MATHEMATICS AND STATISTICS:

CRITICAL SKILLS FOR AUSTRALIA'S FUTURE

KEY FINDINGS AND RECOMMENDATIONS OF THE NATIONAL STRATEGIC REVIEW OF MATHEMATICAL SCIENCES RESEARCH IN AUSTRALIA

DECEMBER 2006
www.review.ms.unimelb.edu.au

THE FUTURE OF MATHEMATICAL SCIENCES IN AUSTRALIA IS IN JEOPARDY...

"The mathematics skill base in any country is too important for its future prosperity to let short term market mechanisms act alone. We sincerely hope that leaders in Australian government, academia and industry will collaborate with the mathematics and statistics community to develop an appropriate vision, and spark an Australian renaissance in our field."

— Professor J P Bourguignon, Dr B Dietrich, Professor I M Johnstone*

"Australia's distinguished tradition and capability in mathematics and statistics is on a truly perilous path. The decline has already taken its toll: the university presence has been decimated, in part by unanticipated consequences of funding formulas and by neglect of the basic principle that mathematics be taught by mathematicians, and the supply of students and graduates is falling short of national needs."

— Professor J P Bourguignon, Dr B Dietrich, Professor I M Johnstone*

THE CRITICAL NATURE OF MATHEMATICAL SCIENCES[1]

The mathematical sciences are fundamental to the well-being of all nations.

They drive the data analysis, forecasting, modelling, decision-making, management, design, and technological principles that underpin every sector of enterprise. Their influence extends beyond science related disciplines to financial services, the humanities, arts and the social sciences.

They are vital to research, development and innovation in business and industry, science and technology, national security and public health.

Worldwide demand for new mathematical solutions to complex problems is unprecedented and has led to an appreciation of the power of cross-disciplinary research within the mathematical sciences and with other disciplines.

The result is international competition for mathematical talent. This presents challenges for Australia. We need a strong base in the mathematical sciences. If we don't have it, our options for solving complex problems, adding intellectual value to new technologies, spearheading innovation and continuing to compete globally will be severely hampered.

Australia has a reputation for world class and innovative mathematical research, which can only be maintained through increased backing from governments, universities and industry. While this country cannot develop research expertise in all branches of the mathematical sciences, it must cultivate the depth needed to remain at the leading edge of key areas of innovation and the breadth to adapt new technologies to national benefit.

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.

If Australia is to maintain its place in the technological world, it needs greater investment in its fundamental mathematical sciences infrastructure.

[1] The term 'mathematical sciences' is used to encompass mathematics, statistics and the range of mathematics-based disciplines.

* ***International reviewers, National Strategic Review Of Mathematical Sciences Research In Australia***

Professor Jean-Pierre Bourguignon, Director, Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, France

Dr Brenda Dietrich, Director, Mathematical Sciences, IBM Thomas J Watson Research Center, Yorktown Heights, New York, US

Professor Iain M Johnstone, Department of Statistics, Stanford University, Stanford, California, US

...AND THIS MATTERS

KEY FIND

The Review had four key findings

1 Mathematical research in Australia is becoming increasingly narrowly focused.

At a time when, internationally, the major scientific advances are being made through collaborations between different branches of mathematics and other scientific disciplines, and by countries that invest heavily in mathematical research and education, Australian mathematicians and statisticians are becoming increasingly isolated and under-resourced.

Across most fields of mathematics and statistics, research output in Australia has become dependent on a small number of highly productive individuals working more or less in isolation.

Inadequate resources are available for fostering vital collaborative links between mathematicians and statisticians in research, academia, industry and education.

The loss of a small number of key mathematical scientists puts Australia at risk of a major collapse in research capability. Excessive reliance on a small number of scientists with specialised interests is eroding the broad skills base needed for a robust and adaptable research community.

2 The number of mathematics and statistics students and lecturers at Australian universities is critically low.

In the past decade, mathematical science departments in the Group Of Eight universities have lost almost a third of their permanent academic staff.

Mathematics departments in smaller universities have disappeared, and a number of formerly strong departments have halved in size.

Relative funding of mathematical sciences departments in universities is inadequate and does not reflect either their crucial importance or the real cost of delivering quality training of students.

In 2003, the Organisation for Economic Co-operation and Development (OECD) Education At A Glance report showed that only 0.4% of Australian university students graduated with qualifications in mathematics or statistics, compared with the OECD average of 1%.

There is clear evidence that the current supply of trained mathematicians and statisticians is inadequate and decreasing.

The nation's capacity to support research, research training and advanced education in mathematics and statistics is diminishing rapidly. The concentration of mathematical and statistical expertise in only a few universities undermines access to quality research, research training and undergraduate education in the mathematical sciences. As a result, Australian universities are unable to meet the demands of business, industry, government and the school sector for mathematically-trained graduates.

3

Mathematicians and statisticians are not teaching all the university courses in mathematics and statistics. Many university courses such as engineering that should include a strong mathematics and statistics component, no longer do.

As well as ensuring an adequate supply of properly trained mathematics and statistics specialists, the Australian university system needs to ensure that students from other disciplines, such as economics, education, engineering, and the biological and medical sciences, receive appropriate training in mathematics and statistics.

Mathematical and statistical material taught to students in other disciplines — service teaching — needs to be up-to-date, accurate and presented in a way that meets the present and emerging needs of these disciplines. Such teaching is best delivered by mathematicians and statisticians.

Competition for scarce funds available for teaching leads to the transfer of service teaching from university mathematical sciences departments to non-specialists in other departments.

The transfer of mathematics and statistics service teaching to other departments delivers a poorer educational outcome. It is a major cause of the erosion of the national mathematical sciences infrastructure.

4

Not enough trained mathematics teachers are entering the high school system. Australian students are abandoning higher-level mathematics in favour of elementary mathematics.

Increasingly, high school mathematics is being taught by teachers with inadequate mathematical training.

Nationally, the percentage of Year 12 students taking higher level – advanced and intermediate – mathematics fell from 41% in 1995 to 34% in 2004. This is limiting the level of training that can be supplied in undergraduate degree programs such as commerce, education, engineering and science.

Australian universities are lowering mathematics prerequisites and this is undermining enrolments in high school mathematics.

Australia will be unable to produce the next generation of students with an understanding of fundamental mathematical concepts, problem-solving abilities and training in modern developments to meet projected needs and remain globally competitive.

INGS

Australia needs its own mathematical sciences infrastructure and supply of properly trained mathematicians and statisticians.

Without these, Australia's existing industries will become less competitive, and the ability to participate at the cutting edge of scientific research and commercial innovation, or even to be aware of developments, will be compromised.

Mathematicians and statisticians take a long time to train and need local experts to train them. There is global competition for mathematical sciences expertise.

Without supporting infrastructure and a vibrant local mathematical sciences community, Australia cannot properly train enough mathematical scientists, the best of those who are trained will not stay, and Australia will be unable to attract replacements.

Outsourcing research to offshore providers is not a viable solution. International competitors will not sell cheaply the intellectual property Australia needs to become more competitive. For example, defence-related research and highly confidential commercial research and development cannot be safely outsourced.

INFRASTRUCTURE AND PERSONNEL FOR PRESENT AND FUTURE NEEDS MUST BE SUPPORTED

- The health of mathematics and statistics rests with the nation's universities, where the researchers and teachers of the next generation are trained, and where the fundamental mathematics and statistics that underpins future applications is developed.
- A critical mass of mathematicians and statisticians, within a distinct mathematical sciences department or school, is essential to keeping a core of research and teaching expertise intact and supporting flexible and evolving interdisciplinary links.

NETWORKING AND COLLABORATION ARE CRITICAL TO SOLVING NEW TECHNOLOGICAL PROBLEMS

- There are significant, proven benefits in bringing together mathematical scientists and research experts, and clients in other scientific disciplines and from business, industry and government, to work on joint projects.
- An appropriate balance between core discipline training and applications is needed for effective interdisciplinary collaboration.
- Collaborative national and international research networks are a cost-effective and essential way of maintaining vibrant, adaptable and up-to-date research capacity. Networks need long-term support.
- Mathematical sciences institutes are an effective way of supporting national and international collaboration and providing access to new ideas in a timely and cost effective manner.

THE WAY FORWARD

AUSTRALIAN MATHEMATICAL SCIENTISTS MUST RESPOND TO NEW CHALLENGES AND CHANGING CIRCUMSTANCES

- Mathematical scientists must promote the intrinsic value of mathematics and statistics to all Australians.
- Industry, teachers, researchers and academics must work cooperatively to improve support for the mathematical sciences and encourage greater numbers of students to pursue mathematics and statistics.
- Mathematical scientists of most value to the nation in the near future will have:
  - Sound fundamental understanding of deep mathematical and statistical concepts;
  - Facility with theoretical analysis;
  - Competence in operating research-level computer software;
  - Experience with mathematical or statistical modelling and in group collaborations; and
  - Excellent written and oral communication skills.
- Educational programs in universities must recognise and nurture these attributes.

A cross-section of Australian CEOs and senior executives from listed companies reported that they needed to add intellectual value to their products and innovations through skills in commercialisation, communication, computing, hardware and software development, optimisation, risk analysis, modelling and engineering disciplines.

They had a general expectation that graduates from science, engineering and allied degrees should have the requisite mathematics skills. Almost all preferred to, and did, source their graduates from Australian universities.

However, for most, their links with universities were either informal, limited to one university that met their particular needs, or with science or engineering departments rather than mathematics departments.

While most thought their graduates were adequately skilled on job entry, some put graduates through introductory, catch-up or specific on-the-job training. Most emphasised the need for government to drive a new thinking about mathematics, science and technology in the community, to improve the perception and popularity of science-based education.

AUSTRALIAN INDUSTRY NEEDS MATHEMATICALLY TRAINED GRADUATES

"I'd like to see Australia positioned as a globally recognised developer of new technology and technology products — not necessarily in production of those products — and in commercialisation and ownership of new technologies, electronic engineering and software development skills".

— **Graham Davie**
CEO, Redflex

"Mathematics skills... are very important because they appear in every facet of every job nowadays. Finance, research, statistics, money management, presenting information — maths is endemic. The sooner people acquire these skills, the better equipped for life they are."

— **Damian Lismore,**
Chief Financial Officer, Biota

"Our hopes for delivering and maintaining a well-skilled country must be linked to rebuilding the infrastructure of the mathematical and other enabling skills through our education system."

— **Peter Taylor,** *Chief Executive, Engineers Australia*

KEY RECOMM

The mathematical sciences in Australia require an immediate and substantial capital injection to build a critical mass of research, education, industry and government interaction, and ensure we maintain our technical and problem-solving capability.

1 Significantly increase the number of university graduates with appropriate mathematical and statistical training

2 Broaden the mathematical sciences research base

This must be followed up with significant annual funding to maintain a healthy mathematics and statistics infrastructure for national benefit.

A capital injection and ongoing funding will build, maintain and enhance:

- University mathematics and statistics departments essential to building core expertise
- Networking and collaboration to get the best value from widely geographically distributed departments in Australia
- Networking and collaboration with the best overseas mathematicians and statisticians.

1a. RE-BUILD and/or **MAINTAIN** mathematical sciences departments in every Australian university, to provide a mutually supportive core informed by fundamental developments in the mathematical sciences. This is essential both for the specialist training of mathematicians and statisticians, and for appropriate training of other users of mathematics and statistics.

1b. ENSURE service teaching of mathematics and statistics is performed by mathematicians and statisticians, to provide up-to-date, soundly based courses.

1c. PROVIDE every university with the appropriate mathematical and statistical consulting infrastructure to ensure that research undertaken by staff and students is efficiently planned and the results validly assessed. This infrastructure is best provided from within a mathematical sciences department, rather than by relying on dispersed individual consultants with inadequate peer support.

2a. RE-ESTABLISH the critical mass for mathematical sciences research by rebuilding the numbers of permanent academic staff in mathematical sciences departments and providing career paths in Australian universities for talented early-career mathematicians and statisticians.

2b. PROVIDE new, additional and ongoing funding for Australia-wide networking to increase the strength of the national research enterprise.

2c. ENCOURAGE interdisciplinary work, especially in biological and medical sciences and in newly emerging areas. Ensure that such work is properly valued in research assessments and by granting agencies.

2d. Since 2002, the Australian Mathematical Sciences Institute (AMSI) has supplied strong, unifying support for mathematical research, education and industry liaison. **PROVIDE** funding for AMSI that supports its critical role in providing national infrastructure for national and international collaboration.

MENDATIONS

3 Identify, anticipate and meet industry needs for a pool of tertiary-trained expert mathematicians and statisticians

3a. CREATE internship programs for undergraduates, research students and academic staff to spend time in industry and provide opportunities for industry-based mathematical scientists to contribute to teaching and research within universities.

3b. ENCOURAGE and **SUPPORT** applications for Linkage Grants and other schemes that bring together government, university and private resources for commercial and strategic collaboration.

3c. BUILD on existing structures and collaborations with international networks.

3d. INCREASE the engagement of mathematical scientists with the wider university community by joint appointments with other departments, interdisciplinary projects and shared supervision of research students and post-doctoral fellows.

3e. DEVELOP short courses and post-graduate programs to meet current and emerging needs of business and industry.

4 Ensure that all mathematics teachers in Australian schools have appropriate training in the disciplines of mathematics and statistics to the highest international standards

4a. ENSURE future teachers of mathematics in schools acquire adequate discipline knowledge — appropriate to the teaching level — provided by mathematical sciences departments, as well as education in the practicalities of teaching school mathematics. Faculties of education and mathematical sciences departments need to cooperate to ensure that both these aspects of the training of teachers are properly addressed.

4b. DEVELOP national accreditation standards for teachers of mathematics at all levels of schooling, to ensure that the mathematics training expected of teachers aligns with international best practice; and develop appropriate education programs to ensure that future teachers meet these standards.

4c. DEVELOP appropriate mathematics courses for trainee teachers, teachers requiring re-training, and those in the process of changing careers. **PROVIDE** relevant professional development in mathematical content for all mathematics teachers.

5 Encourage greater numbers of high school students to study intermediate and advanced mathematics

5a. In liaison with tertiary representatives, state and territory education departments, **DEVELOP** secondary mathematics syllabuses to take appropriate account of the legitimate needs of post-school education, in terms of topics covered and the level of understanding developed.

5b. PROMOTE the vast – and increasing – range of rewarding careers available through studying mathematics and statistics.

5c. REWARD students for taking intermediate and advanced mathematics at high school by including scaling or bonus mechanisms when computing the Equivalent National Tertiary Entrance Rank (ENTER) or other tertiary entrance scores.

"In this ever more competitive global economy, Australia's science, engineering and technology skills need to match the best in the world."
— **Prime Minister John Howard,** speech in Sydney, 18 September 2006

"Every advanced industrial country knows that falling behind in science and mathematics means falling behind in commerce and prosperity."
— **Gordon Brown, UK Chancellor of the Exchequer,** Budget speech, March 2006

CONTACTS

Associate Professor Barry Hughes,
Department of Mathematics and Statistics,
The University of Melbourne
T: +61 3 8344 5557
E: hughes@ms.unimelb.edu.au

Professor Hyam Rubinstein,
Department of Mathematics and Statistics,
The University of Melbourne
T: +61 3 8344 5550
E: rubin@ms.unimelb.edu.au

The full Review is available online at
www.review.ms.unimelb.edu.au

WORKING PARTY

Chair:
Professor Hyam Rubinstein, FAA, Department of Mathematics and Statistics, The University of Melbourne

Executive Director of Review:
Associate Professor Barry Hughes, Department of Mathematics and Statistics, The University of Melbourne

Professor Jean-Pierre Bourguignon, Director, Institut des Hautes Etudes Scientifiques, Bures-sur-Yvette, France

Dr Brenda Dietrich, Director, Mathematical Sciences, IBM Thomas J Watson Research Center, Yorktown Heights, New York, US

Professor Iain M. Johnstone, Department of Statistics, Stanford University, Stanford, California, US

Professor Peter Hall, FAA FRS, Mathematical Sciences Institute, Australian National University

Dr Edwin van Leeuwen, Global Manager – Exploration and Mining, BHP Billiton

Ms Jan Thomas, Executive Officer, Australian Mathematical Sciences Institute

ADVISORY COUNCIL

Chair:
Professor Michael Cowling,
FAA, President, Australian Mathematical Society Inc., School of Mathematics, University of New South Wales

Industry, university and government representatives from Australia, New Zealand, and the United Kingdom.

Australian Academy of Science