Math matters

The sum and the product of our difficulties: Challenges facing the mathematical sciences in Australian universities

Peter Hall

There is little dispute that the mathematical sciences in Australia are in decline. In some fields the fall is precipitous. My own, statistics, is a case in point. Indeed, it is doubtful we could adequately fill as many as half of the Chairs of Statistics that are currently vacant in Australia, or which will become vacant during the next decade.

In one or two other areas, for example theoretical mathematics, it is not so long since we were blessed by a cluster of brilliant, younger scientists. But the wake they leave is beating against a sandbar; there are few young men and women stepping up behind them. This decline in mathematics will likely sap the strength of Australian science and engineering well into the future, since the technologies that our nation must create and develop, in order to advance our economy and our culture, will rely on the mathematical sciences.

The decline of Australian mathematics can be quantified in a variety of ways. For example, the number of mathematicians working in Australian universities is today between 60 and 70% of what it was in the mid 1990s. The number of Honours mathematics graduates in the five-year period from 1997 to 2001 was only three-quarters of what it had been in the previous five years [4]. The number of Departments of Statistics remaining in Australia is today only three; fifteen years ago there were at least three times that number, when there were fewer than half as many universities as now, and when the demand by employers for trained statisticians was far less than at present. The shortage of statistics graduates in Australia is so acute that it inhibits foreign investment [2].

It is less easy to identify the reasons for the decline. They are multifaceted and interacting, and as a result their combined impact is greater than one would expect from the sum of the individual contributions. To an extent, a decline can be seen abroad, too, for example in the US. However, there it is being driven by the demand for mathematicians to work in newly developing areas of science and technology, not (as here in Australia) by funding cuts to higher education. Nations with stronger mathematical-science cultures than our own often successfully supplement their depleting ranks of mathematicians by drawing the strongest from Australia; see, for example, [6], [7].

In comparison with the mathematical-science communities in Europe and North America, that in Australia is fragile. This is due partly to its significant contraction during the last decade. Very few new, continuing positions in mathematics are available, and the number of ARC-funded research fellowship posts, in the mathematical sciences, has recently declined. For many mathematical scientists, the only way to ensure a secure, attractive career path is to leave the country.

Particularly in applied fields, strong demand for mathematically skilled employees from both industry and foreign universities has put mathematics in Australian universities under exceptional pressure. At the other end of the mathematics spectrum, theoretical mathematics, the tumult in our universities during the last decade has driven away senior, as well as younger, mathematicians.

Of course, issues outside the university sector play a role in producing these outcomes. The problems are linked to the well-publicised shortfall in trained, skilled mathematics teachers in schools. This has meant that the mathematics background of the average Australian university student has declined over the last thirty years. The problem is becoming steadily more serious. For example, under the Commonwealth Government's latest Relative Funding Model, it is financially advantageous for a university to offer a prospective mathematics teacher a BEd degree (during which time they cover less material than in the first half of a BSc degree in mathematics), rather than a BSc plus a Diploma of Education.

Other 'external' factors, too, deserve more attention than they sometimes receive. For instance, the similarity of Australian culture to that of several other countries, for example of Canada, the UK and the USA, where performance in the mathematical sciences is (on the whole) more highly valued, makes it relatively attractive for Australian mathematicians to emigrate. Mathematicians in continental Europe, for example, report less tendency of their nationals to leave. A senior French colleague has observed that, while most of his younger staff wish to work in North America for a period, they often return home, even though doing so sometimes means enduring lower pay and inferior working conditions.

All these problems have contributed to the particular difficulties we face in Australia. But the catalyst that has helped to multiply the impact of the difficulties has been the relative indifference of the Commonwealth Government's science and education policies to the consequences, especially for Australia as a whole, of lack of investment in the mathematical sciences.

This indifference does not arise through an absence of information from us. Many Australian mathematicians have contributed to the plethora of recent reviews of Australian science and Higher Education. But it is not clear that our voice has been heard. Had we, in our research, circumnavigated our problems as assiduously as the government has managed, without moving determinedly to solve them, we would have long since lost our research grants, and might have been shed from the nation's shrinking mathematics work force. There has been a fair degree of federal fiddling, while Australian mathematics burns.

In particular, access by mathematical scientists to ARC research fellowships has become increasingly difficult. The breadth of coverage of theoretical mathematics on the relevant ARC committee has been halved, from two to one. The need for a separate ARC Mathematical Sciences panel is now acute. And the much-lauded Federation Fellowship program has done little to keep Australia's top mathematical scientists in the country.

For example, during 2002 and 2003 we lost Vikram Krishnamurthy (a particularly gifted stochastic analyst) and Nick Wormald (an especially strong combinatorialist) to Canadian Research Chairs. The Canadians' bold, but highly successful, program offers 'research and salary support for outstanding researchers at the peak of their careers, as well as for those whose careers are ready to take off.' It is often ranked ahead of Australia's Federation Fellowship scheme, in that it creates substantially greater depth in the research community. Indeed, Canada is well on the way to achieving its goal of 2000 Canadian Research Chairs by 2005. The irony that this program should work so well against Australia, for example by taking Krishnamurthy and Wormald from us, is probably lost on the architects of our Federation Fellowship scheme.

Another reason we lose so many mathematical scientists abroad, and why relatively few mathematics students choose to go on to graduate work today, is that mathematics teaching in Australian universities is poorly funded. Class sizes are high, little assistance is available for tutorials or grading, and (in all but a few universities) there are no longer opportunities for streaming students into 'advanced' and 'standard' courses, in order that gifted students might receive an especially challenging education.

Commonwealth funding for higher education, expressed as a percentage of GDP, has fallen each year for the last eight, from 0.72% in 1996–7 to 0.53% in 2003–4. Moreover, mathematics courses in particular are insufficiently well funded. For example, in 2005, under the Relative Funding Model announced by the Commonwealth Government in *Our Universities: Backing Australia's Future*, government financial support for a mathematics or statistics student will be only two-thirds of that for a student of computer science. The cost of teaching an average computer science course is scarcely more than that for, say, a typical statistics course.

The result will be a continuation of the downward spiral which has decimated statistics education in Australian universities, and brought the teaching of mathematics to its nadir. Courses will be directed towards an ever-decreasing common denominator of students, in order to maximise class sizes and recover the expenses of teaching. Students will be given basic numeracy skills, but increasingly they will be denied the opportunity to train as mathematical scientists.

The strategic importance of the mathematical sciences to Australia's future can hardly be overstated. Virtually all contemporary technologies, especially those in which Australia is endeavouring to gain a foothold (e.g. bioinformatics and information & communications technology) have mathematics at their heart. Internationally, the need to increase mathematics skills across all scientific disciplines is being repeatedly endorsed. Biology, once one of the least quantitative sciences, is currently absorbing the lion's share of science research budgets in many countries, and is moving rapidly to heighten its participation with the mathematical sciences community. For example, four of the eight recommendations of the US blueprint for undergraduate training of future research biologists call for increased involvement with the mathematical, physical and information sciences [1]. However, it may not any longer be possible for Australia to move in the same direction; as we grow our commitment to the biological sciences we are strangling the mathematical sciences.

More broadly, the reasons mathematics is so vital to Australia's future are the same as those for which the US National Science Foundation established the 'NSF Mathematical Sciences Initiative,' increasing its commitment to mathematics at a rate of 20% per year, year after year:

Science is becoming more mathematical and statistical — not only the physical and information sciences, but also the biological, geophysical, environmental, social, behavioral, and economic sciences. There is a vital need for mathematicians and statisticians to collaborate with engineers and scientists to explore *the frontiers of discovery, where science and mathematics meet and interact. Another reason is that the technical work force, as well as society at large, needs more mathematical skills today then ever before. Technology-based industries fuel the growth of the US economy, which, in turn, relies on large numbers of college graduates well versed in mathematics, science, and engineering. In our increasingly complex world, the need for broad mathematical and statistical literacy becomes ever more acute* [8].

Tondeur, a recent director of the Division of Mathematical Sciences at the NSF, sees an extremely bright future for this field, fueled by its unique ability to port intellectual innovation directly to applications, and to produce economic benefits across an extraordinarily broad spectrum. He writes elsewhere that

...the opportunities for the mathematical sciences at the beginning of this century are fantastic. This century is going to be one of unprecedented pervasiveness of mathematical thought throughout the sciences and our learning culture. In a data driven world, mathematical concepts and algorithmic processes will be the primary navigational tools. The challenge for the mathematical sciences community is to seize this opportunity, and thereby help the world of tomorrow [9].

The Australian mathematical sciences community is attempting to achieve these goals, for example through the fledgling Australian Mathematical Sciences Institute. Until now, AMSI has been funded largely by cadging resources from individual universities and state governments. Its success in this regard has recently been rewarded by federal assistance for its education initiatives, through the recently-announced award to AMSI of Australia's International Centre of Excellence for Mathematics Education. This positive outcome, and the successful bid for the ARC Centre of Excellence for Mathematics and Statistics of Complex Systems, have demonstrated both the potential and the unity of the Australian mathematical sciences community. However, national funding for AMSI's broad research mission, in addition to its roles in teaching, training and learning, is needed.

The problems created by the decline of the mathematical sciences impact on our nation's security. Intelligence agencies in all developed countries rely on university mathematics departments to produce men and women with the necessary analytical and technical skills. When those departments are having difficulty maintaining their courses, the problem has a security dimension. The US National Security Agency acknowledges that it is the world's largest employer of mathematicians. It was a major supporter of the NSF's push to expand its funding for the mathematical sciences. Its former director, General W.E. Odom, has described the importance of this relationship:

While serving as the director... I realized that world-class mathematicians devoted to cryptology and cryptanalysis were critical for success. I was even more fascinated when I was made aware that continuing advances in mathematics are no less critical to breakthroughs in all *of science and technology... Even leading scientists in other fields sometimes are not aware that they are limited by extant mathematics and that new mathematics can be developed, leading to major advances in their own work... A strong mathematics community is critical to both the economic and the military health of the nation. This is why I became involved in support for mathematics as a public policy issue* [5].

Commenting on Tondeur's work for the NSF, Odom remarked that 'he and the [NSF] director found some remarkable support in the White House and in the Office of Management and Budget, where mathematics is now seen as a high-payoff investment' [5]. In stark contrast, policies for funding research in Australia encourage university managers to view mathematics in the opposite way — as an investment with especially low returns, and as a field which should be discouraged relative to expensive, equipment-intensive fields such as the experimental sciences.

Indeed, the fact that, in Australia, the quantity of external research income drives the level of block-grant research funding has led some research managers to support fields which either attract large quantities of commercial income (regardless of intellectual or scholarly level), or which demand large, expensive equipment purchased through research grants; and to discourage the inexpensive intellectual sciences, in particular mathematics. Pointing to league tables of 'research performance' produced by the Commonwealth Education Department, in which rankings are determined by research inputs, university managers have argued that the 'research performance' of mathematicians is inferior to that of experimental scientists, and that traditional ways of assessing performance (for example, by peer review) are 'subjective' relative to the government's approach based on dollars of research income (garnered from almost any source). These specious arguments have depressed both morale and the level of resourcing of the mathematical sciences in Australia. They are the apocryphal-but-true tip of an iceberg of horror stories that Australian mathematical scientists tell about the funding of their discipline.

The Education Department responds that their formulae were never meant to be used in this way. That is most likely true, but Education bureaucrats would know from their own experience (e.g. with outsourcing) that ways of measuring, and rewarding, performance impact massively on the ways in which people actually do perform. If the Department measures and rewards performance in terms of numbers of research dollars earned, or numbers of papers published, or numbers of PhD students graduated, without any attempt to ascertain quality, then it can only feign surprise when it finds that university managers visit the same superficial criteria on individual academic staff members.

For all these reasons, the Australian mathematical sciences community has been served poorly by government policies on research and Higher Education. In many instances those policies have not rewarded excellence, despite the optimistic claims that have been made for them. They have in fact seriously penalised some highly performing Australian mathematical scientists; and they have not created adequate career paths for younger Australian mathematical scientists, resulting in many of them leaving for abroad, or not returning after doing their graduate work overseas.

These major areas of neglect are arguably those in most serious need of redress, if mathematics in Australian universities is to be maintained consistently at high levels. Along with a need for better support of mathematics teaching in universities, they comprise our primary requests for improvement. We seek:

- increased funding for university mathematics teaching, at a level that is current for courses in computer science, permitting (for example) streaming of mathematical science curricula into 'advanced' and 'standard' courses;
- more research fellowships, perhaps with teaching components (like the US VIGRE program; see, for example, [3]), to allow young, first-rate Australian mathematicians to start Australian careers;

- fundamental changes to the Commonwealth Government's way of measuring research performance, so that it does not discriminate against the intellectual sciences, and so that it measures quality rather than quantity.

It is in the national interest that the decline in the mathematical sciences in Australia be reversed. Tondeur [8] notes that 'public literacy in mathematics and statistics, and appreciation of their role in modern day life, are critical for societal progress.' However, this literacy, and this appreciation, are in retreat in Australia. If we do not properly resource the mathematical sciences, our nation will not be able to achieve the ambitious goals it must set itself if it is to be successful, and secure, in an increasingly competitive and dangerous world.

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Mathematical Sciences Institute, Australian National University, Canberra, ACT 0200
E-mail: Peter.Hall@maths.anu.edu.au