Submission to the 2006 Review of Mathematical Sciences

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I welcome the opportunity to make a personal submission to the Review. In this submission, I have given my views on some of the problems facing the mathematical sciences in Australia, and suggested some components of the solution. These suggestions are not intended as a presumptive usurpation of the committee's responsibilities, but reflects my view that, if one highlights a problem, one is obliged to offer a possible solution. My suggested solutions should be viewed in that light.

From this perspective, my opinion is that the major problems facing the mathematical sciences in this country are three-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 second is an attitudinal change in students due to a changed educational emphasis. An attitude is being bred in schools that it does not matter whether a student succeeds in mastering a concept, so long as an effort is made and that effort is rewarded. There are degrees of success, to be sure, but the concept of failure is considered to be potentially damaging to the self-esteem of students, and so must be avoided. This attitude is particularly problematic for subjects in which a substantial body of knowledge needs to be assumed and built upon as opposed to subjects in which studies can be commenced at a variety of levels and at varying degrees of depth and sophistication.

As a consequence, subjects like mathematics and statistics in particular, and to a large extent physics and chemistry, are struggling. 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.

The third problem is not restricted to the mathematical sciences, and is harder to define. It reflects the growth of what could be called government-led attempts to enforce a measurable accountability on universities. This is coupled with the rise of a managerial class within universities with a strong desire to measure everything measurable (and many things not measurable), in the illusory hope that they can thereby improve outcomes. This approach denies or ignores the self-respect or professionalism of the profession. As my colleague Ed Barbeau of the University of Toronto puts it, this is *the collective sense among practitioners that they have a responsibility to themselves and*

to their colleagues for quality (how it comes to be defined through consensus) as well as a broad obligation to society along with sufficient autonomy to realize that the judgments are ultimately in the hands of those who can make them. This seems to be very much present in most universities and professional societies, is under serious attack in the teaching profession .... Barbeau is writing of the situation in Canada and in the top US institutions. I would argue that in Australia this responsibility is also under attack in universities.

Barbeau goes on to comment *Attack the integrity of our professionals and you are really in trouble. This is not to say that there cannot be accountability, but what the outside has to do is to inform itself what the mechanisms are and adopt policies to monitor when they function effectively and how to challenge them when they do not.*

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.

On a more positive note, there has, in recent years, been a growing appreciation by Governments at both the State and Federal level of the importance of the mathematical sciences, and of the need to nurture them. 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). This latter is doing important work in producing exemplary teaching aids for teachers of mathematics in the middle school years. The Australian Research Council has funded MASCOS, the Centre of Excellence for the 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 40% of their income from the Federal Government. At the same time, the Federal Government wishes to impose an increasing level of control and accountability on universities.

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

The 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

potential genius. Each year or two, on average, at my own university, the University of Melbourne we graduate one outstanding student, and each decade or so a potential genius. 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 were better there 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 for 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. Their mathematical education should not be provided by Education faculties, but by discipline experts. 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? 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 ICE-EM and Education faculties, it is far from sufficient. Too much of State Education Department's professional development budget is spent on training courses for anti-bullying strategies, 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 .

The Federation Fellowship scheme was designed to attract back to Australia talented Australian academics. Regrettably, it has largely not been used for that purpose. Furthermore, not one mathematician or statistician has received a Federation Fellowship! (I exclude a couple of recipients who could more properly be called computer scientists.) So if this ill-conceived scheme is to continue, it should be made friendlier to the mathematical sciences, and stick to its aim of "buying back the farm."

An alternative view, held my 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 that the ARC College of Experts, who determine who gets funded, greatly 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 so disadvantages mathematics. This would make it possible to permanently retain some of the outstanding young post-doctoral 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, and such people could really ensure that we develop a world class mathematical system. I see such a scheme as pivotal to our success in achieving even one world class mathematical science 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 prestigious 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 willingness and ability at 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.

Australia's greatest ever home-grown mathematician is 30 year old Terry Tao, who has held a full professorship at UCLA for 5 years. A colleague joked that 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 non-existent. 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 their inability to find appropriately qualified statisticians. Such schemes have to be introduced thoughtfully. 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. Given that education brings more money into the Australian economy today than wheat, (perhaps a poor analogy, 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 turn, has 3 additional 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.