A National Strategy for Mathematical Sciences in Australia

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Prepared in consultation with the Australian Council of Heads of Mathematical Sciences.

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1. A national strategy for mathematical sciences in Australia

Most of the great innovations that have changed the way people live over the past two centuries were enabled by mathematics.[1] Without mathematics, there would be no cars, no planes, no mobile phone networks, no electric lights, and certainly no computers.

Our dependency upon mathematics, moreover, is steadily increasing. The sequencing of the human genome was as much a triumph of mathematics as it was an achievement in biological science. The challenges of predicting our climate and our economy will only be resolved by using mathematics. The pervasiveness of computers has drastically increased the need for ordinary citizens to understand mathematics.

Mathematics isn't just important. It is a critical skill that every Australian citizen should be able to develop in order to improve their lives and the lives of those around them. Mathematics enables technological innovation in our world. It is elemental to all forms of commerce. It is the foundation upon which all sciences and all areas of engineering depend.

Yet there is evidence that Australian mathematics and mathematics education are in serious trouble. Several major studies have been conducted in recent years of relevance to the development of mathematical sciences in Australia:

- 2006 National Strategic Review of Mathematical Sciences in Australia[2]
- 2005 Review of Statistics[3]
- 2008 ACER Research Monograph, *Participation in Science, Mathematics and Technology in Australian Education*[4]
- 2007 Productivity Review of Public Support for Science and Innovation[5]
- 2006 Australian Council of Deans of Science study[6]

These reviews show that Australian mathematics and mathematics education are in a dire state. They show that demand in the Australian economy for graduates with substantive training in mathematics or statistics has outstripped supply in recent years. They show that demand for mathematics teachers continues to be an area of particular pressure and that the quality of mathematics education has declined in Australia over the past decades, leading to rising inequality. They also indicate that, without concerted action, there is little prospect for turning the situation around.

In response to these challenges, Australia's mathematical scientists have developed innovative and collaborative ways of working together. Many remarkable developments still occur and our best students are very good indeed. But in 2006, international reviewers reported:

... we found the nation's distinguished tradition and capability in mathematics and statistics to be on a truly perilous path.[7]

We are therefore calling upon all Australian governments to act, and to act now. Australia urgently needs a national strategy for mathematics and mathematics education.

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1 'Mathematics' encompasses mathematics, statistics and the range of mathematics based disciplines commonly referred to as 'mathematical sciences'.

2 See http://www.review.ms.unimelb.edu.au/FullReport2006.pdf. For brevity this will be referred to as the '2006 Review'.

3 Statistical Society of Australia Inc, *Statistics at Australian Universities: An SSAI-sponsored Review*, December 2005

4 http://research.acer.edu.au/acer_monographs/4/

5 http://www.pc.gov.au/projects/study/science/docs/finalreport

6 *The Preparation of Mathematics Teachers in Australia.* See http://www.acds.edu.au/

7 Footnote 1, p.1

2. The challenges

2a. Demand for mathematics and statistics graduates—and graduates with substantive mathematics within other degrees such as engineering and economics—in the Australian economy has outstripped supply in recent years and is forecast to continue doing so.

- Demand for mathematicians and statisticians in the Australian economy grew by 52% between 1998 and 2005, corresponding to an annual growth rate of 5.4%.[8]
- Demand for mathematicians and statisticians has been forecast by the Australian Government to grow by 33% between 2006 and 2013, corresponding to an annual growth rate of 3.5%.[9]
- CSIRO Mathematical and Information Sciences, other agencies and industries have reported difficulties in filling positions, and this has hampered growth opportunities.[10]

2b. Demand for mathematics teachers continues to be an area of particular pressure.

- In 2007, 40% of senior mathematics teachers in Australian schools did not meet the requirement of three years of university study in mathematics – having risen from 30% in 1999.[11]
- In the most recent study of staffing in schools, the highest rates of unfilled vacancies were reported in mathematics, with 10% of secondary principals reporting at least one unfilled teacher vacancy.[12]

2c. Unsurprisingly, the quality of mathematics education has declined in Australia over the past decade.

- The US and English education systems have much in common with Australia's but their students now outperform Australian students in Year 4 and Year 8 mathematics tests, as measured by TIMSS (Trends in International Mathematics and Science Study).[13]
- Between 1995 and 2007, the performance of Australian Year 8 students dropped from above average—for all tested nations—to below average. In this period Australian Year 8 students' performance went from statistically above that of the US and English students to statistically below that of their counterparts.
- Between 1995 and 2007, the number of Year 12 students doing 'advanced' mathematics courses has declined by 20% (from 25,000 to 20,000), while the number of Year 12 students doing 'intermediate' mathematics courses has also declined.[14]
  The decline is shown as percentages of the Year 12 cohort in Appendix 1.

2d. Should current trends in tertiary mathematics education continue, there is little prospect of turning the situation around.

- In 2003 the percentage of students graduating with a major in mathematics or statistics from Australian universities was 0.4% compared with an OECD average of 1%. As shown in Appendix 2 there has been continued decline.
- The number of universities not offering a major in mathematics or statistics is not improving and is probably worsening.[15]

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8 DEST, Audit of Science, Engineering and Technology Skills, 2006.

9 ibid. Global financial situation may affect these predictions.

10 Footnote 1, Chapter 2

11 ACER, Participation in Science, Mathematics and Technology in Australian Education, 2008.

12 *Staff in Australian Schools 2007*. See http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/sias2007.htm

13 http://www.acer.edu.au/timss/

14 ICE-EM, Participation in Year 12 Mathematics, Publications in Mathematics, No.2, May 2006.

15 See http://www.amsi.org.au/pdfs/Questionnaire_summary.pdf. Data currently being collected will quantify current situation.

2e. This is devastating since it will lead to rising inequality in access to mathematics education for young Australians.

- Even in relatively well-off suburbs of Melbourne, public schools cannot offer mathematics enrichment at Year 10 or the most advanced Year 12 subject. Nearby private schools can.[16]
- Regional universities have been closing mathematics departments compounding the difficulty of finding mathematics teachers for rural and remote areas. No student in the Northern Territory has access to a three-year sequence of university mathematics or statistics unless they move interstate, an expensive and often culturally difficult option.

2f. There are worrying ramifications for the future of Australian science.

- Mathematics is the only science subject whose study consistently enhances performance across all fields of science.[17]
- The Australian Council of Deans of Science observes that: "Intermediate, and especially, Advanced Mathematics students are essential for a strong science, research and innovation capacity. The statistics at hand indicate that numbers in these areas are shrinking and students are instead electing to take Elementary Mathematics."[18]

16 Communication from mathematics teacher – available on request.

17 Sadler & Tai, Science, 317, 457-8, 2007.

18 *The Preparation of Mathematics Teachers in Australia* (2006). See http://www.acds.edu.au/

3. Recent Government actions

Consecutive Australian Governments have introduced three measures:

- Funding model – the 2007 budget increased funding per equivalent full-time student in mathematics and statistics by approximately $3,000.
- HECS[19] reduction – from 2009 students enrolled in any undergraduate mathematics and statistics course are liable for the lowest 'national priority' rate. Graduates taking up related occupations, including teaching, can apply for reductions to their loan (HECS) repayments.
- Established a process to develop a national mathematics curriculum for schools.

These measures adopted by the Australian Government to support Australian mathematics are welcome but will have limited impact without modification.

Funding model
Changes to the funding model were strongly supported by the mathematics and statistical community and are absolutely necessary for the future of Australian mathematics. However the changes have not worked as originally intended.

Many universities have not passed on any of the increase to departments and the number of staff in university mathematics departments continued to decrease. Consequently there was no discernible impact on the key performance indicators listed in the 2006 Review.[20]

HECS reduction
Similarly the HECS reductions are welcome measures widely supported by the mathematical and scientific community. Importantly, they address an equity issue. Beginning teachers with degrees and DipEd qualifications had been incurring significantly more debt than those with four-year BEd degrees with little discipline base study.

However, fee reductions for mathematics were tried and abandoned in two Australian universities, when they made little impression on enrolments.[21] There is little evidence that students are aware of the reductions or that it reflects mathematics and statistics as being a government priority. The measure is also not linked to mathematical and physical sciences specifically. Furthermore, mathematics majors with degrees not labelled as BSc are ineligible for loan reductions if they become teachers of mathematics.

National Currlicum
The national curriculum initiative is welcome. If it is comparable with curricula in other nations, if it raises expectations of achievement for all students, and if it makes provision for the mathematically talented, a national curriculum could in theory lift the quality of mathematics education across Australian schools.

Experience from the introduction of a national curriculum in England in the late 1980s was that it had little effect on student achievement and participation until other measures were taken. Specifically these included raising the awareness of the importance of mathematical sciences and improving mathematics teacher supply and quality.

19 The old terminology – HECS rather than 'annual student contribution amount' – is being used as it is clearly understood

20 http://www.amsi.org.au/pdfs/Questionnaire_summary.pdf

21 Deakin and University of Western Sydney

4. Our Solutions

To complement the measures already taken, a coordinated national mathematics and statistics strategy is suggested that addresses:

- perceptions of the usefulness of mathematics and statistics;
- the serious shortfall of well-qualified teachers of mathematics in schools;
- the diminished state of mathematical sciences in the university sector; and
- mathematical and statistical infrastructure for business, industry and research.

4a. Mathematical sciences and their importance to Australia

Mathematical sciences are a hidden achiever. It is not obvious to the community at large that mathematics and statistics are critical to the vast majority of technologies they use every day. Four measures are therefore proposed that would put mathematics and statistics clearly into the public arena. These measures are intended to inspire students and their parents to appreciate both the importance of the mathematical sciences and the many exciting career options that depend upon developing good mathematical skills.

1. *Political leadership* – We are calling upon the Prime Minister and his parliamentary colleagues to reinforce the importance of mathematics to the future well-being of Australia and Australians.[22]
2. *Community awareness* – We are asking for a national campaign to promote mathematical sciences, their contribution to modern life and to Australia, and the critical role they play in many career options.[23]
3. *Student Encouragement* – We are looking to the Australian Government to promote its HECS reduction to beginning tertiary mathematics students.
4. *Teacher prizes* – We are recommending that the Prime Minister introduce annual Prime Minister's Prizes for mathematics teaching.[24]

4b. Well-qualified teachers of mathematics in schools

If more Australian students are to study advanced mathematics and if students at all levels are to have an appropriate number of hours of instruction[25], it is clear that additional measures must be taken by our governments. The following seven initiatives address the current inequity in access to a quality mathematics education. Inequitable access is now endemic in Australia. The proposed measures are designed to improve the quality and quantity of mathematics teaching and learning and provide a mechanism for rewarding good mathematics teachers in primary and secondary schools.[26]

1. *Meaningful registration* – Australia needs a national registration system for teachers of mathematics, differentiated as appropriate for primary, junior secondary and senior secondary classes and based on content knowledge as well as pedagogical knowledge. Once registration is in place, it can inform workplace planning, including the allocation of teacher education places so there is a better match with teacher supply and school curriculum needs.[27]

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22 Briefing notes would be prepared by the mathematical sciences community

23 A draft action plan already exists and would be up-dated. See http://www.maths.org.au/pdfs/careers.pdf

24 When originally introduced it was suggested that the science prize would include mathematics teachers but this has never happened. There is a prize for primary and for secondary science teaching. Prizes have since been introduced for history and music.

25 Five hours has been suggested for primary and four for secondary to Year 10. See: www.coag.gov.au/reports/docs/national_numeracy_review.pdf

26 The measures counter difficulties of across the board pay increases specific to mathematics teachers and possible problems with 'merit' based pay that may make teachers reluctant to move to 'difficult' schools.

27 For data on current imbalance see: http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/survey_final_year_teacher_edu

2. *Primary specialists* – We also need to develop a distinct registration category of 'primary mathematics specialist' that attracts a substantial financial reward. 'Primary mathematics specialist' should be a distinct registration category linked to further studies in both mathematics and pedagogy.[28]
3. *New teachers* – The current economic situation provides opportunities to recruit suitable career-change professionals to mathematics teaching. We are seeking government support for career-change professionals interested in teaching mathematics. This would include income support, the development of courses appropriate to their needs, and 'golden handshakes' to acknowledge the additional work related skills they bring to schools.
4. *Tenure* – In conjunction with the States and Territories, we want government schools in Australia to ensure that all new teachers of mathematics have on-going positions after an initial probationary year.
5. *Refocus the HECS reduction* – We are asking the federal government to re-assess the HECS reduction for BSc graduates entering teaching to include graduates from other degrees (such as engineering, computer science etc) who meet the requirements of 1 above for senior secondary school teaching of mathematics.[29]
6. *Professional development* – We want all Australian governments to provide improved opportunities and support for teachers teaching 'out-of-field' to meet subject-based registration requirements as defined by 1.
7. *Promote equity* – We believe the Australian Government should provide substantial financial inducements to experienced and well-qualified mathematics teachers who are prepared to take positions in rural, remote and underachieving schools for a minimum of, for example, three years.

4c. Mathematical sciences in the university sector

Mathematical sciences will never be strong in Australian schools, communities and businesses without an appropriate foundation in our universities. However political leadership is needed if Australia is to develop an outstanding higher education system for mathematics.

Our universities need to ensure that all Australian students have access to a major in the mathematical sciences should they wish to pursue one.[30] The integrity and standard of mathematics and statistics courses taught outside mathematical sciences departments must be monitored for content and standards. Our federal government needs to provide a more strategic use of the HECS reductions to encourage students to include mathematics and statistics in science degrees. We also need to be certain that our immigration policies do not cause Australia to lose in the international competition for mathematical talent.[31] To these, and related, ends we are proposing eight additional measures.

1. *Political leadership* – We believe the Minister of Education should write to all universities asking what improvements have been made to support mathematics and statistics since the funding for teaching these disciplines was increased in 2008.
2. *University leadership* – We want Australian Government compacts or similar agreements to ask universities specifically what steps they are taking to increase the number of graduates in mathematics and statistics.

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28 England is aiming for a specialist in every primary school. See: http://publications.teachernet.gov.uk/default.aspx?PageFunction=productdetails&PageMode=publications&ProductId=DCSF-00433-2008

29 Some provision for students at the University of Western Australia who do not have BSc label have already been made.

30 The designation of mathematics as part of the strategically important subjects program as in the UK could also be helpful. See: http://www.hefce.ac.uk/aboutus/sis/

31 The 2006 international reviewers noted that Australian universities were neglecting '…the basic principle that mathematics be taught by mathematicians'.

3. *Enabling infrastructure* – We are suggesting that Australian Government compacts or similar agreements also ask all universities in receipt of ARC and NHMRC funding to state what provision they have made for the mathematical and statistical expertise needed across disciplines.
4. *Refocus the HECS* – We are asking the Australian Government to re-assess the value of the HECS reduction for science students who are not completing a minimum of two semesters of mathematics or statistics.
5. *Direct scholarships* – As an alternative to HECS reductions, we want the Australian Government to consider providing up-front scholarships for students who undertake a mathematics major in their undergraduate degrees.
6. *Mathematics course accreditation* – We are calling for HECS reduction for mathematical units not taught by a mathematical sciences department to be monitored for mathematical and statistical content.
7. *Teacher training accreditation* – We are calling for the mathematics content of teacher education courses not taught by mathematics departments also to be accredited.
8. *Simpler immigration* – We are suggesting that the Australian Government simplify immigration procedures for mathematical scientists already in universities and intending to stay permanently.

4d. Mathematical and statistical infrastructure

The Australian Mathematical Sciences Institute (AMSI)[32] is core infrastructure supporting many activities that simply would not occur otherwise. An example is an industry workshop in July where the OECD is funding 15 participants from developing countries.[33] Another example is the internship program for postgraduate students.[34] Until the mathematical sciences are rebuilt, AMSI is the only way that Australia can provide collaborative, national mathematical infrastructure across the broader research community, business, industry and education. Through its members and the Australian Council of Heads of Mathematical Sciences for which it provides administrative support, AMSI is well placed to provide core support for teaching and research in mathematics as well as evidence for policy in the mathematical sciences.[35] We are calling for support for this mathematical and statistical infrastructure in four ways.

1. *Support AMSI* – We are asking the Australian Government to fund AMSI's core infrastructure and operations as recommended in the 2006 Review.[36]
2. *National expertise* – We are asking for policies to encourage AMSI's mission for the diffusion of mathematical and statistical expertise to business and industry, including SMEs, especially through its internship program.
3. *Use AMSI* – We are recommending that all governments use AMSI's national, collaborative infrastructure to provide evidence for government policy in the mathematical sciences.
4. *Statistical consulting* – We are calling for all universities to establish a mechanism to support 'intellectual infrastructure', specifically internal statistical consulting services.

32 Winner of the 2008 Fast Thinking and Open Universities National Innovation Award for Science Innovation. See: www.amsi.org.au

33 http://www.amsi.org.au/energy.php

34 http://www.amsi.org.au/Industry_internships.php

35 Gary Banks, Chair of the Productivity Commission, suggested 'going to the experts'. See: http://www.pc.gov.au/speeches/cs20090204

36 2006 National Strategic Review of Mathematical Sciences in Australia

5. A national strategy

The mathematical sciences are in need of repair. The time has passed when any single initiative will suffice and a coordinated national strategy is now required. The issues discussed here should be of concern in every State and Territory and in every electorate. The inequitable access to a quality mathematics education is a national disgrace. It will not be solved by isolated measures.

Many of the proposals put forward concern education. However, mathematical infrastructure for business, industry and research also concern the Science and Innovation portfolio. This is where policy for the promotion of science is currently situated and is where new policies for the promotion of mathematical sciences may possibly belong.

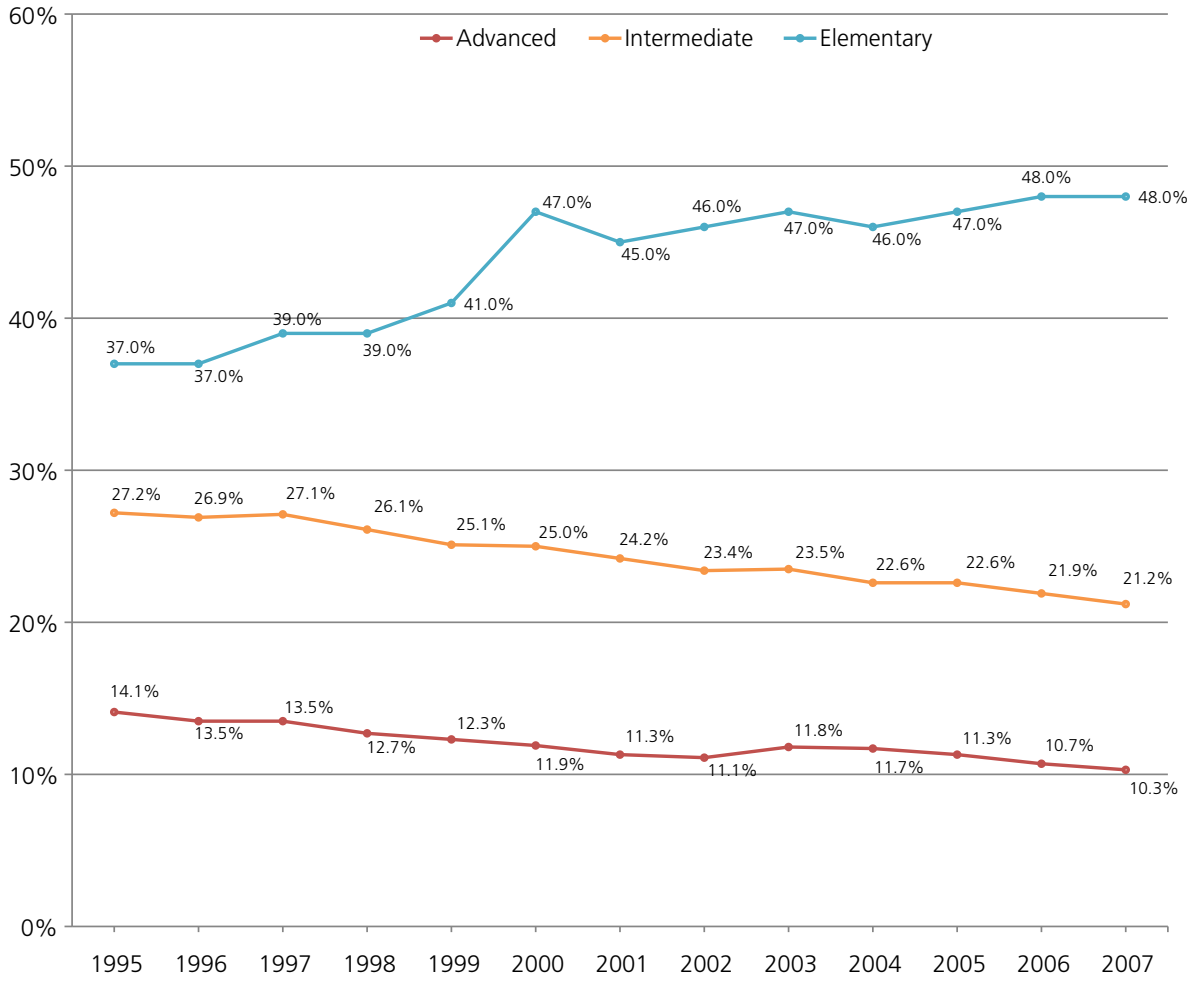
In recent years, the UK has turned its performance in mathematical sciences and education around in a remarkable way by combining aggressive teacher recruitment with substantial inducements, regulation of teacher education numbers to match demand from schools, an impressive careers program supported by the government and professional societies, and the designation of mathematics as part of the strategically important subjects program. Two tables from the London Mathematical Society concerning applicants for undergraduate mathematics programs and graduate teacher numbers are shown in Appendix 3.

The truth is Australian mathematics and mathematics education are in a dire state. But the British example shows that it is possible, by acting strategically, to turn things around. The mathematical sciences community asks for a bipartisan, national approach to ensure that similar results can be achieved in Australia. To quote the 2006 Review:

"Australia is a big country, with a dispersed population. Ensuring a mathematical sciences base that supports teaching, research, and industry in remote and rural areas as well as the major population centres is a challenging task. ***With sufficient will it can be done."***

Appendix 1

Update on Year 12 mathematics student numbers



Note:

1. An Advanced student is one who takes an Advanced subject.
2. An Intermediate student is one who takes an Intermediate subject but NOT an Advanced subject.
3. An Elementary student is one who takes an Elementary subject but NOT an Intermediate subject NOR an Advanced subject.

The 1995-2004 numbers are taken from the report "Participation in Year 12 mathematics across Australia 1995-2004", ICE-EM Publications in Mathematics No. 2, May 2006, ISBN 978-09775254-6-1.

International Baccalaureate student numbers are not included.

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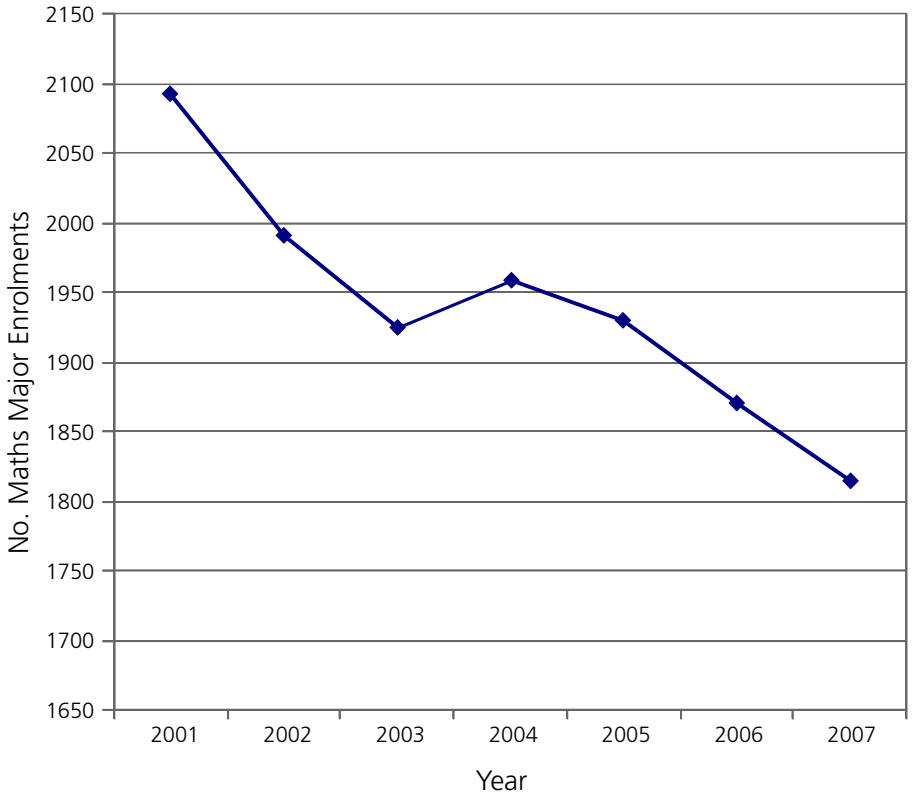
Appendix 2

Number of Mathematics Majors Student Enrolments 2001-2007



(Data provided by DEEWR Higher Education Statistics Unit)

Appendix 3

Table 1 - Numbers of applicants to undergraduate mathematics degrees in the UK

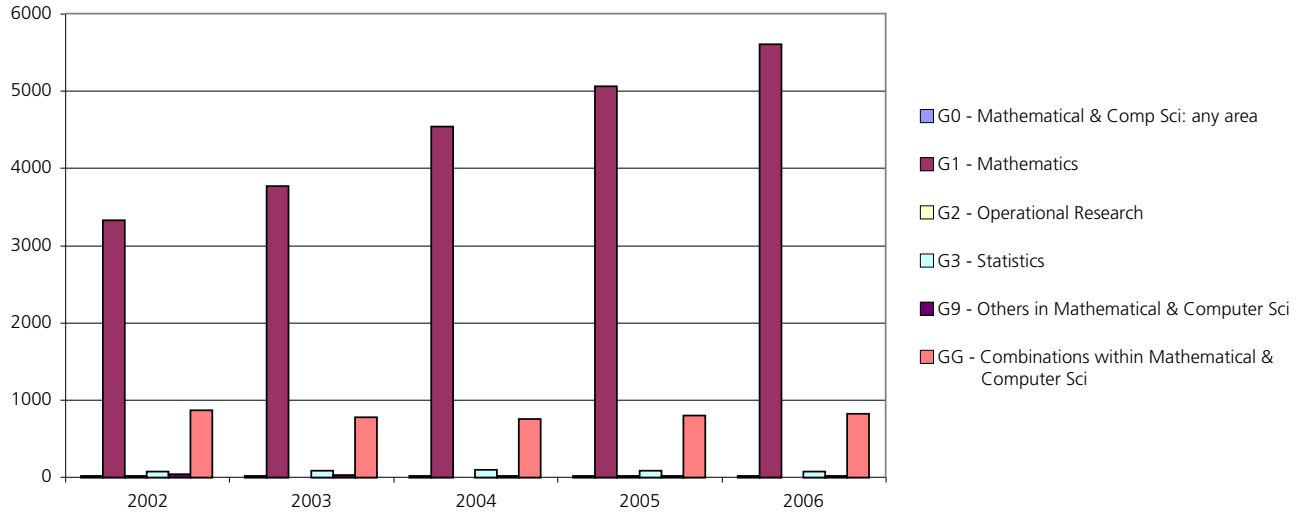
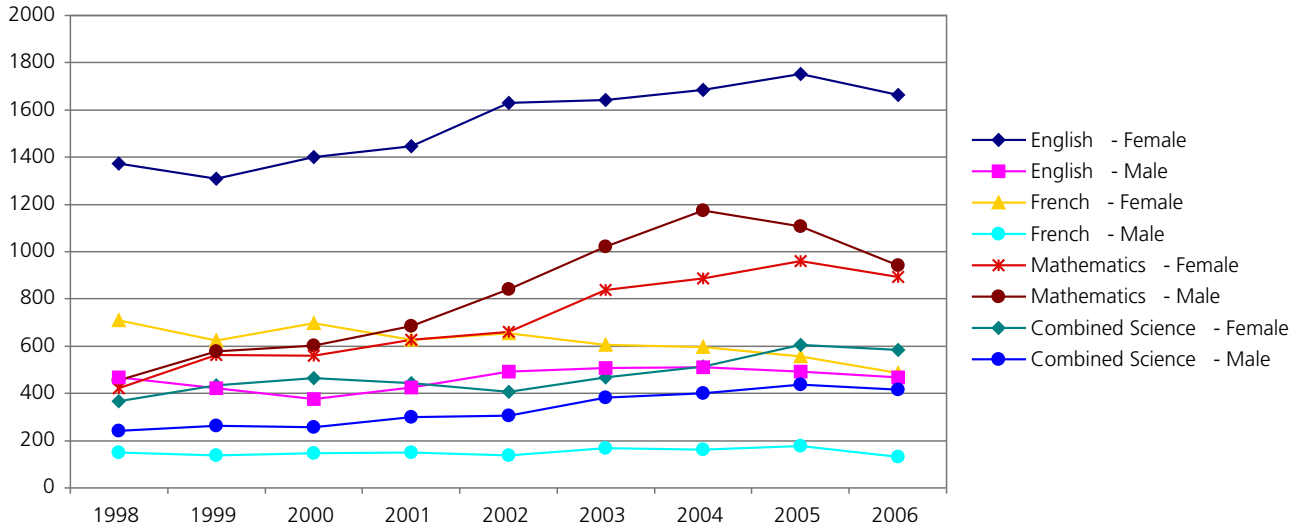


Table 2 - The number accepted to PGCE courses by subject, from 1998 to 2006

	Subject							
	English		French		Mathematics		Combined Science	
Data	Female	Male	Female	Male	Female	Male	Female	Male
1998	1372	467	711	151	421	456	368	243
1999	1309	421	625	137	563	579	435	264
2000	1401	376	696	146	559	603	466	256
2001	1447	425	627	151	627	684	442	301
2002	1630	492	654	137	661	841	406	307
2003	1641	509	606	168	838	1020	469	382
2004	1685	510	597	161	886	1173	514	400
2005	1753	491	557	177	959	1107	607	438
2006	1663	469	486	132	892	943	583	415



(Data from Graduate Teacher Training Register)

Notes

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