Discipline Profile of the Mathematical Sciences

Maths for the future:
Keep Australia competitive

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AMSI
AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Summary

This document is a profile of the mathematical sciences discipline in Australia, highlighting trends as they apply to school education, higher education, research and research training. Broadly, the data shows that the demand for mathematical and statistical skills at all these levels far outstrips supply. In particular, declining interest in advanced mathematics courses at Year 12 poses an immense challenge to securing Australia's future skills base.

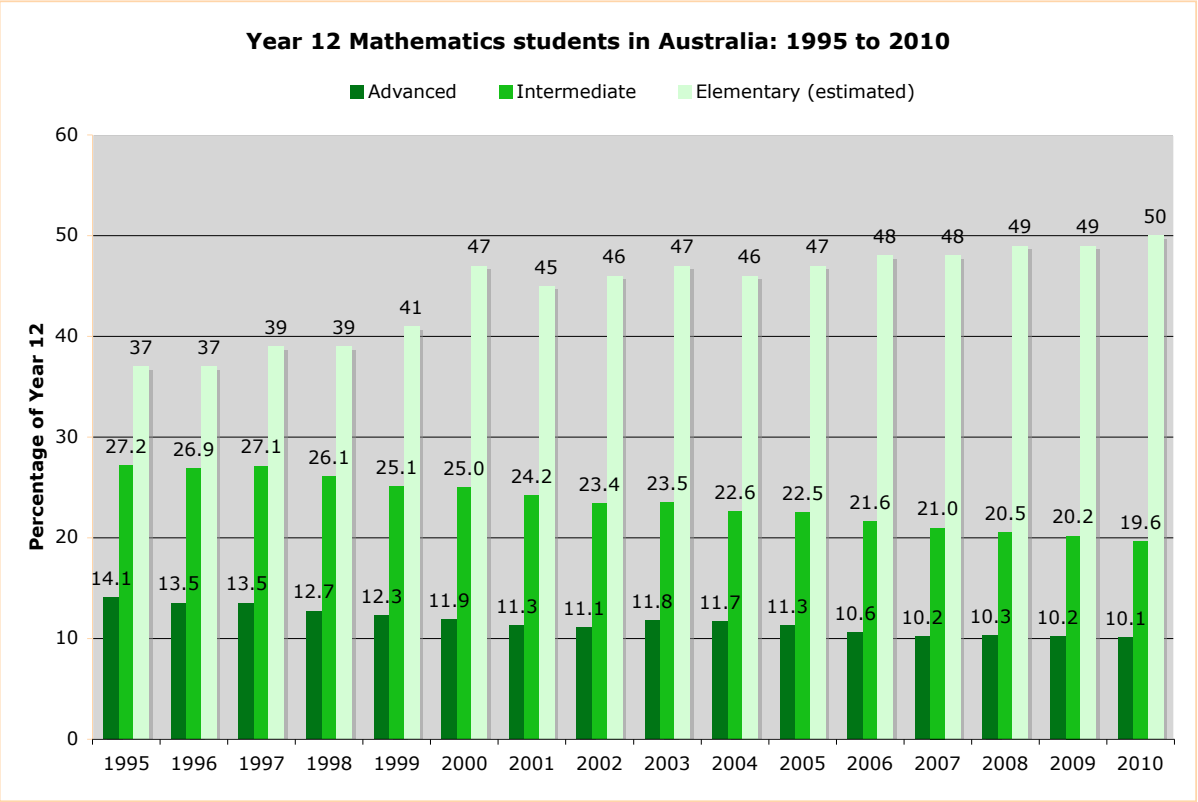
Note: this document does not currently cover the research enterprise of Australia's government agencies such as ABS, BoM, CSIRO and DSTO, or the private sector in areas such as finance and mining. Research training is predominantly the domain of universities with some co-supervision and postdoctoral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

School Education

Australia is facing a shortage of qualified mathematics teachers. A significant number of secondary school students do not have access to high quality mathematical expertise at a time where they are making decisions about tertiary level study. Declining enrolments in intermediate and advanced mathematics subjects at year 12 are of particular concern to the overall health of the discipline.

Enrolments at Year 12

The proportion of year 12 students enrolled in calculus-based mathematics subjects has been declining over the past 15 years. These subjects, often referred to as *intermediate or advanced*, serve as prerequisites to most university science and engineering courses including the mathematical sciences. The proportion of students studying elementary mathematics subjects at year 12 continues to grow, but at the expense of the more demanding subjects.

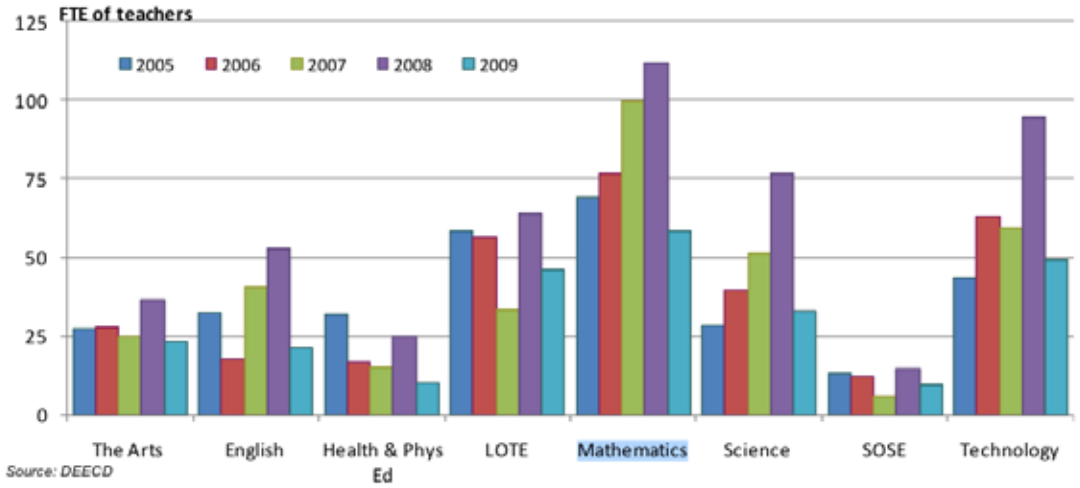


Barrington, F (2011), *AMSI Interim Update on Year 12 Mathematics Student Numbers*

Supply of Qualified Teachers

Mathematics teaching positions are among the most difficult jobs to fill in government secondary schools. Only 68% of Year 11 and 12 mathematics teachers have received three or more years of tertiary education in mathematics. The proportion of Australian primary school teachers with a major in mathematics is well below the international average. The ageing secondary teacher population and falling graduation rates indicate an endemic problem.

Figure 10.3 Difficult to Fill Vacancies in Government Secondary Schools by Learning Area, 2005–09



Department of Education and Early Childhood Development, Victoria (2009), *Teacher Supply and Demand Report*

Table 6.10 Teachers teaching in selected areas: qualifications, experience and professional learning activities

Current field of teaching	Percentage of teachers in field in each category			
	Years of tertiary education in field			Have training in teaching methodology in field
	Two years	Three or more years	Total with two or more years	
Biology 11 -12	7	78	85	66
Chemistry 11-12	14	73	87	74
Physics 11-12	16	60	76	72
General Science 7/8-10	6	38	44	56
Mathematics 11-12	13	68	81	75
Mathematics 7/8-10	11	53	64	60
Information Technology 11-12	13	40	53	46
Information Technology 7/8-10	7	24	31	26

Note: General science 7/8 – 10 refers to teachers teaching General Science and not Biology Chemistry or Physics at Years 11 and 12.

Source: McKenzie, Kos, Walker & Hong (2008). Staff in Australia's schools 2007. DEEWR: Canberra. Table 6.14.

Ainley J., Kos J., Nicholas M. (2008), *Participation in Science, Mathematics and Technology in Australian Education*, ACER

Table 6.12 Percentage of Year 4 students whose teachers report having a major area of study in science in selected other countries for 2002 and 2003

	With primary education specialisation and without a major in science or maths		with a major in science		With a major in maths not science		Science or maths major and without a specialisation in primary education		Other	
	%	SE	%	SE	%	SE	%	SE	%	SE
Australia	72	4.1	14	2.9	9	2.6	1	0.5	4	1.4
Belgium(Flemish)	59	3.2	25	3.5	11	2.4	2	1.2	2	0.7
Chinese Taipei	28	3.2	30	3.8	4	1.6	17	3.4	22	3.6
England	64	4.3	8	2.6	7	3.0	5	1.8	16	2.7
Hong Kong SAR	43	5.1	22	3.8	6	2.7	8	2.4	21	3.9
Japan	54	4.1	14	3.0	6	2.1	3	1.4	23	3.6
New Zealand	63	3.2	17	2.6	13	2.1	1	0.6	5	1.4
Ontario Canada	63	5.1	8	2.1	3	1.8	5	2.1	21	3.9
Russia	35	3.7	52	4.0	7	2.0	1	0.8	5	1.6
Scotland	79	3.6	6	2.0	7	2.2	1	0.1	7	2.3
Singapore	23	3.4	32	3.7	19	3.1	15	2.6	12	2.8
United States	73	2.9	8	1.7	5	1.5	3	1.0	10	1.8
International Av.	50	0.8	23	0.7	7	0.5	8	0.4	13	0.5

Note: Standard errors for countries indicate the precision of the sample statistics and are approximately three or four percentage points.
Years specified as 2002 and 2003 to correspond with data collection times that match the stage in the school year in northern and southern hemispheres.
Source: Martin et al 2004: 258.

Ainley J., Kos J., Nicholas M. (2008), *Participation in Science, Mathematics and Technology in Australian Education*, ACER

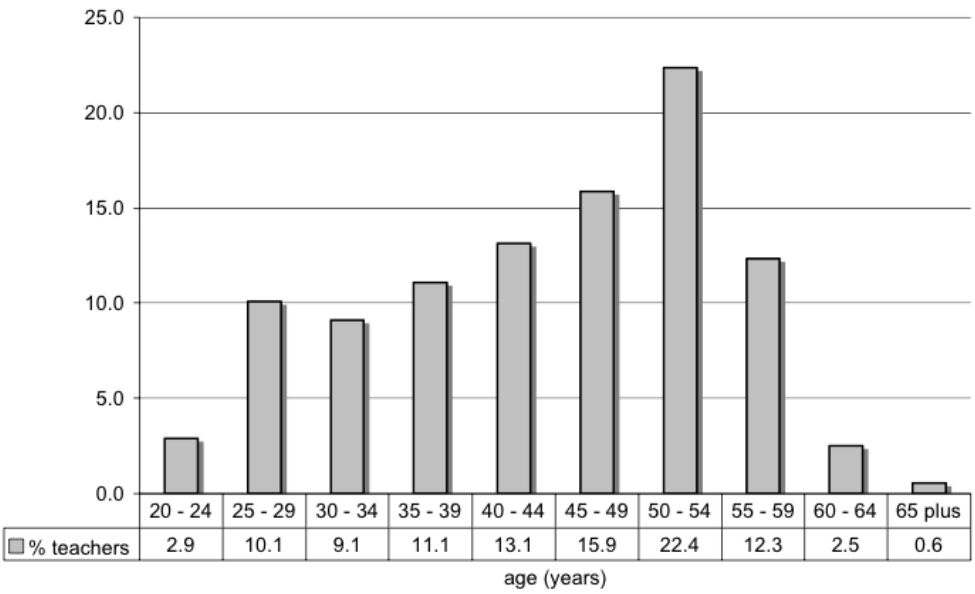


Figure 6.1 Age distribution of secondary school mathematics teachers

Harris K. & Jensz F. (2006), *The Preparation of Mathematics Teachers in Australia*, report prepared for the Australian Council of Deans of Science

Higher Education

Teaching and academic staff numbers in university mathematics and statistics departments are declining. Institutions are relying heavily on casual teaching staff, and are reporting difficulties in finding qualified staff to fill ongoing positions in key areas. Only a handful of Australian universities have strong mathematics and statistics departments that support significant PhD graduations. Starting salaries for mathematics and statistics graduates are among the highest in the country.

Teaching

The Group of Eight, which accounts for a large proportion of Australia's research activity in the mathematical sciences, lost almost a third of its teaching and research staff between 1995 and 2005. In 2000, The Federation of Australian Scientific and Technological Societies found that mathematics departments are facing "difficulties in making appointments in key areas such as financial mathematics and statistics, and some universities no longer offering a three year degree majoring in mathematics or statistics".[1] Due to budget constraints, non-specialists from other departments often teach mathematics and statistics components of courses such as engineering and economics.[2]

Table 2: 'Teaching and research' staff (normal academic staff) in mathematical sciences departments in the Group of Eight universities 1995–2005: statistics gathered from questionnaires returned by the departments.* Staff whose positions are classified as 'teaching only' or 'research only' are not listed here.

	1995			2005			change 1995 to 2005	
Teaching & Research	male	female	total	male	female	total	number	percent
Adelaide	33	9	42	18	6	24	–18	–42.9%
Melbourne	34	3	37	29.5	5	34.5	–2.5	–6.8%
Monash	46	5	51	21.6	4.5	26.1	–24.9	–48.8%
NSW	61	6	67	40.23	9.1	49.33	–17.67	–26.4%
Sydney	60	4.5	64.5	33.08	5.33	38.41	–26.09	–40.4%
WA	33.1	2	35.1	22.5	2	24.5	–10.6	–30.2%
Queensland	26.83	1.6	28.43	22.8	5.05	27.85	–0.58	–2.0%
ANU Mathematics	12.5	0.5	13	8	3	11	–2	–15.4%
ANU FAS	19	1	20	12	1	13	–7	–35.0%
Total Go8	325.43	32.6	358.03	207.71	40.98	248.69	–109.34	–30.5%

* *Except for two Monash university staff transferred to other departments and several econometricians from ANU transferred to other departments, all losses represent genuine loss of employees from the university. Staff from the ANU Department of Finance and Applied Statistics whose expertise is in finance rather than statistics are excluded to avoid misleading data arising from department restructuring.*

The National Strategic Review for Mathematical Sciences Research in Australia (2006), *Mathematics and Statistics: critical skills for Australia's future*

[1] Thomas, J (2000), *Mathematical Sciences in Australia: Looking for a Future*, Federation of Australian Scientific and Technological Societies, p.2

[2] The National Strategic Review for Mathematical Sciences Research in Australia (2006), *Mathematics and Statistics: critical skills for Australia's future*, p.9

Course Availability & Graduation Rates

The OECD average graduation rate for undergraduate mathematics and statistics is 2.5 times greater than that in Australia. There is also a long-standing gender imbalance at honours level with male students accounting for approximately 70% of honours degree completions.

Table 6.1: Proportion of higher education graduates by field of study, Australia compared to the OECD, 2003

	Australia %		OECD % (country mean)	
	A	B	A	B
Education	11.8	1.5	13.6	18.5
Humanities and the arts	11.0	9.2	11.5	8.9
Social sciences, business and law	37.7	45.3	32.2	28.4
Services	2.7	6.4	2.8	10.8
Engineering, manufacturing and construction	7.3	10.8	13.1	17.2
Agriculture	1.0	2.5	2.0	2.1
Health and welfare	13.8	13.7	13.2	19.2
Life sciences	3.0	1.0	2.9	1.1
Physical sciences	2.1	0.3	2.5	0.8
Mathematics and statistics	0.4	n	1.0	1.1
Computing	9.2	9.3	3.9	8.0
Not known or unspecified	n	0.1	3.4	3.5

Source: Organisation for Economic Cooperation and Development (2005) *Education at a Glance*, Table A 3.5.

* Type A programmes are for a minimum of 3 years tertiary full-time equivalent, and are designed for entry to advanced research programmes and professions with high skill requirements, while type B programmes are for a minimum of two years tertiary full-time equivalent, and focus on practical, technical or occupational skills for direct entry into the labour market.

Audit of science, engineering & technology skills (2006)\, Department of Education, Science and Training

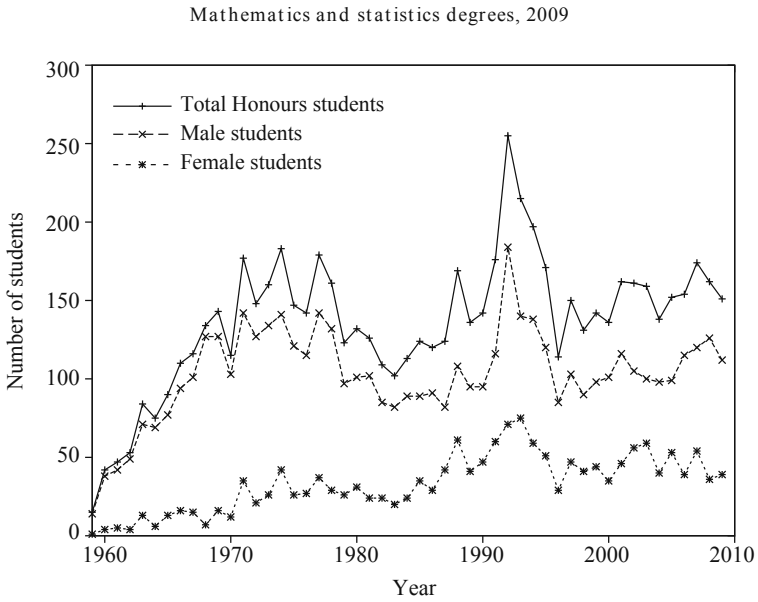


Figure 1. Number of Honours degrees completed in mathematics and statistics, 1959–2009.

Johnson, P (2010), *Higher Degrees and Honours Bachelor Degrees in mathematics and statistics completed in Australia in 2010*, Gazette of the Australian Mathematical Society, vol. 37, no. 5, p. 265

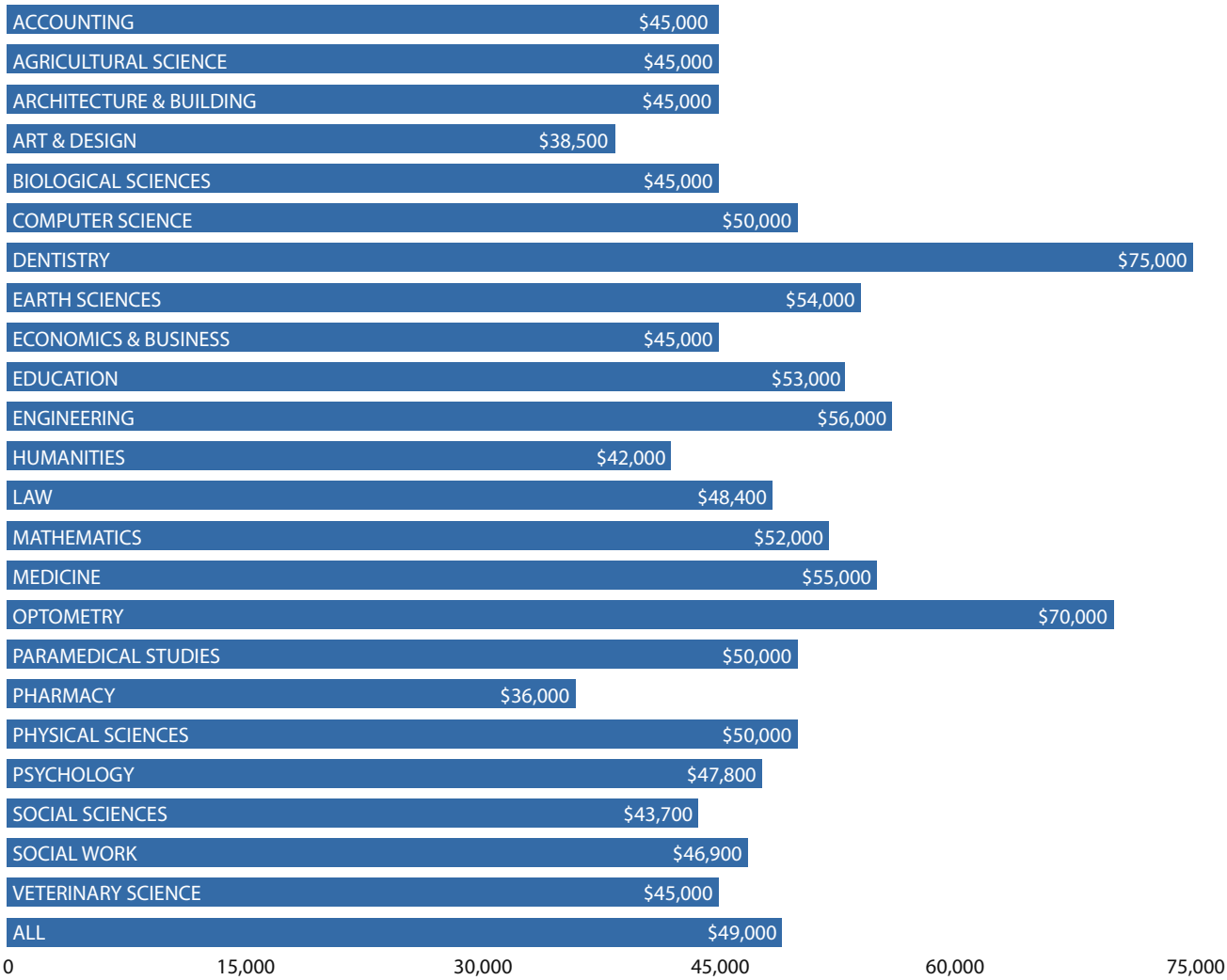


Figure 4: *Median starting salaries of bachelor degree graduates in first full-time employment and aged less than 25, 2011 ($,000)*

Research and Research Training

Research by Australian mathematical scientists is of high quality but low volume, reflecting the discipline's size. Demand for mathematical sciences doctoral holders is predicted to increase by 55% from 2008 levels by 2020, yet actual workforce numbers are declining. In 2010, more than half of the mathematics and statistics PhD graduates came from just 6 universities.

Discipline Research Performance

Australian mathematical scientists conduct high quality research relative to international standards. University-based research activity is largely confined to Group of Eight universities, leaving many institutions with insufficient activity to support PhD graduations. Activity in statistics is particularly worrying. Escalating demand for mathematics and statistics PhD graduates cannot be met without increasing the volume and distribution of research activity at Australia's universities.

Projects by Research Fields, Courses and Disciplines (RFCD Code)

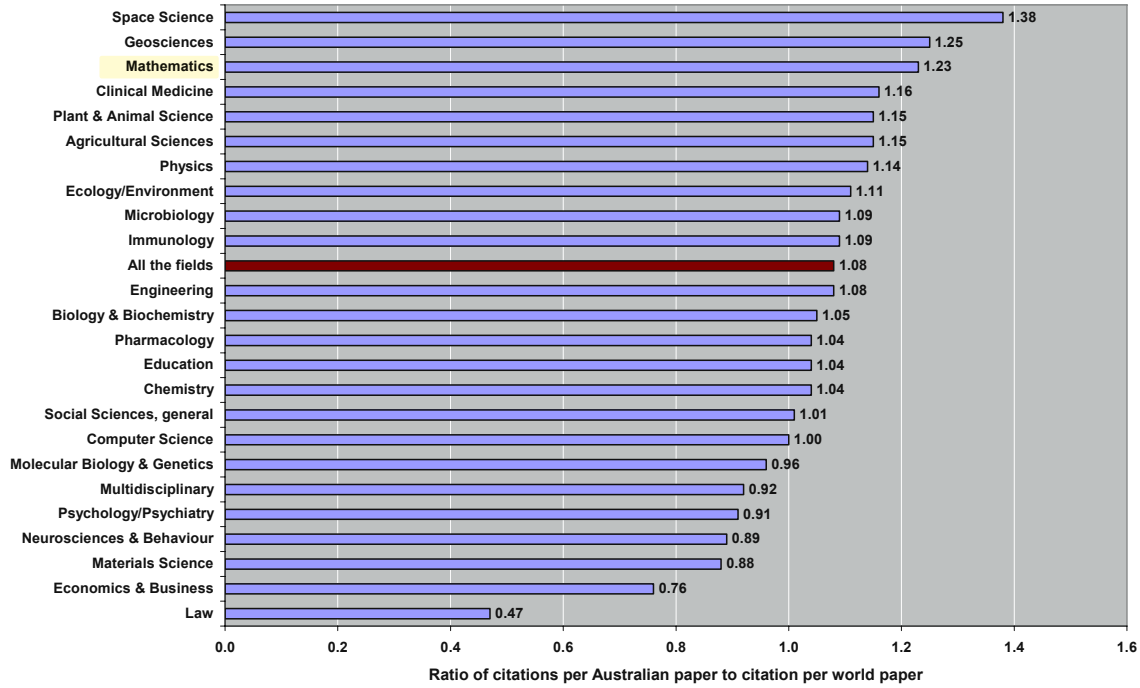
Discovery Projects – Proposals for funding commencing in 2010*

RFCD	Classification	Proposals Considered	Proposals Funded	% Success Rate
30	AGRICULTURAL, VETERINARY AND ENVIRONMENTAL SCIENCES	90	22	24.4%
31	ARCHITECTURE, URBAN ENVIRONMENT AND BUILDING	42	9	21.4%
38	BEHAVIOURAL AND COGNITIVE SCIENCES	194	63	32.5%
27	BIOLOGICAL SCIENCES	563	126	22.4%
25	CHEMICAL SCIENCES	267	57	21.3%
35	COMMERCE, MANAGEMENT, TOURISM AND SERVICES	134	20	14.9%
26	EARTH SCIENCES	180	46	25.6%
34	ECONOMICS	99	31	31.3%
33	EDUCATION	111	19	17.1%
29	ENGINEERING AND TECHNOLOGY	651	142	21.8%
43	HISTORY AND ARCHAEOLOGY	137	39	28.5%
28	INFORMATION, COMPUTING AND COMMUNICATION SCIENCES	336	57	17.0%
40	JOURNALISM, LIBRARIANSHIP AND CURATORIAL STUDIES	26	6	23.1%
42	LANGUAGE AND CULTURE	145	29	20.0%
39	LAW, JUSTICE AND LAW ENFORCEMENT	95	25	26.3%
23	MATHEMATICAL SCIENCES	173	58	33.5%
32	MEDICAL AND HEALTH SCIENCES	169	33	19.5%
44	PHILOSOPHY AND RELIGION	72	18	25.0%
24	PHYSICAL SCIENCES	270	63	23.3%
36	POLICY AND POLITICAL SCIENCE	83	19	22.9%
37	STUDIES IN HUMAN SOCIETY	153	28	18.3%
41	THE ARTS	78	15	19.2%
	Total	**4068**	**925**	**22.7%**

*Withdrawn Proposals are not included

Australian Research Council (2009), *Discovery Projects Funding Outcomes: Selected Statistics*, Retrieved from <http://www.arc.gov.au/ncgp/dp/dp_outcomes.htm>

5.1.14 Impact of Australian scientific publications relative to world – by field of research, 2001-05



Source: Thomson ISI, National Science Indicators database, 2006.

Table 5-21
Rank in S&E article output, by country/economy and selected S&E broad field: 1995 and 2005

	All fields		Engineering		Chemistry		Physics		Geosciences		Mathematics		Biological sciences		Medical sciences	
Country/economy	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005	1995	2005
U.S.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Japan	2	2	2	3	2	3	2	2	5	3	8	7	3	2	3	3
UK	3	3	3	5	6	8	6	7	2	2	4	5	2	3	2	2
Germany	4	4	4	6	3	4	3	4	6	5	3	4	4	4	4	4
China	14	5	8	2	11	2	7	3	15	7	9	3	20	7	21	11
France	5	6	6	7	5	6	5	5	4	6	2	2	5	5	5	7
Canada	6	7	5	8	10	12	9	12	3	4	5	10	6	6	7	6
Italy	8	8	10	10	8	10	8	8	9	9	6	6	7	8	6	5
Spain	11	9	15	12	9	9	11	11	11	10	10	8	11	9	11	10
South Korea	22	10	13	4	15	11	15	9	35	19	24	12	29	13	31	14
Australia	9	11	12	14	14	17	17	18	7	8	11	13	8	10	9	9
India	12	12	9	11	7	7	10	10	13	12	17	21	14	12	19	20
Russia	7	13	7	13	4	5	4	6	8	11	7	9	9	18	22	28
Netherlands	10	14	14	18	13	16	14	17	10	13	13	16	10	11	8	8
Taiwan	18	15	11	9	17	14	20	13	23	15	20	20	22	19	20	16
Sweden	13	16	16	19	18	21	18	19	12	18	15	18	12	14	10	12
Brazil	23	17	25	16	25	15	21	15	24	16	19	15	19	15	24	17
Switzerland	15	18	19	21	16	18	13	16	16	14	16	19	13	16	12	15
Turkey	34	19	26	17	29	20	37	25	29	21	44	27	34	24	25	13
Poland	19	20	18	20	12	13	12	14	27	29	14	14	25	23	28	26

UK = United Kingdom

NOTES: Countries initially ranked on 2005 total article output. Article counts from set of journals covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI). Articles classified by year of publication and assigned to country/economy on basis of institutional address(es) listed on article. Articles on fractional-count basis, i.e., for articles with collaborating institutions from multiple countries/economies, each country/economy receives fractional credit on basis of proportion of its participating institutions. China includes Hong Kong.

SOURCES: Thomson Scientific, SCI and SSCI, http://scientific.thomson.com/products/categories/citation/; ipIQ, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Science and Engineering Indicators 2008

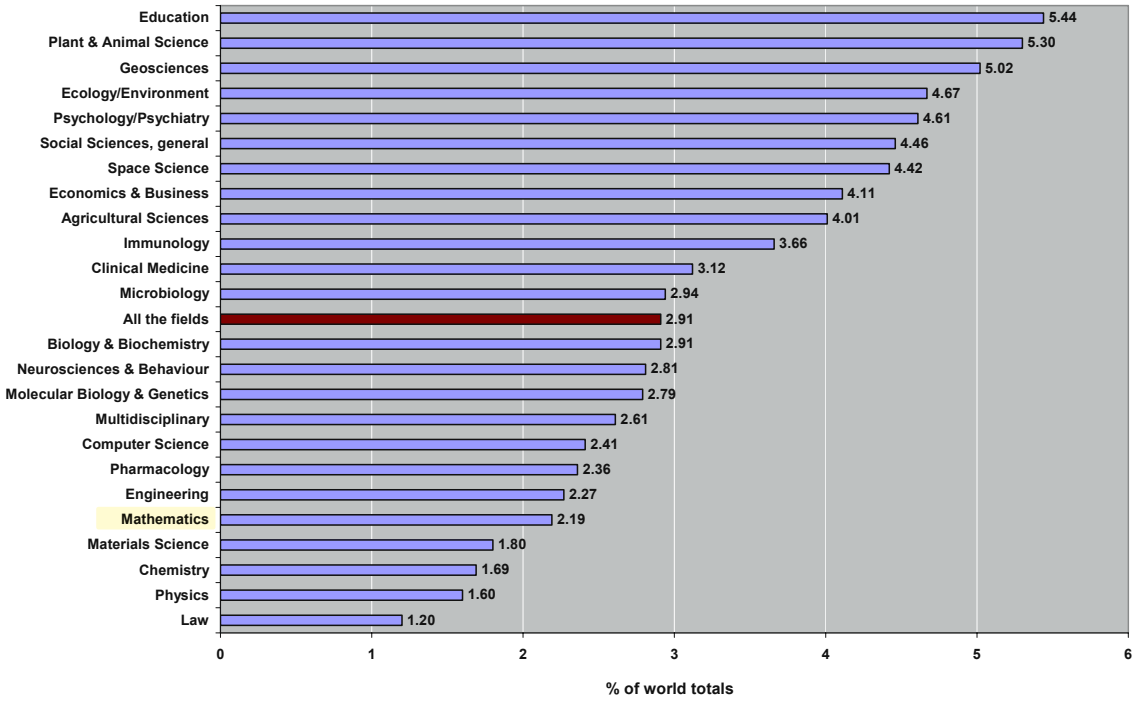
01 MATHEMATICAL SCIENCES

Institution	01 Mathematical Sciences	0101 Pure Mathematics	0102 Applied Mathematics	0103 Numerical and 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
Australian National University	4	5	4	n/a	3	5	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	n/a	n/a	n/a	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	3	3	2	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
Flinders University	n/a	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
James Cook University	2	n/a	n/a	n/a	n/a	n/a	n/a
La Trobe University	2	2	3	n/a	n/a	n/a	n/a
Macquarie University	2	3	n/a	n/a	2	n/a	n/a
Melbourne College of Divinity	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
Murdoch University	n/a	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
RMIT University	2	n/a	3	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	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
University of Ballarat	2	2	n/a	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
University of Melbourne	5	4	4	n/a	4	5	n/a
University of New England	4	4	n/a	n/a	n/a	n/a	n/a
University of New South Wales	4	3	4	5	3	4	n/a
University of Newcastle	3	3	5	n/a	n/a	n/a	n/a
University of Notre Dame Australia	n/a	n/a	n/a	n/a	n/a	n/a	n/a
University of Queensland	4	3	4	5	5	4	n/a
University of South Australia	3	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
University of Sydney	5	4	4	3	3	5	n/a
University of Tasmania (inc. Australian Maritime College)	3	2	n/a	n/a	n/a	n/a	n/a
University of Technology, Sydney	3	n/a	3	n/a	n/a	4	n/a
University of the Sunshine Coast	n/a	n/a	n/a	n/a	n/a	n/a	n/a
University of Western Australia	4	5	4	n/a	3	n/a	n/a
University of Western Sydney	3	3	n/a	n/a	n/a	n/a	n/a
University of Wollongong	3	3	3	n/a	2	n/a	n/a
Victoria University	2	1	3	n/a	n/a	n/a	n/a
Total UoEs evaluated	**24**	**18**	**17**	**5**	**12**	**6**	**0**

Note: a score of 3 and above (to a maximum of 5) indicates that the research output is of international standard. An entry of n/a indicates that the volume of research output was below the ARC's threshold for assessment or was not covered by the Scopus bibliometric service.

Australian Research Council (2010), *Excellence in Research Australia: 2010 National Report*, p.5

5.1.13 Australian scientific publications as a percentage of world totals – by field of research, 2001-05



Source: Thomson ISI, National Science Indicators database, 2006.

Supply and Demand

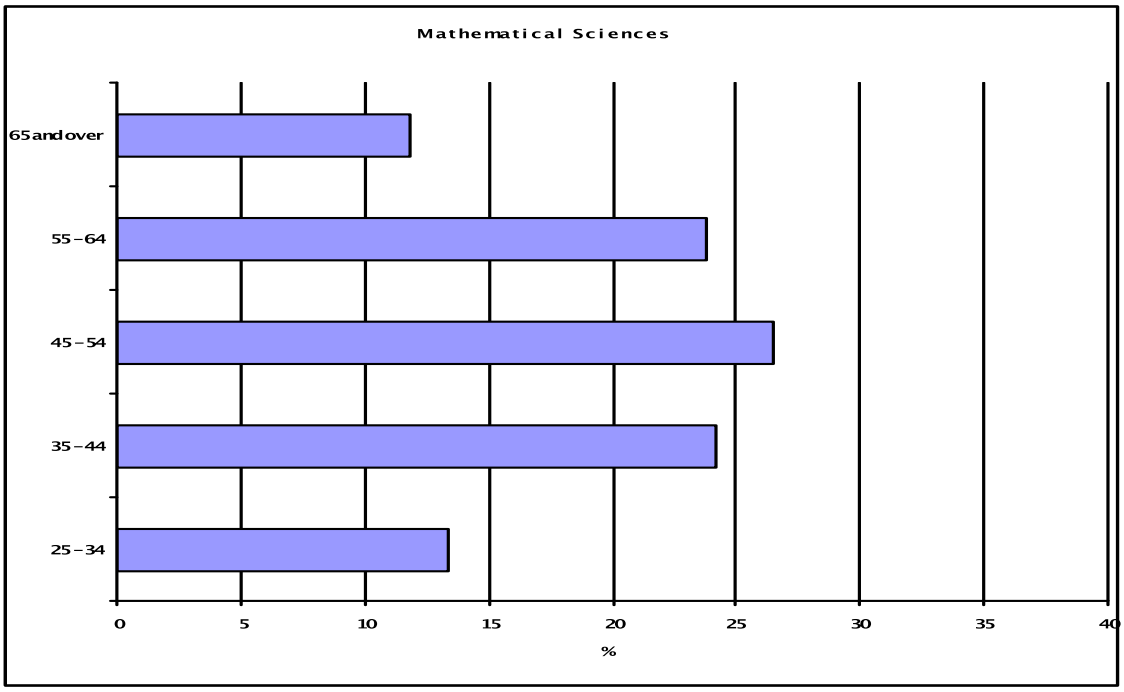
Demand for mathematics and statistics PhD graduates is tipped to increase by 55% from 2008 levels across all sectors of the Australian economy by 2020. Meeting this demand is hampered by an aging population of highly qualified mathematical scientists and a steady but inadequate PhD graduation rate. The graduation rate in the mathematical sciences is low in both absolute terms and as a proportion of advanced research degree completions in all fields. Comparison of graduation rates with the age distribution of doctoral holders in the mathematical sciences shows that the current PhD graduation rate is insufficient to replenish the skill lost through retirement.

TABLE 14: PROJECTIONS OF SIZE OF DOCTORATES EMPLOYED, BY DETAILED FIELD OF EDUCATION, 2007-08 TO 2019-20, AUSTRALIA

	Size of employed workforce				Change 2007-08 to 2019-20	
Field of qualification (ASCED)	2007-8	2011-2	2015-6	2019-20	Number	Per cent
Biological Sciences	20,878	23,489	26,637	29,957	9,079	43.5
Other Natural and Physical Sciences	8,477	9,896	11,865	14,075	5,598	66.0
Chemical Sciences	6,674	7,171	8,136	9,181	2,507	37.6
Medical Studies	7,303	7,809	8,372	8,957	1,654	22.6
Studies in Human Society	4,796	5,443	6,286	7,185	2,389	49.8
Mathematical Sciences	4,610	5,226	6,144	7,173	2,563	55.6
Process and Resources Engineering	4,533	5,276	6,082	6,946	2,412	53.2
Philosophy and Religious Studies	3,784	4,344	5,040	5,820	2,036	53.8
Behavioural Science	3,735	4,123	4,776	5,501	1,766	47.3
Physics and Astronomy	3,707	3,909	4,582	5,376	1,669	45.0
Computer Science	2,846	3,265	3,859	4,530	1,684	59.2
Other Education	2,460	2,821	3,265	3,725	1,266	51.5
Earth Sciences	2,629	2,871	3,273	3,703	1,075	40.9
Business and Management	1,997	2,238	2,583	2,949	952	47.7
Law	1,586	1,875	2,257	2,696	1,110	70.0
Economics and Econometrics	2,036	2,090	2,294	2,485	449	22.1
Language and Literature	2,463	2,421	2,467	2,479	16	0.7
Political Science and Policy Studies	1,279	1,542	1,915	2,346	1,067	83.5
Environmental Studies	1,316	1,541	1,863	2,215	899	68.3
Other Engineering and Related Technologies	1,416	1,572	1,785	2,020	604	42.7

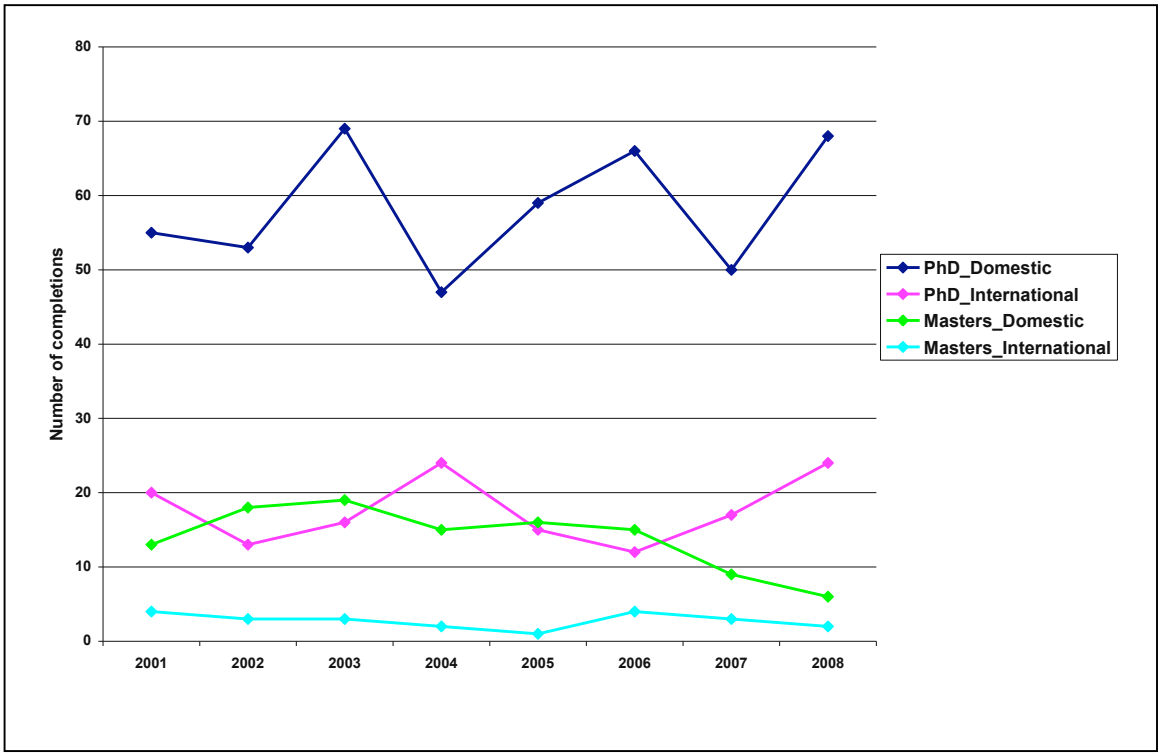
Source: CoPS, *MONASH* forecasts, March Quarter 2009 customised data and ACER adjustments

Figure 68: Age distribution of mathematical sciences Doctorate holders, 2006



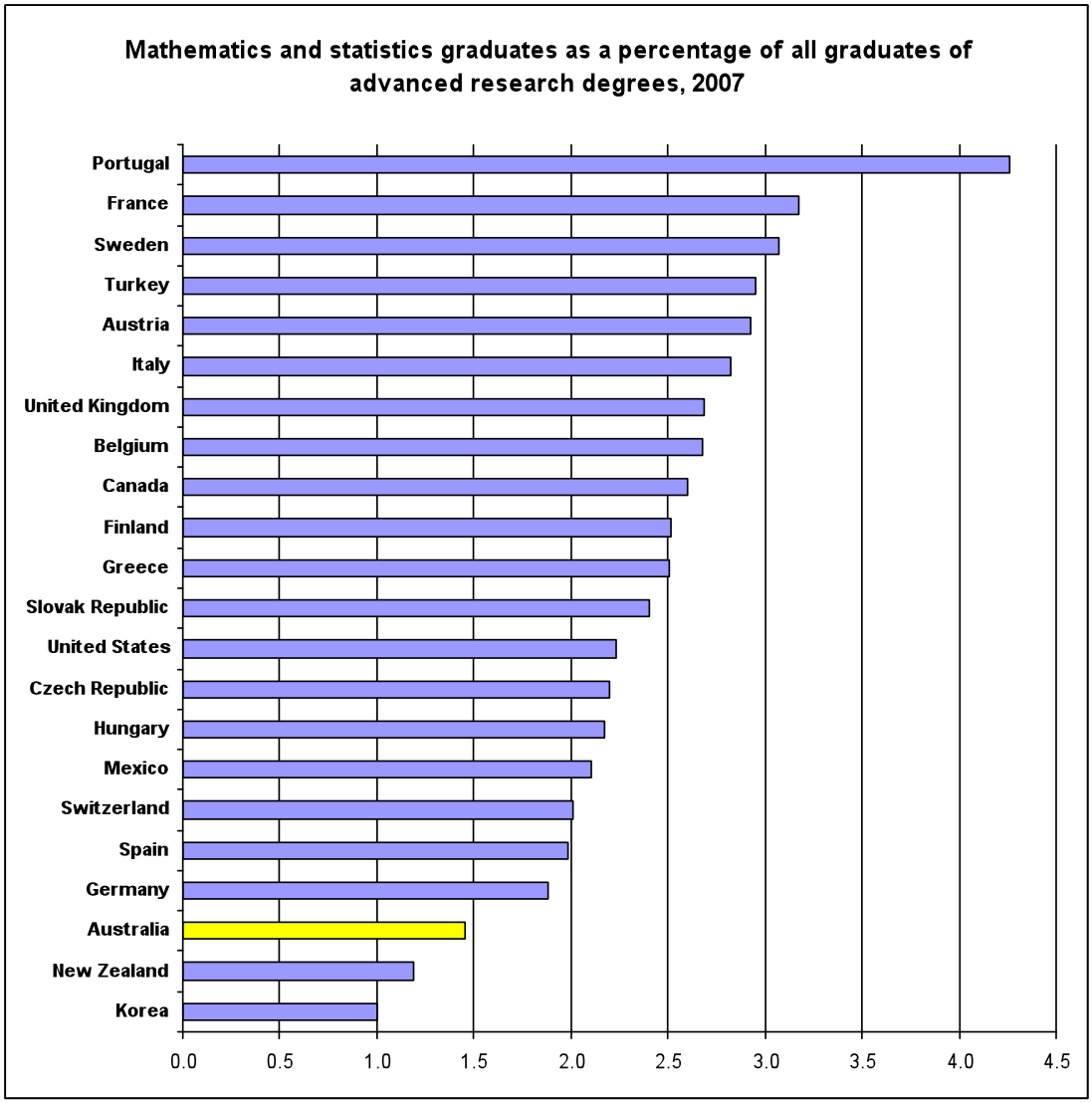
ABS Census of population and housing 2006, special tabulation.

Figure 72: Mathematical sciences HDR completions, 2001-2008



Source: DEEWR University Statistics, unpublished data.

Mathematics and statistics graduates as a percentage of all graduates of advanced research degrees, 2007



Source: *OECD Stat Extracts* Online Database.
Note: This data should be approached with care – differences in higher education systems can produce anomalous results when countries try to standardise their information to possibly incompatible OECD reporting requirements.

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