Math matters

Tony Guttmann

The Mathematical Sciences—is there a future?[1]

Last year, at a Summer School in Canberra, Nobel Laureate (Physics) Steven Chu advised the student participants that the best investment they could make in their future was to study mathematics. His argument was that mathematics is the language of science, and whether one works in the traditional areas, such as physics, chemistry, finance or genetics, or the newer disciplines of nanotechnology, biotechnology, or information systems, mathematics is the key to explaining existing phenomena and predicting new ones.

Despite its importance, the situation of mathematics in Australia is marginal. The mathematical sciences eke out a tenuous existence. At the school level, we have a growing crisis in the number of properly trained teachers, a decline in the number of year 11 and 12 students undertaking higher level mathematics (which is essential for tertiary study of the more mathematically focussed courses) and a school student body performing at the mid-level in international comparisons, and well below the performance of our closest neighbours and major trading partners, such as Singapore, Hong Kong, China and Japan. There is also the tendency of educational authorities in some States to "dumb-down" the curriculum to make it more accessible. The current situation in WA is a case in point.

From my perspective, the major problems facing the mathematical sciences in this country are two-fold. One is underfunding—a condition readily addressed in theory, though harder to achieve in practice, and I shall expand on this problem below.

The other is an attitudinal change in students due to a changed educational emphasis. An attitude is being bred in schools that efforts are by definition successful. There are degrees of success, to be sure, but the concept of failure, or unsatisfactory work is considered to be potentially damaging to students, and so must be avoided. An extreme example is, upon asking "what's 2+2?" when answered "5", to respond "very good, that's really close!" In schools, and also in universities in consequence, there is a flight to subjects where, so it is said, one person's opinion is as good as another's, there is no right or wrong, and even perceptions of quality are in the eye of the beholder.

As a consequence, subjects like mathematics and statistics in particular, and to a large extent physics and chemistry, where concepts of correct and incorrect are fairly clear, are struggling. Many students of history can discuss World War II in terms of the social or societal impact, but may not be able to tell you in which century it was, let alone that it was from 1939–1945, thus linking the war to other events of that period. I don't believe there is any short term solution to this problem, except to expose it. It is more advanced in the UK than in Australia, and has led to an attitude of entitlement among too many young people, who are unfamiliar with struggle, and hence robbed of the joy of success, particularly after a period of struggle.

On a more positive note, there has, in recent years, been some appreciation by Governments at both the State and Federal level of the importance of the mathematical sciences, and of the need to nurture them.

[1] Based on my submission to the Review of Mathematical Sciences, 2006

The Victorian Government has funded the Australian Mathematical Sciences Institute (AMSI), while the Federal Government has funded the International Centre of Excellence for Education in Mathematics (ICE-EM). The Australian Research Council has funded MASCOS, the Centre of Excellence for Mathematics and Statistics of Complex Systems. But these three centres, valuable though they are, represent a total investment of less than $5 million p.a., which is, by Government spending levels, petty cash.

At universities, things are grim. With the increasing reliance on full-fee paying overseas and local students, the Federal Government has gradually been withdrawing from the funding of universities. Many of our top universities now receive less than 30% of their income in direct grants from the Federal Government. As not many full-fee paying students are studying the mathematical sciences, this naturally disadvantages the discipline in the eyes of Vice Chancellors, who have to keep the enterprise afloat. At the same time, the Federal Government wishes to impose an increasing level of control and accountability on universities.

Another concern is that disciplines, like engineering, that have traditionally included a substantial body of mathematics in their program, are slowly but inexorably decreasing the amount of mathematics they require, and/or the level of mathematical pre-requisites for an entering student.

One problem is the Federally recommended discipline funding formula that is disadvantageous to mathematics departments—that is to say, a university will get more money from the Federal Government for, say, a computer science student than for a mathematics student. Can universities be blamed for increasing the resources in computer science, in preference to mathematics, under such a regime?

One consequence of this is that Australia has no truly world class Department of Mathematics or Mathematical Sciences, despite pockets of excellence, and a general perception that we punch above our weight. There are several reasons for this, and I will consider a few. Firstly, I believe that mathematical talent, like musical talent, is distributed fractally. For each 1000 very good mathematics students, there will be 100 excellent such students, 10 outstanding students and 1 virtuoso. Each year or two, on average, at my own university, the University of Melbourne we graduate one outstanding or virtuoso student. He or she will almost invariably go to the USA for graduate study, will undertake postdoctoral training there, and be offered a Faculty position at a top university and will make their career there. If we are lucky, they will return to Australia to visit family occasionally, and we may benefit from a research seminar, or a short course of lectures at best.

By way of comparison, if one of our world class sportsmen, like Thorpe, Hackett, Henry or Mottram, went off to the US because conditions there were better, there would be a national outcry! One reason they don't is that they have superb conditions here, and are reasonably rewarded for their efforts.

We do however benefit from Ph.D graduates from Europe and Asia, and, to a lesser extent, from North America, who come to work with mathematicians in those pockets of excellence I referred to above. Many of them love Australia, the lifestyle, and the climate. Most would willingly stay, but the number of permanent positions available at universities is tiny. So the situation is that we fail to keep, or attract back, our best students, and nor do we keep our best visitors! As the overseas trained scholars represent a huge investment by their home countries in their education, Australia is really wasting a valuable opportunity here.

Having sketched some of the problems, let me outline some, possibly radical, solutions. Firstly, we need to improve the situation in schools by offering more professional development to existing mathematics teachers, more incentives for mathematics graduates to enter the teaching profession, and a better path for teacher training.

The training of teachers can be improved by making sure that mathematics teachers have a mathematics degree, followed by a Dip. Ed. or equivalent. (And the integrity of Dip. Ed courses, in terms of their focus on mathematics teaching, must be ensured). Their mathematical education should not be provided by Education faculties, but by discipline experts. ICE-EM is helping by producing exemplary teaching aids for teachers of mathematics in the middle school years. Secondly, to address the current shortfall in teacher numbers, salary loadings should be paid to teachers in disciplines in which it is difficult to find sufficient numbers, like the mathematical and basic sciences. Some may claim that this is unfair, but consider that such teachers already have to saddle the burden of a higher HECS debt than, say, an Arts graduate, so they have paid more to become a maths/science teacher. Is it so unfair that they should then, in turn, be paid more? In the UK, prospective mathematics teachers pay no fees, and get a cash bonus on signing on, which totals some £25000 over three years.

As a measure to address the shortage of properly trained mathematics teachers as quickly as possible, short term retraining courses for highly numerate individuals from other disciplines, such as engineering, may also be cost effective. Attempts to retrain teachers from areas entirely outside mathematics, as has been attempted in some States, should be resisted.

While some professional development is provided by State education authorities, it is far from sufficient. Too much of the State Education Department's professional development budget is spent on training courses for values education, and classroom discipline matters. Important though these are, discipline specific professional development is at least equally important. Indeed, a well-informed, engaging teacher is much less likely to have discipline problems than one struggling with the material, and whose uncertainty will be all too clear to the class.

These measures may halt the decline in students taking higher level mathematics. While the number of students undertaking year 12 mathematics has kept pace with population growth, looking more carefully at the numbers, one sees that the lowest level of year 12 mathematics is showing significant growth, mid-level is growing in line with population growth, but higher level maths is in decline. This is a disaster for a country that wants an appropriate supply of home-grown engineers, scientists, finance experts, statisticians and related professionals.

At the University level, we should bite the bullet and strive to build a few world class mathematical science departments, while at the same time ensuring that an adequate undergraduate mathematical education is available at all universities .

An alternative view, held by some of my colleagues is that, for a small and somewhat scientifically isolated country like Australia, it would be a mistake to strive for one or two world class departments. Having excellence concentrated in one place leaves it vulnerable to stochastic extinction, either as a victim of the tall poppy syndrome, or just being subject to ill-advised decisions by managers. Similar arguments apply against trying to create a Harvard or Stanford of the south—unless of course the Higher Education budget is substantially increased, which doesn't seem likely.

Another danger (of the proposed system of just one or two world class mathematical science departments), is the bleeding of student talent to those departments and the demoralisation of talented academics who do not have the opportunity of employment at those top institutions. A possible solution to this is to make some changes to the current ARC structures. At present, mathematics is bundled up with information sciences. This is both an unnatural and an uneven conjunction. The number of information science panel members of the ARC College of Experts, who determine who gets funded, significantly exceeds the number of mathematical scientists. Secondly, the nature of scientific publication in the two areas is quite different. A mathematician will frequently labour over a major piece of work for a year, two years, or more, whereas the publication of comparatively brief , and more frequent, conference proceedings is the norm in the information sciences. I suggest that a stand-alone panel be established for the mathematical sciences, ideally with increased funding. But the Canadian model for funding mathematical scientists is certainly worthy of close scrutiny. In Australia, a small number of high fliers typically receive grants of $100,000 pa or more. This limits the number of recipients. In Canada however, nearly every productive mathematician actively prosecuting internationally competitive research is likely to be funded. The average grant size is 1/3 to 1/4 of that received by their Australian counterparts.

I stress that this suggestion relates only to research grants for established scientists in fully funded positions. It would need to be accompanied by more research fellowships—at all levels—that go directly to individuals, these to be taken up at the institutions of the candidates' choice.

The activities of ICE-EM and AMSI will also be vital to ensure that students at all universities have access to the very best mathematicians, through the funding of international conferences, summer and winter schools and the creation of Access Grid rooms. All these activities are currently being funded, to an extent, but could be substantially expanded.

The Federal Government could financially encourage universities to bolster their mathematical sciences departments. One way would be to change the funding model that is so disadvantageous to mathematics. This would make it possible to permanently retain some of the outstanding young postdoctoral fellows that come to this country. Another is to provide earmarked infrastructure funding. I have recently returned from China where I attended the opening of the Nankai Institute of Mathematics in Tianjin. This building, which dwarfs most academic buildings on Australian campuses, is equipped with the most modern facilities, a world class library, state-of-the-art communications and computer systems, but most of all, superb people. China is attracting back many of its expatriates, frequently by the mechanism of joint appointments. This would be the fastest and probably most cost-effective way for Australia to benefit from the outstanding home-grown talent currently working overseas. I believe a number of expatriate Australians would welcome the opportunity of a joint appointment, say half a year at an Australian university and the other half at a US or European one. The influx of such people could really ensure that we develop a world class mathematical system. Perhaps a first step might be to make appointments encompassing the (Northern hemisphere) summer. I see such developments as pivotal to our success in achieving even one world class mathematical sciences department.

Another activity might be to set up exchange schemes with our mathematically talented near neighbours, such as Singapore, China, Japan, Korea and Taiwan. Such schemes exist, but they are rare and not well encouraged or promoted.

We also need a system to recognise, reward, and protect our young stars while they develop their talents. A young Australian mathematician, Akshay Venkatesh, from University of Western Australia, has recently been appointed to a tenured Associate Professorship at the Courant Institute in New York. He is 23 years old, and just a couple of years out from his Ph.D. It is inconceivable that such an appointment could be made in Australia. Mathematicians seeking promotion must be "the complete package". Research excellence is not enough. They must have demonstrable, and documented teaching skills, and have shown both the willingness and the ability to perform a variety of administrative tasks. While accepting the reasonableness of this, it precludes recognition of outstanding, but by virtue of their youth, less broadly experienced people, who are the ones in the long term who will make a substantial difference to the discipline.

Australia's greatest home-grown mathematician is 30 year old Terry Tao, who has held a full professorship at UCLA for 5 years. A colleague joked that if he'd remained in Australia he'd now be writing his application for promotion from Lecturer A to Lecturer B! As it is, he has already won some of the top awards open to a mathematician, including the Bocher Prize, a Clay Research Award and a Conant Award. Surely, in the headlong rush to make universities indistinguishable in structure from the Public Service, there is room for a mechanism to nurture and encourage sheer mathematical talent, perhaps sparing such people from a high teaching load or burdensome administration while they develop their mathematical virtuosity?

The industry employers of mathematicians also have a responsibility to nurture the hand that feeds them. Our banks and financial institutions will happily employ all the Ph.D graduates we can produce. Other industries are also increasingly recognising the power of mathematical training, and the quality of analytic skills it imparts—so that sector specific skills can be readily grafted on. Yet the financial support offered by industry, by way of scholarships, endowments, summer internships etc. is virtually nonexistent. This must change—and it would be for everyone's benefit for it to do so. The situation is equally bad, or perhaps worse, in Statistics, where at least one international drug company is threatening to close down their Australian research laboratories because of its inability to find appropriately qualified statisticians. Such schemes have to be introduced thoughtfully, however. In the US we had the situation, in some instances, where young scientists had to go door knocking to seek half their salaries.

Related to this is Australia's reliance on education as an export industry. As currently structured, this has the unwanted side effect of preventing us from providing local employers with a sufficiently large graduate pool, as our educational resource is being used to provide education to those who will return to their home countries. Given that education brings more money into the Australian economy today than wheat, (perhaps a poor comparison, in light of recent events in the wheat industry) it seems reasonable to expect the Government to put more money back into it to increase the local graduate pool in areas of high demand.

Ten years ago, a committee of enquiry into the mathematical sciences in Australia recommended the establishment of an industry-focussed mathematical research institute. Canada has such an institute in MITACS. In Australia, AMSI and MASCOS, while substantially charged with other aims, are also expected to provide similar facilities and services, and earn income like MITACS. Yet MITACS has just been funded for a further 7 years to the tune of C$7 million p.a., which exceeds the total budget of all three existing Australian mathematics research centres. Canada, in addition, has 3 purely research-focussed mathematical research institutes. In short, Canada, with a population comparable to ours is pumping much more money into the basic sciences in general and the mathematical sciences in particular.

The measures I have outlined are not particularly expensive. They do however require a change in attitude in the educational sector and the Governments that fund it. They are not guaranteed to work, and will create problems of their own. However I am confident that they would create a much more lively, vibrant and engaged mathematical sciences sector. If Australia is to be other than the world's quarry, we must effectively address these problems.

Department of Mathematics and Statistics, The University of Melbourne, VIC 3010
E-mail: T.Guttmann@ms.unimelb.edu.au