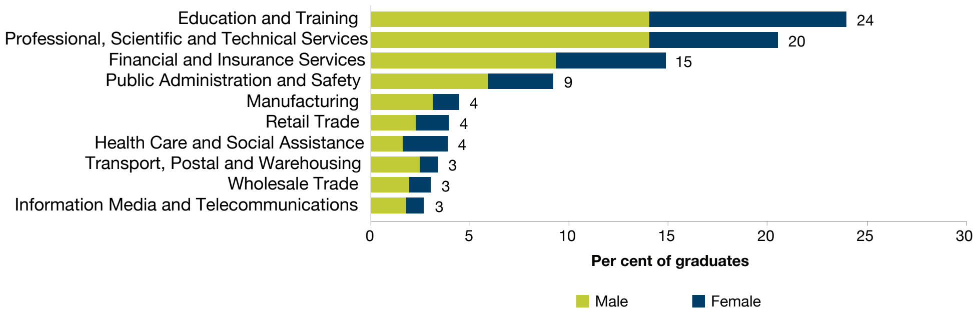
Figure 3.10 Employment status of STEM graduates, by field



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.

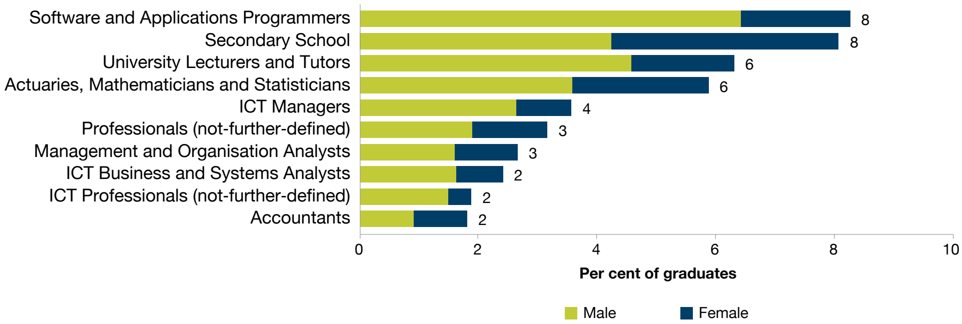
Figure 3.11 Top ten industry divisions of employment for Mathematical Sciences graduates with qualifications at bachelor level and above, by gender



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 ten 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.

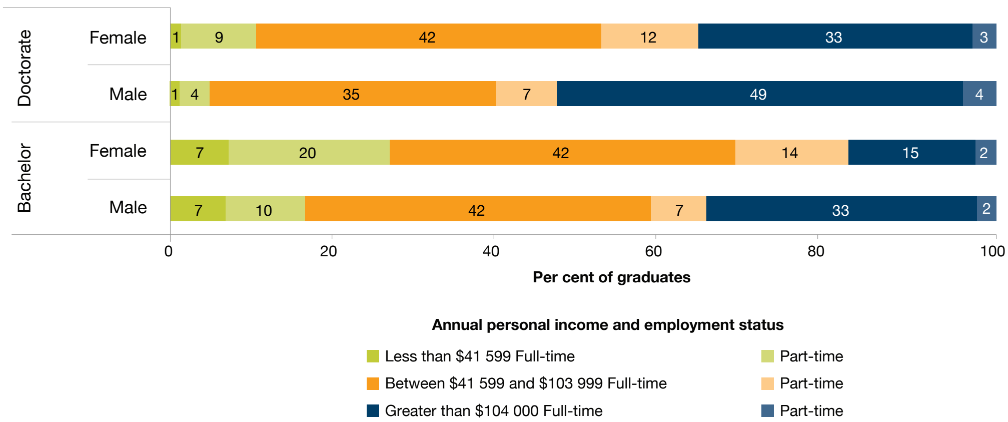
Figure 3.12 Top ten unit group level occupations for Mathematical Sciences graduates with qualifications at bachelor level and above, by gender



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 diversity 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.

The mathematical sciences have **a higher sustained success rate** for research grants from the Australian Research Council than other disciplines
(page 43)

Citation rates of Australian mathematical research in statistics and applied mathematics **outperform 15 countries** within the European Union
(pages 46 & 47)

RESEARCHING OUR WAY TO THE TOP

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. Mathematical Sciences have been relatively successful in obtaining ARC funding, most notably in the form of Discovery Projects.

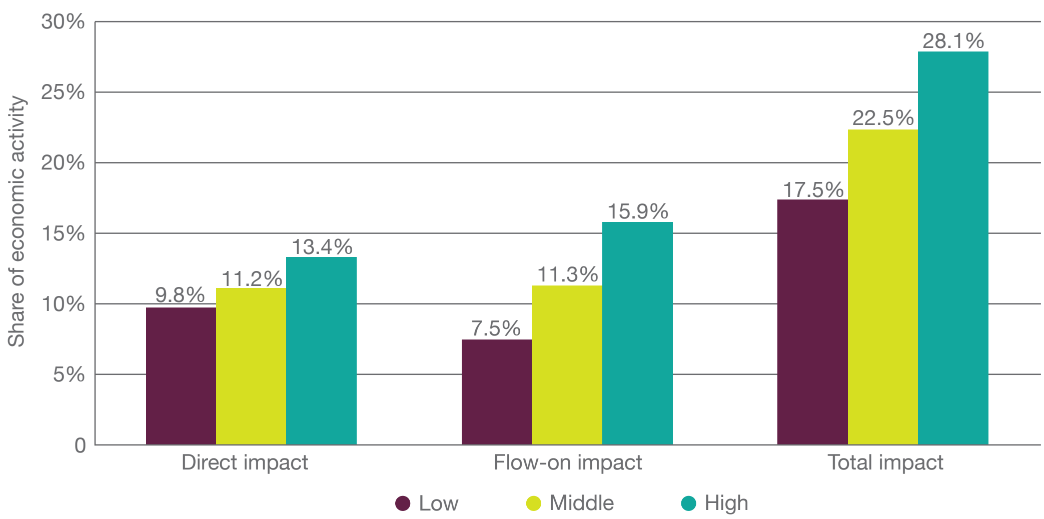
In terms of volume output, the mathematical sciences are one of Australia's a smallest disciplines, generating around 2.15 per cent of the total number of mathematical sciences publications in the world. The fields of Statistics and Applied Mathematics have obtained citation rates above 15 countries of the European Union between 2002 and 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 sciences (mathematics, statistics, physics, chemistry and earth sciences research, undertaken and applied in the past 20 years) contribute substantially to the Australian economy. A recent estimate of the direct impact (productivity improvement) of these combined sciences would be worth 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 based industries runs to an additional 11.3 per cent or $147 billion annually—see figure 4.1.

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, most often rely on mathematical sciences research. 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.

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.*

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 2		5
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, it is higher education expenditure in Research and Development (HERD) that contributes the most to mathematical science research ($167 million or 1.7 per cent of STEM funding). This is 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 spends a minuscule fraction of its R&D expenditure on the mathematical sciences—0.2 per cent or $29 million.

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

Table 4.4 Australian research expenditure, by sector

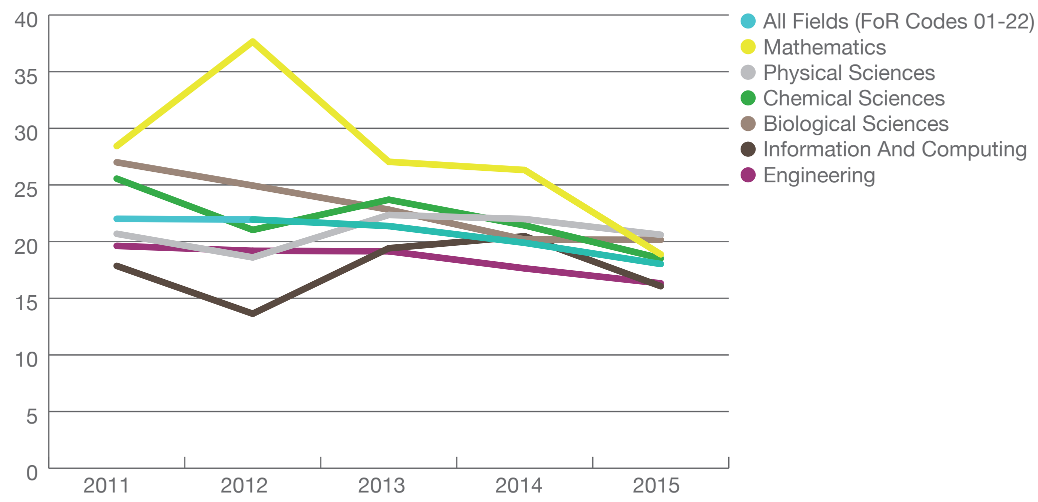
	HERD (2012)		BERD (2011–12)		GOVERD (2011–12)	
Field	$ million	%	$ million	%	$ million	%
Total	9 609	*	18 321	*	3725	*
STEM	6 978	72.6	17 833	97.3	3303	93.5
STEM excluding Medical & Health Sciences	4 156	43.2	16 891	92.2	2820	79.8
Humanities & Social Sciences	2 632	27.4	489	2.7	230	6.5
Breakdown of STEM	$ 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

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 2001–11 were on par 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 three years between 2011 and 2014.

The mathematical sciences experienced a reversal in this trend in results for the 2015 funding round with success rates falling slightly below those in physical and biological sciences. It is important to note, however, that in the 2015 round the ARC funded fewer projects in all fields of research. For example, the number of ARC Discovery Projects funded for commencement in 2015 dropped to 665 in total across all sciences, much lower than the long-term average of 860 proposals funded annually. This came as the mathematical sciences increased the number of Discovery Project proposals from 171 in 2014 to 196 in 2015. This resulted in further downward pressure on the discipline's proposal success rate. The total dollar value of all funded Discovery Projects also fell to $250 million in 2015, down from its long-term annual average of $268 million.

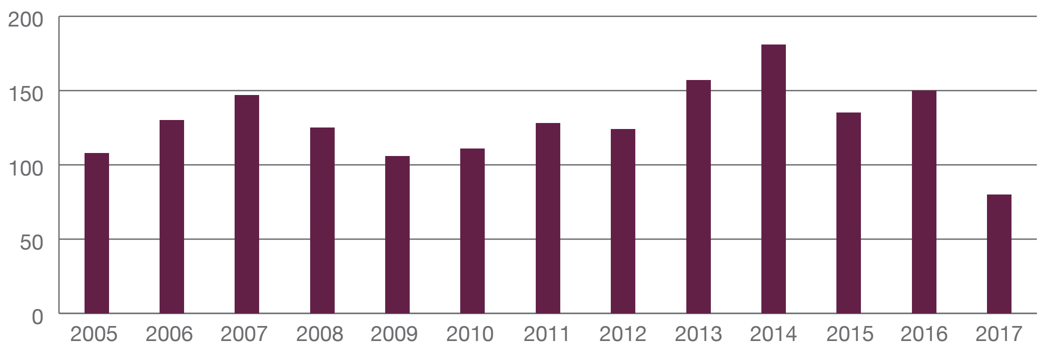
In summary, viewed comparatively with other science fields, the mathematical sciences discipline has maintained a strong ARC grant success rate.

Figure 4.5 ARC success rates of Discovery project proposals 2011–2015 (%)



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 Number of ARC grants held and hosted at participating universities 2012–2015

	Discovery Projects				Linkage Projects			
	2012	2013	2014	2015	2012	2013	2014	2015
Total Go8 universities	139	159	133	149	14	12	15	7
Total ATN universities	14	12	14	18	6	2	2	6
Total RUN universities	3	3	3	4	0	0	0	0
Total IRU universities	7	8	8	5	0	1	1	1
Total unaligned universities	16	16	14	9	4	3	5	5
Total all universities	179	198	172	185	24	18	23	19

Source: *AMSI University Survey 2013, 2014, and 2015 preliminary results.*

The actual distribution of ARC funding among universities according to the AMSI Survey is shown in table 4.7. Such funding is largely limited to Group of Eight (Go8) universities.

On average, Go8 universities estimated their ARC funding success rate at 36 per cent between 2012 and 2014. Estimates by other universities fluctuate enormously from very high success rates to no ARC funding success at all. Figure 4.8 depicts comparative ARC funded staff levels at Go8 universities (in blue) and other universities (in orange) for 2013, 2014 and 2015 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 level A and B. Interestingly, during 2013 to 2015 period the number of level A staff at Go8 universities fell. In 2014, however, the number of level B staff increased before falling again in 2015.

Figure 4.8 Number of ARC-funded staff at participating universities 2013–2015

Source: *AMSI University Survey 2013, 2014, and 2015 preliminary results.*

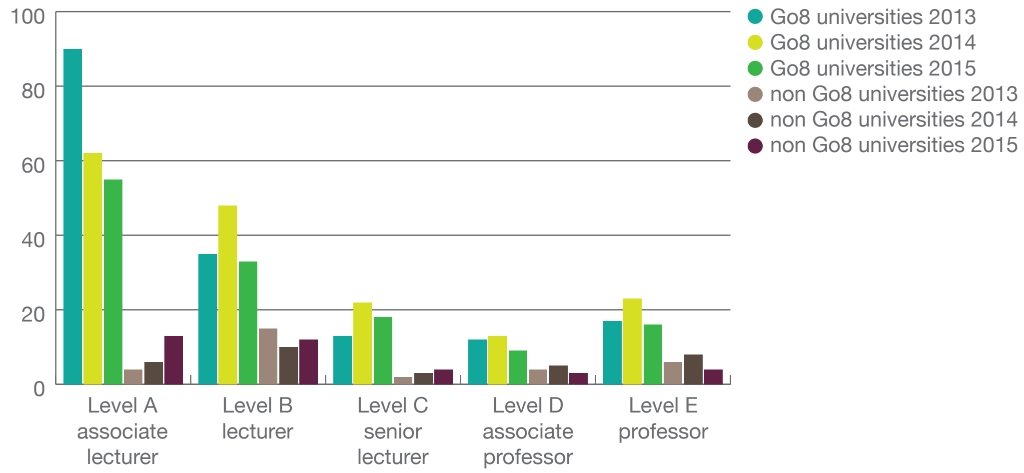


Figure 4.9 highlights ARC research grant areas given within mathematics field of research "01" and also highlights other fields of research given specific funding for their maths component. Further details about these classifications and fields of research (FoR) codes may be found in the 2012 ERA Evaluation 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 4.9 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.*

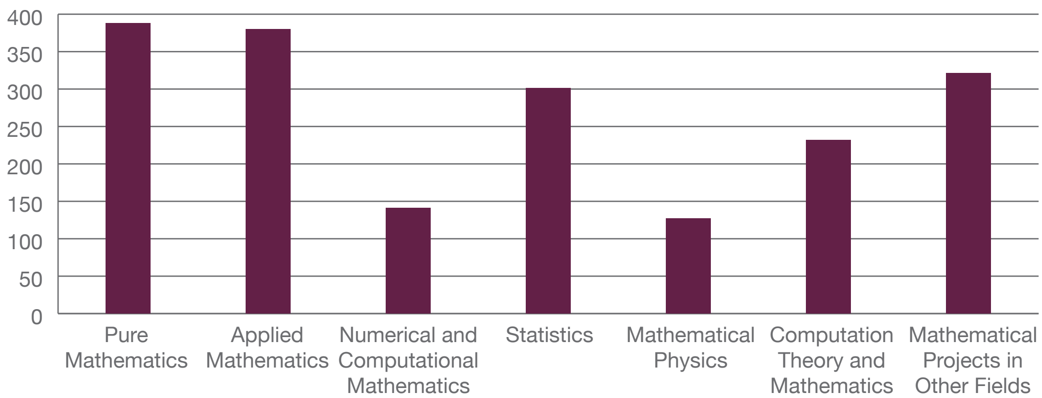
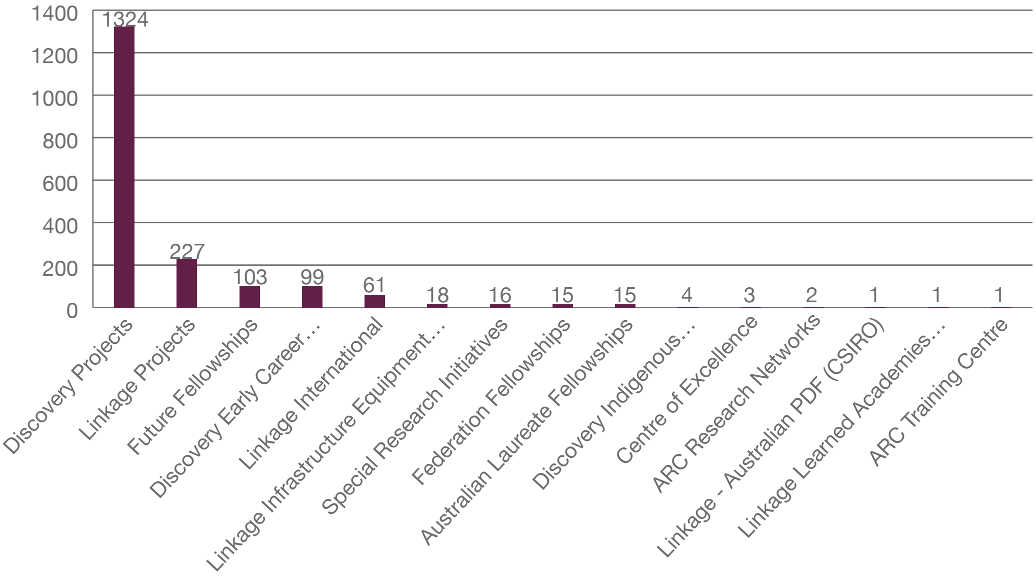


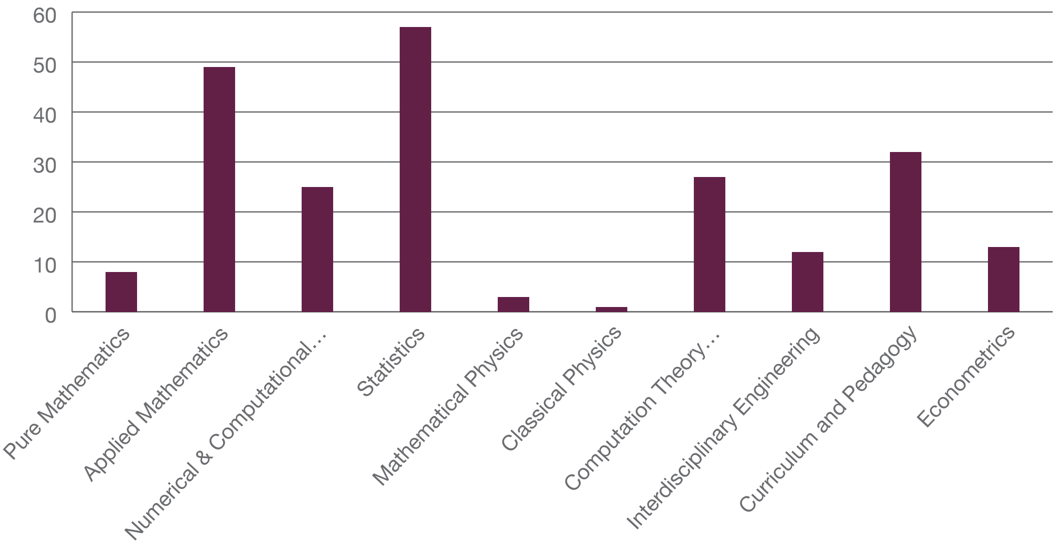
Figure 4.10 confirms the majority of ARC research funding in the mathematical sciences comes in the form of Discovery Projects. The number of Linkage Projects (joint research projects with industry and other organisations) in the mathematical sciences is surprising at first glance. However, many of these are in Mathematics and Numeracy Curriculum and Pedagogy, Engineering or Econometrics. Most others are in the fields of Applied Mathematics, Statistics or Computation Theory; very few Linkage Projects have a Pure Mathematics component—see figure 4.11.

Figure 4.10 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 4.11 ARC Linkage 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.*

4.3 RESEARCH OUTPUT AND QUALITY

In terms of volume output, the Australian mathematical sciences are a small area of research. Table 4.12 shows that in the period 2002–2012 the mathematical sciences generated around 20,000 publications—2.15 per cent of the world total.

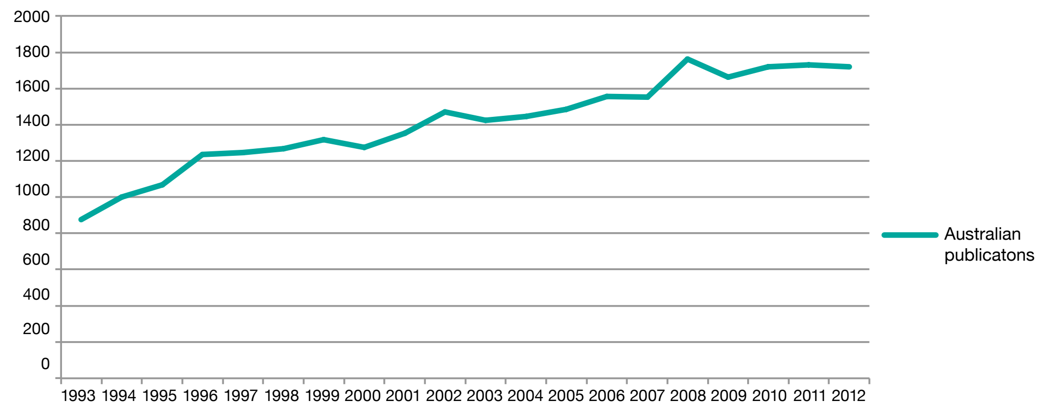
Table 4.12 STEM publications by field 2002–2012

Source: Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, table 2–2, page 9.

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

Figure 4.13 Australian mathematical publications (MathSciNet) in the period 1993–2012

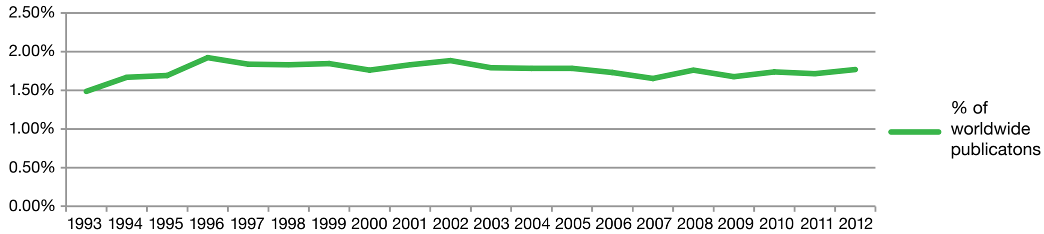
Source: MathSciNet database on publications in mathematics originating from Australian universities, 1993–2013.



MathSciNet is the worldwide database of mathematical publications. Figure 4.13 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 4.14 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 4.12, but this can be attributed to MathSciNet only covering a fraction of scientific papers in statistics and mathematical physics.

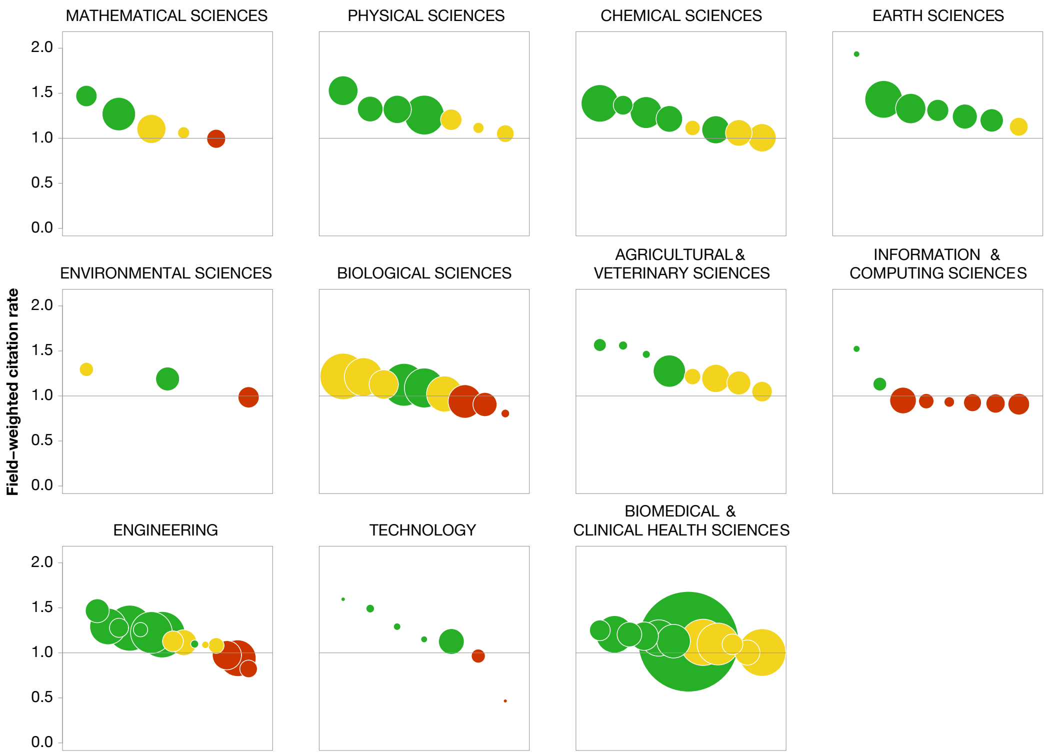
Figure 4.14 Australian publications as a percentage of worldwide mathematical publications in the period 1993–2012

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 4.15 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 4.15 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 4.16 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

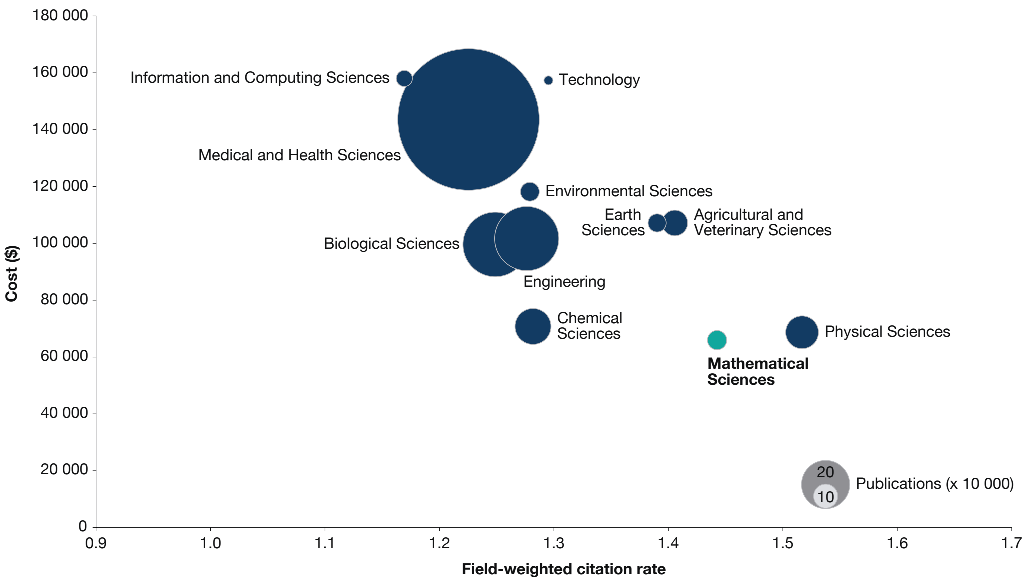
***Source:** Office of the Chief Scientist, Benchmarking Australian Science, Technology, Engineering and Mathematics, November 2014, table 3–1, page 23.*

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 4.16 defines the 3.1 per cent as the share of the top 1 per cent of global STEM publications by citation rate.

Figure 4.17 offsets generation costs of Australian research publications against their citation rates. Despite modest funding, figures shown attest to the quality and output of mathematical research, with cost per mathematical publication remaining low and citation rates relatively high.

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 4.17 Cost per publication and citation rate, by field



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 UoE's) 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 (table 4.18) 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 UoE's 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, however, increased from 17 in 2010, to 22 in 2012 and 23 in 2015. Mathematical Physics has remained stable, Numerical and Computational Mathematics has decreased down to three (with only three of the four UoE's assessed receiving a rating), and Statistics has risen to 12 after a low of 10 in 2012
- At the four-digit level, all sub disciplines with the exception of Mathematical Physics experienced rating increases. This is especially apparent for Statistics, which has increased its rating to five—well above world standard—for all but one of the units that were evaluated
- All sub disciplines at the four-digit level attracted a rating at or above world standard (against 62 per cent of UoE's in all research disciplines), with 39 per cent of the evaluated units receiving the highest rating of five (against 32 per cent of UoE's 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 4.18 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
MCD 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**

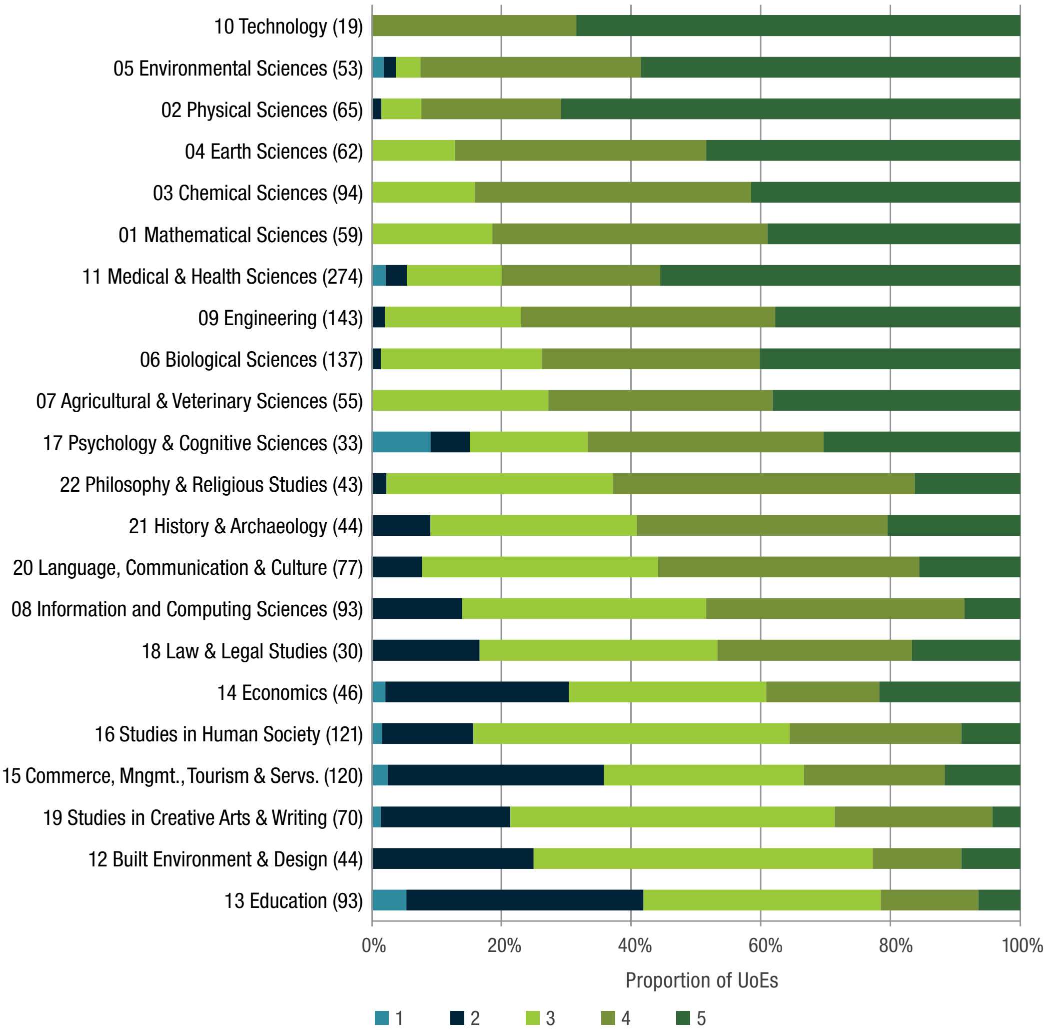
Source: *ARC/ERA, Section 4, ERA 2010 Institution Report, page 264 and ARC/ERA, Section 4, ERA 2012 Institution report, page 309.*

***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 The University of Sydney, University of New South Wales, University of Adelaide, The University of Melbourne, Monash University, The Australian National University, The University of Western Australia and The 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 The University of Newcastle
MathSciNet: Mathematical Reviews Database, maintained by the American Mathematical Society
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, The 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 2015 AMSI UNIVERSITY SURVEY

In 2015 universities (members and non-members of AMSI) were sent a comprehensive survey questionnaire with enquiries about their staffing situation, teaching, student numbers and a host of other data. To date, 28 universities have provided data in response to the survey. This *Discipline Profile* contains the preliminary results.

A final report of the AMSI Member Survey 2015 will be published on the AMSI website later in 2016.

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

The Australian National University
Bond University
Curtin University
Deakin University
Federation University
Flinders University
Griffith 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
University of New South Wales
University of New South Wales Canberra (ADFA)
The University of Newcastle
The University of Queensland
University of South Australia
University of Southern Queensland
The University of Sydney
University of Technology, Sydney
University of the Sunshine Coast
The University of Western Australia
University of Wollongong
Western Sydney University

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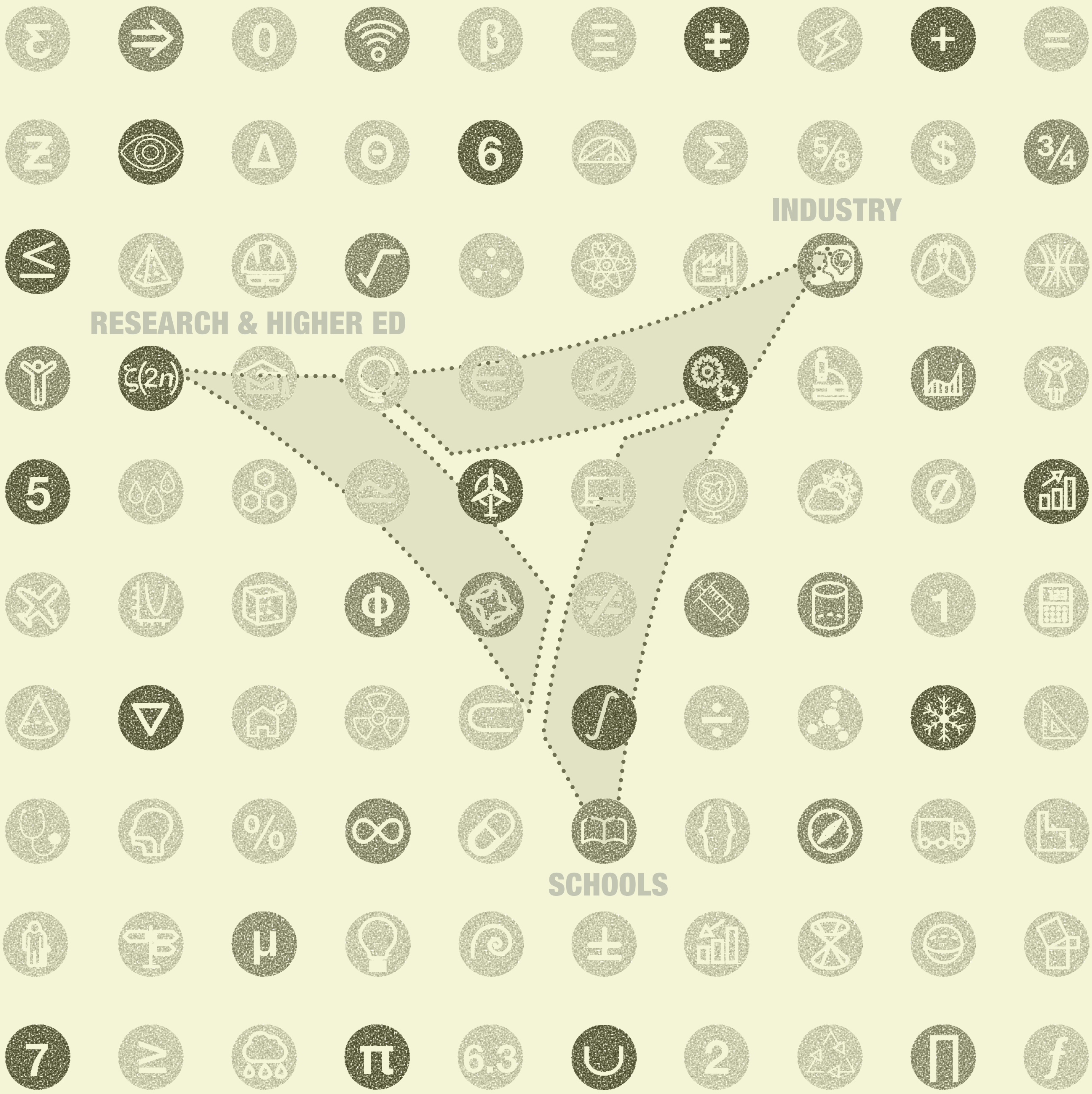

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