Mathematical Sciences in Australia
A Report for IMU
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Mathematical Sciences in Australia

Mathematical science is the language of science and technology, of engineering and the environment. Mathematical science stands behind many of the technologies, such as the internet, mobile phones and GPS systems, which have profoundly changed how and where we do business, communicate and socialise. It is a cornerstone of business and finance, health and medicine, biotechnology and industry.

Australia is strongly aware of the importance of mathematical sciences. A survey of Australian businesses and organisations undertaken by a Queensland Smart State Working Party in 2010[1] clearly identified the pervasiveness of mathematical science and its application across a range of industries and sectors – from research to not-for-profit organisations – and highlighted an ongoing demand for maths skills. The survey results emphasised the importance of mathematical capability not just in maths-based occupations or sectors, such as engineering, ICT or financial services, but also in other roles to support informed and evidence-based decision-making in corporate communications or community services.

This document provides an overview of mathematical sciences in Australia. The aim of the overview is to provide support for an application for an upgrade of status by the IMU of mathematical sciences in Australia.

Summary

The following summary provides an overview of mathematical sciences in Australia at present.

Australia's Investment in Mathematical Sciences

The following examples illustrate Australia's investment in Mathematical Sciences:

- The proportion of Australian service exports that are knowledge intensive has increased over the past 10 years; knowledge intensive service exports have increased from 39% of all service exports in 1998-1999 to almost 58% in 2008-2009[2].

[1] *Making Maths Matter*, Queensland Government Chief Scientist Office, 2010.
[2] Calculations based on ABS, Foreign Trade, unpublished data; OECD Stan Indicators Database, viewed 29 October 2010..

- The majority of Australian BERD (business' expenditure on R&D) was invested in the maths-related disciplines of engineering (54%) and information and computing sciences (26%) in 2008-09. Pure mathematical science was also explicitly identified as a BERD category (0.14%)[3]. Of the gross expenditure on R&D (GERD), of which BERD is a component, 0.088% of business expenditure was dedicated explicitly to mathematical sciences.
- Expenditure on R&D in the field of mathematical sciences stood at $215 million in 2006-07. Mathematical sciences is ranked number 10 in terms of R&D expenditure by field of research, as identified by the ABS in accordance with international practice[4]. R&D expenditure in the mathematical sciences is performed mainly in the higher education sector; this is consistent with investment in most other disciplines[5].

Australia's Excellence in Mathematical Sciences Research

The 2010 Excellence in Research in Australia (ERA) Report[6] lists Mathematical Sciences as its first Field of Research, with 6 subcategories: Pure Mathematics, Applied Mathematics, Numerical and Computational Mathematics, Statistics, Mathematical Physics and Other Mathematics.

The report contained the following figures for the mathematical sciences :

- Average rating: 3.2/5
  a rating of 3 or more is above world standard; 86% of assessed Units received a rating above world standard
- Full time equivalent researchers assessed: 880
- Research outputs: 8659
  Research outputs increased 28% over the reference period
- Research income: $104M
- Research Commercialisation Income: $22M

The mathematical sciences has its own RFCD (Research Fields, Courses and Disciplines)[7] in the Australian Research Council (ARC) classification scheme. In 2010, the mathematical sciences achieved the greatest success rate in ARC funded primary research (Discovery) grants: 58 grants approved out of 173 submitted, a 33.5% success rate compared with a national average success rate of 22.5%.

[3] Calculations based on ABS (2010) 8104.0 – Research and Experimental Development, Businesses, Australia, ABS, Canberra
[4] ABS cat. No. 8112.0 Research and Experimental Development, All Sector Summary, 2006-07.

[5] Ibid.
[6] Australian Research Council ERA National Report, 2010.
[7] Australian research is divided into 22 RFCD codes

Australia's Mathematical Sciences Organisations

Australia has over 20 national mathematical sciences organisations. Examples are given below.

Australian Mathematical Sciences Institute (AMSI)

AMSI[8] is a collaborative venture of 10 leading Australian universities with a nation-wide membership of 26 universities, two government agencies, the Australian Mathematical Society and the Australian Mathematics Trust. AMSI employs the equivalent of 8 full-time staff at its central office.

The mission statement of AMSI is:
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.*

In the research and higher education sector AMSI has an annual program which consists of:

- A 4 week residential summer school for 100 honours and postgraduate students;
- A 2 week residential winter school for 25 early career researchers;
- A one week bioinformatics symposium;
- An undergraduate vacation research scholarship program;
- The national sharing of 15-20 honours subjects in the mathematical sciences via Access Grid and delivered by AMSI members;
- The placement of around 25 PhD students annually into 3-5 month internships with public and private enterprise (along the lines of the MITACS intern program);
- A workshop program supporting around 15 events a year around Australia attended by more than 300 researchers and postgraduate students. This program is overseen by AMSI's Scientific Advisory Committee. It brings around 40 international visitors to Australia per year;
- A national lecture tour by an eminent mathematical scientist, in conjunction with one of the professional societies[9] .

AMSI's University membership (26 altogether) employed around 710 full time equivalent (FTE) research and teaching staff, 540 FTE postgraduate research students and 190 FTE Honours (fourth year undergraduates). [One year average over the years 2008-10.]

Australian Association of Mathematics Teachers (AAMT)

[8] www.amsi.org.au
http://www.amsi.org.au/images/stories/downloads/pdfs/general-outreach/annualreports/AMSI_annual_report2010-11.pdf
[9] http://www.amsi.org.au/research-a-higher-education/lecture-tours/amsi

AAMT[10] is the nation's premier organisation of school mathematics educators. It aims to support and enhance the work of teachers, promote the learning of mathematics, and represent and promote interests in mathematics education. It is a federation of 12 associations of teachers of mathematics from all Australian states and territories and has around 5000 individual and institutional members.

AAMT: Publishes hard copy and electronic newsletters for members.; Publishes three refereed journals (available by subscription), as well as other books, statements and conference proceedings; Provides selected Australian and international mathematics education resources through its mail order catalogue; Acts as a consultant and lobbyist on mathematics education issues; Conducts and supports a variety of projects and activities; Facilitates the professional networking of teachers and educators; Conducts national conferences; Advocates the development and use of its *Standards for Excellence in Teaching Mathematics in Australian Schools*.

Australian Council of Heads of Mathematical Sciences (ACHMS)

The ACHMS provides an annual forum for the 43 heads of university schools or departments of mathematics and/or statistics, presidents of the 7 professional societies associated with mathematics and statistics and representatives of the National Committee for Mathematical Sciences, Australian Mathematics Trust, Science & Technology Australia, AMSI and the relevant government agencies such as CSIRO and the Australian Bureau of Statistics. The ACHMS is supported by AMSI.

Australian Mathematics Society (AustMS)

The Australian Mathematical Society (AustMS) is a national society of mathematicians in Australia. Founded in 1956, its mission is the promotion and extension of mathematical knowledge and its applications.

The Society plays the following roles:

- Promotes mathematics in the community (through programs such as the "Sticking with Mathematics" media campaign);
- Represents the interests of the profession to government;
- Produces publications and submissions; Holds conferences and seminars ; Provides awards recognition of outstanding contributions to the mathematical sciences.

AustMS represents all professional mathematicians in Australia, both pure and applied. The special interests of applied mathematicians are represented by ANZIAM (Australia and New Zealand Industrial and Applied Mathematics), a division of AustMS [11]. The Society also has a number of

[10] http://www.aamt.edu.au/
[11] http://www.anziam.org.au/

affiliates, including the Australian Mathematical Sciences Institute, the National Committee for Mathematical Sciences, the Statistical Society of Australia Incorporated, the ARC Centre of Excellence in Mathematics and Statistics of Complex Systems (MASCOS), the Australian Association of Mathematics Teachers (AAMT), the Australian Mathematics Trust (AMT) and the Mathematics Education Research Group of Australasia Inc. (MERGA).

Accreditation, which allows the member the use of the postnominals GAustMS, MAustMS, or FAustMS, is a way of the Society recognising a member's qualifications and experience.

Publications of the Society include the Journal of the Australian Mathematical Society, the Bulletin, the Gazette, the Lecture Series and a sponsored publication by Halsted Press, Counting Australia In: The People, Organisations and Institutions of Australian Mathematics, authored by Graeme Cohen (488pp).

Australian Society for Operations Research

ASOR[12] was founded on 1st January, 1972 and has about 400 members nationwide. ASOR is affiliated to the International Federation of Operational Research Societies (IFORS). It serves the professional needs of OR analysts, managers, students and educators by publishing a National Bulletin and National and Chapter Newsletters. The society also serves as a focal point for operations researchers to communicate with each other and to reach out to other professional societies. The Society's objectives are to: Foster the development of the science of Operations Research; Foster the application of Operations Research wherever appropriate; Foster the widest possible exchange of information and ideas on Operations Research and related subjects; Define standards of knowledge in and to further the study of Operations Research.

Combinatorial Mathematics Society of Australasia (CMSA)

CMSA was formally established in 1978, having existed informally since 1972. The Society's aims are to facilitate, encourage and foster the branch of mathematics known as combinatorics throughout Australia and New Zealand. CMSA is governed by a Council and currently has over 150 members.

CMSA publishes the *Australasian Journal of Combinatorics*, with three volumes annually. The journal is refereed to a high standard and attracts submissions from around the world.

CMSA sponsors and oversees the organisation of the annual Australasian Conference on Combinatorial Mathematics and Combinatorial Computing (ACCMCC) and the ten-yearly International Combinatorics Conference (ICC). Student participation in these conferences is strongly encouraged through the provision of travel support and the award of a student prize for the best

[12] http://www.asor.org.au/page.php?page=1

student talk. At most every three years, the Society awards the CMSA Medal for outstanding and sustained contributions to combinatorics and the Australasian combinatorics community.

Mathematics Education Research Group of Australasia (MERGA)

MERGA[13] is an association that aims: to promote, share, disseminate and co-operate on quality research on mathematics education for all levels particularly in Australasia; to provide permanent means for sharing of research results and concerns among all members through regular publications and conferences; to seek means of implementing research findings at all decision levels to the teaching of mathematics and to the preparation of teachers of mathematics; and to maintain liaison with other organisations with similar interests in mathematics education or education research.

Founded in 1976, MERGA currently has about 300 individual members and many institutional subscribers from Australia and New Zealand, as well as other countries. MERGA is one of only four multi-national mathematics education societies to have obtained formal affiliation with the International Commission for Mathematical Instruction (ICMI).

MERGA has an annual conference. It also has a regular schedule of publications. These include refereed conference proceedings, two journals, a four-yearly review of mathematics education research in Australasia, books arising from Special Interest Groups, and some sponsored monographs. Electronic newsletters are distributed to members, and there is a moderated list for announcements as well as a web-based discussion forum for members.

National Committee for Mathematical Sciences (NCMS)

The Australian Academy of Sciences has 22 National Committees which are widely representative of its disciplines. Mathematical Sciences is one of these Committees[14]. The broad aims of the committees are to foster a designated branch or theme of natural science in Australia and to serve as a link between Australian scientists and overseas scientists in the same field. The membership of the NCMS includes representation of the professional societies and AMSI.

Recent publications by the NCMS are the National Strategy for Mathematical Sciences in Australia (2009) and the *National Strategic Review of Mathematical Research in Australia* (2006).

Statistical Society of Australia Inc. (SSAI)

SSAI[15] was founded in 1962 and is the sole professional body representing statisticians in Australia. The Society is governed by a Council and incorporates Branches in each of the five mainland States

[13] http://www.merga.net.au/
[14] http://www.science.org.au/natcoms/nc-maths.html
[15] http://www.statsoc.org.au/

and in the ACT. The objective of the Society is to further the study and application of statistical theory and methods in all branches of learning and enterprise. Currently there are some 700 members Australia-wide and membership is open to all those with an interest in statistics and the objectives of the Society. The Society is an affiliated organisation of the International Statistical Institute and is represented on several advisory bodies.

SSAI sponsors a biennial, four-day, Australian Statistical Conference as well as many professional workshops throughout the year. Support and encouragement is also given to outstanding achievement or promise in statistics via a range of medals and prizes. Together with the New Zealand Statistical Association, the Society publishes the Australian and New Zealand Journal of Statistics (four issues per year).

SSAI has a professional accreditation scheme which has the prime objective of indicating to the non-statistical community that the holder of the Accredited Statistician (AStat) qualification has achieved an acceptable level of professional competence in the understanding and application of statistical methods, and is bound by the Code of Conduct of the SSAI. For statisticians at an earlier stage in their career the Graduate Statistician (GStat) scheme indicates that the holder has recently completed a course of study equivalent to a good degree course with a Major in Statistics, including Graduate Diplomas.

Australia's Mathematical Sciences at Tertiary Level

Australia has a large number of mathematical sciences departments. The Australian Mathematical Society lists the following mathematics departments in universities in Australia, that provide web sites with information about staff, research and teaching activities: Australian Defence Force Academy; Australian National University; Bond University; Central Queensland University ; Charles Sturt University; Curtin University of Technology; Deakin University; Edith Cowan University; Flinders University; Griffith University; James Cook University of North Queensland; La Trobe University (Bundoora); La Trobe University (Bendigo); Macquarie University; Monash University; Murdoch University; Queensland University of Technology; Royal Melbourne Institute of Technology; Swinburne University of Technology; University of Adelaide; University of Ballarat; University of Canberra; University of Melbourne; University of Newcastle; University of New England; University of New South Wales; University of Queensland; University of South Australia; University of Southern Queensland; University of Sydney; University of Tasmania; University of Technology, Sydney; University of Western Australia; University of Western Sydney; University of Wollongong; Victoria University.

The following figures provide a profile of activity in learning and teaching in Australian universities:

- the number of universities in the country where mathematics is taught: 39[16]
- the number of universities in which a major in mathematics is taught: 25[17]

[16] DEEWR data, 2009

- the number of universities in which a major in statistics is taught: 15[18]
- the number of universities in which a major of maths and stats is taught: 20[19]
- the number of professors in mathematics in the country: 126 FTE Level E (full professors) and 128 FTE Level D (Associate Professors)[20]

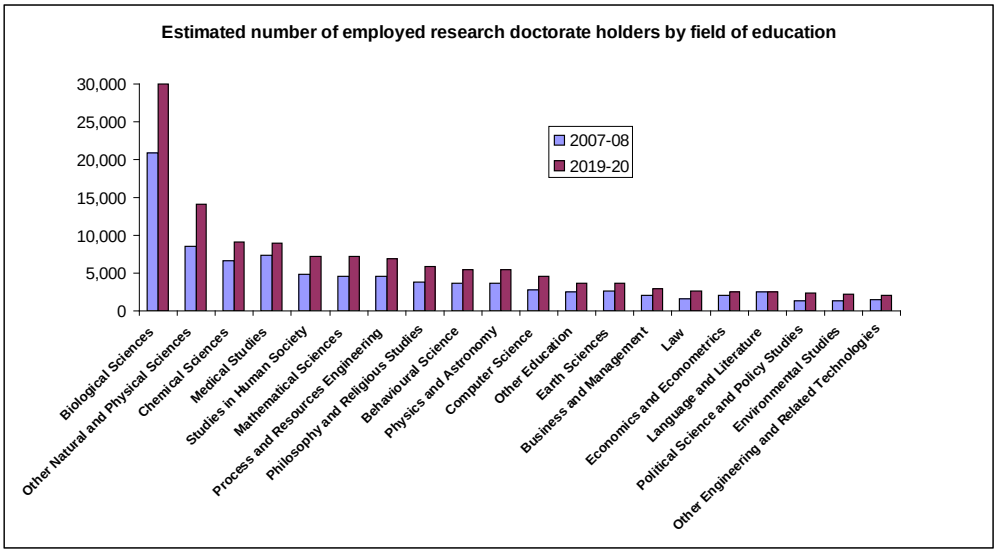
The following trends in mathematical sciences departments over the years 2007-2009 were reported in a 2010 Survey of University Departments, conducted by ACHMS:

- Increase in undergraduate mathematics and statistics subject enrolments (16/17 respondents);
- Increase in mathematics and statistics majors (4/7 respondents);
- Balanced number of honours or equivalent student numbers (5/10 respondents reported an increase; 5 reported a decrease);
- Increase in total number of research students (10/14 respondents)

The Australian Department of Innovation Industry, Science and Research (DIISR) report on Discipline-Specific Case Studies[21] provides the following figures:

- Mathematical sciences PhDs represented approximately 5.2% of Australia's PhD workforce in 2007-08. The PhD workforce in the mathematical sciences was projected to grow by just over 50 per cent by 2020.

[17] AMSI and ACHMS survey, 2010; completed responses from 32 departments
[18] ibid
[19] ibid
[20] ERA 2010 National Report, p. 34; limited to the number that meet the eligible researcher criteria defined in ERA
[21] DIISR Report, 15/03/2011. Quantitative information is based on several national and international data sets, including The Department of Education, Employment and Workplace Relations (DEEWR) higher education statistics collection; Graduate Careers Australia data in relation to employment outcomes of Higher Degree by Research (HDR) graduates; Australian Bureau of Statistics (ABS) survey and census data (Census 2006 and cat. no. 8112.0 Research and Experimental Development, All Sector Summary); The Organisation for Economic Co-operation and Development (OECD) online statistical database; Thomson ISI, National Science Indicators database; and The Australian Research Council (ARC) Excellence in Research Australia (ERA) initiative results from the 2010 assessment exercise. ERA results and analysis for each discipline were supplied by the ARC:



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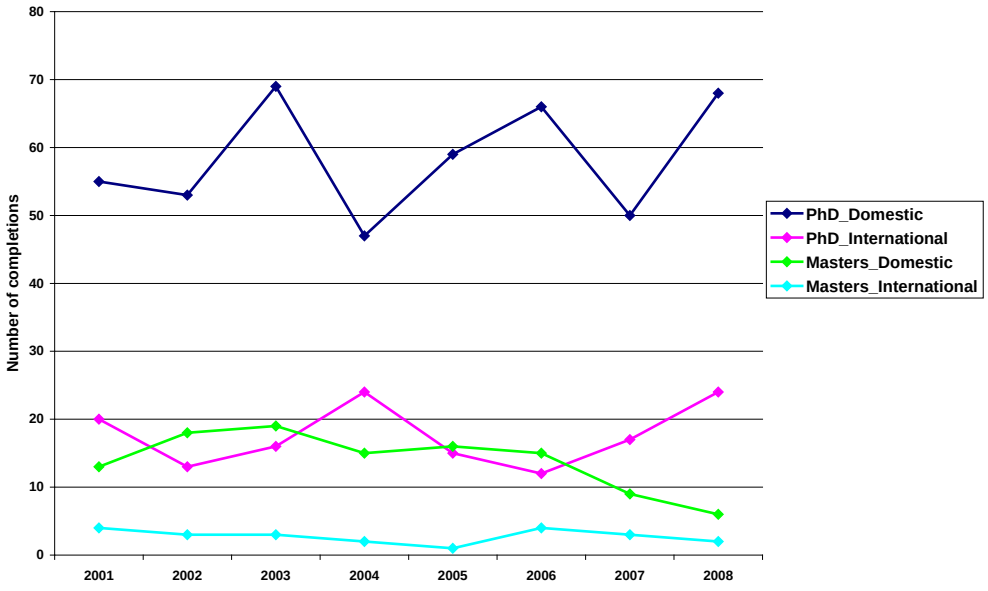

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- Responses to Australia's Graduate Destination Survey 2008 indicate that the majority (82.8%) of mathematical sciences HDR graduates considered their HDR qualification a formal requirement or important to their job – percentages significantly above the average across all disciplines (72%).

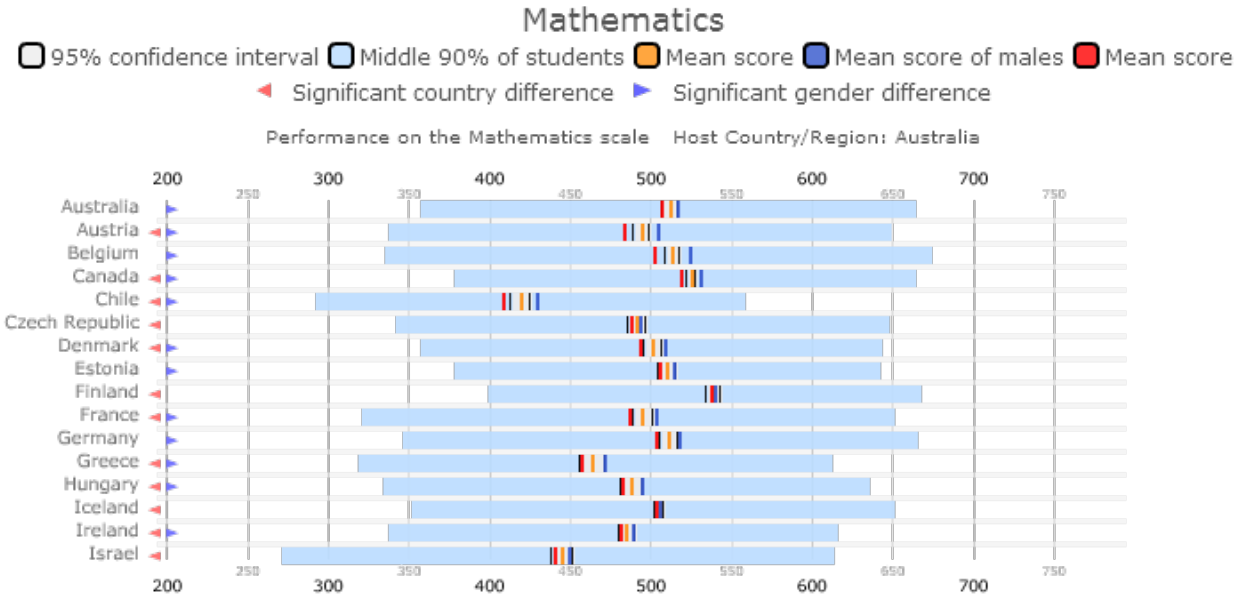
Australia's Mathematical Sciences at Secondary Level

[22] Source: Australian Council for Education Research, *Supply, Demand and Characteristics of the Higher Degree by Research Population in Australia*, Report for the Department of Innovation, Industry, Science and Research, June 2009, p. 54

[23] DEEWR University Statistics, unpublished data

The Trends in International Mathematics and Science Study (TIMSS) is an international assessment of the mathematics and science knowledge of fourth- and eighth-grade (Year 5 and Year 9) students around the world. The assessment is conducted every 5 years. In 2007, 48 countries participated in the assessment and Australia was ranked 14th globally in mathematics[24].

PISA (Programme for International Student Assessment) is an international study of 15 year old students. Since the year 2000 over 70 countries and economies have participated in PISA. The PISA 2009 profiles reported the overall score for Mathematics in Australia as 514 (95% CI 357-665). This is substantially above the overall score for all students of 450 (95% CI 377-541). The following figure is an extract taken from the PISA website[25].



The number of Year 12 Advanced mathematics students in Australia increased from 20,344 in 2007 to 21,233 in 2010[26]. The proportion of the Total Australian Year 12 population taking Advanced mathematics is just over 10%.

[24] TIMSS - Math Achievement of Fourth- and Eighth-Graders in 2007". http://nces.ed.gov/timss/results07_math07.asp

[25] http://stats.oecd.org/PISA2009Profiles/#; accessed 16/12/2011

[26] AMSI report, 2010.

Australian Mathematics Trust

The Australian Mathematics Trust is a not for profit organisation which conducts a pyramid of enrichment activities in mathematics and informatics which enable students to broaden and enrich their knowledge and skill in these subjects beyond what can be done in the classroom.

These pyramids start at the base with large multi-choice competitions which test basic knowledge and the student's ability to use this knowledge in problem solving situations. Students successful at this and wishing to go further may enter more advanced problem-solving events in which they are required to give argument-type solutions, and to learn more formal skills from course work which the Trust has developed. Finally the best students are invited to participate in more elite training which can lead to selection in Australia's teams to participate in the International Olympiads in these subjects. Several hundreds of thousands of students participate in the entry level events.

Together with this the Trust has a large catalogue of publications, which contain systematic collections of problem sets from various competitions and Olympiads and pedagogical books teaching students problem-solving methods of a more advanced nature than found in the school curriculum.

There is a large number of volunteers involved, setting the problems, moderating them, and in administration and a central office of salaried workers in Canberra. The overall governance is carried out by a Board appointed with a view to balance between mathematicians and business skills drawn from the public and private sectors, appointed by the University of Canberra, which is the Trustee, and there is a Trustee which outlines the rules of Trust objectives and management.

Australia's Mathematical Sciences Publications

Many publications relating to mathematical sciences in Australia are published annually. These include:

- Scientific articles published in refereed journal articles;
- Conference papers presented at national and international conferences;
- Government and other agency reports;
- General advocacy and external publications.

There are no direct figures for the number of publications relating to the above. However, a search of Google Scholar restricted to the field of Engineering, Computer Science and Mathematics, on 19th December 2011, revealed the following:

- Search terms "mathematical" "Australia": 32,800 articles in the last 10 years (2001-2011); 16,200 articles in the last two years (2010-2011);
- Search terms "statistical" "Australia": 26,700 articles in the last 10 years (2001-2011); 16,700 articles in the last two years (2010-2011).

As illustration of articles on general advocacy and external publications, over 30 publications related to these topics are listed on the website of the Australian Mathematical Sciences Institute[27].

[27] http://www.amsi.org.au/publications/amsi-publications