Math matters

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By the term *mathematics* I mean all of the various branches of human thought based on the rules of formal (first order) logic and reasoning in an abstract setting. This includes major components of both philosophy and logic. Mathematics is informed by, and informs, disciplines based upon experimental sciences and other aspects of human endeavour. Mathematics is a science, a philosophy and an art, and it uses a very specialised language.

1 Mathematics – a discipline of declining importance

The following are held to be self-evident.

There is no shortage of mathematicians in Australia. The law of the market place (profit-oriented economics) and politics (maintaining and improving our social and economic well-being) provides a clear proof of the validity of this statement. It is a proof which mathematicians may not accept, but we are constrained by the limitations of formal logic and axiomatic systems, so the proof falls outside our restrictive set of parameters.

Far fewer mathematicians are needed in our society if we consider the socio-economic reality. The number of applicants for a mathematics lectureship (level B or C) at Charles Darwin University (CDU) attracted over 60 applicants in 2004. Application numbers in excess of 100 were reported for similar level positions at the University of Melbourne at the same time.

There is no shortage of teachers of mathematics. This was reportedly stated by a state Minister for Education (identity purposely not included). The logic is simple but clearly appropriate. Every mathematics class has a teacher in charge of the class. As the elected member chosen to lead our state education system, we must rely upon the skills and knowledge of that Minister and his advisors.

There is no reason to improve the funding ratios for mathematics in universities. At a time when mathematics faculties are continuing to be trimmed, or staff re-allocated to serviced areas it is a clear economic matter that funding should not be artificially pumped into supporting a declining industry.

There is no need for Government or industry to increase funding levels for mathematical research. It is clear from advertisements in various media outlets that industry needs useful people, ones who can work on a team project to solve practical problems in reasonable time for near-term financial advantage. This is what graduates in more vocational disciplines are trained to do – engineers solve practical problems in practical ways.

Mathematicians are constrained by their lack of practical skills and their desire to find optimal solutions and to generalise a specific problem. Industry needs practical outputs not theoretical niceties. Most of us will have published esoteric papers which take longer to write than it takes to build a house. Which is more valuable? Would we rather have a house or ten pages of abstraction read by two referees and maybe some current research students?

All mathematics conference papers should be refereed. In this way mathematics can partially respond to our modern

economic system even if it is totally unsuitable for our discipline. We can attract a greater share of resources through the rewards of having refereed papers. Our publication rates will increase, and then we can be seen to be more productive. We should follow the lead of our progressive disciplines like education and information technology, or pragmatic disciplines such as engineering.

Mathematicians should be subject to professional registration and regulation like the progressive and expanding disciplines of law, accounting, education, nursing, and engineering. Clearly our standards will improve and our economic value will increase.

Mathematics should adopt outcome-based learning principles and a post-modernist aesthetic. For too long we have poured mathematical knowledge into the brains of students. For too long we have ignored the student's need for self-determination and self-expression. Each individual needs to find their own time, place and methods of absorbing the components of the discipline without the artificial methods and the induced stress of learning formulas and sitting examinations. Self-efficacy is much more important for success.

Because of improvements in technology, mathematics is less important than it was before computers. Mathematicians need to move into the modern world where calculators and computers can do all of the necessary calculations. So much time is wasted teaching problem solving, formulas and equations when methods can be found on the web and there is software to work out the answers.

Mathematics has been made much too complex and takes up too much time in the school curriculum. Modern education is based upon good classroom management, which includes individual learning programs and extensive report writing. Text books are insensitive to the needs of individuals, so it is imperative that every teacher develops an individual program for each student, that reports emphasise the positive aspects of a student's learning outcomes, and feedback should only be expressed in terms of outcomes relative to the student's own educational aspirations.

The training of mathematically competent people is archaic. It takes too much time and individual effort. Our ever–changing society would benefit from much shorter training times so that mathematicians become productive sooner, more flexible and are able to be produced on demand.

Mathematics should be optional at school. A lot of kids don't like it and many teachers don't like teaching it. Besides it can be learnt as needed when studying other subjects or in bridging courses for TAFE or university. Just-in-time learning is much more efficient, and students are more motivated because it is more relevant.

2 The Australian reality

Forty percent of next year's first-year engineering students will need to do a six months remedial maths course ([1])

How is it that we have gone from teaching Latin in year 12 to teaching remedial English in first year of university? ([2])

The issues that we face in mathematics are common to all core disciplines. Processes and training have replaced education. Long-standing government policies and funding models are continuing to undermine education in Australia.

Recent debate concerning the control of education in Australia is pertinent but still seems to miss the point, as the debate appears to be more about control than about fixing a major problem. An indication of real desire to address the problem could begin with appropriate funding to recognise and support the rebuilding of core disciplines at universities, which

the Federal Government effectively controls through funding and legislation.

The current EFTSL funding model is destroying staff and destroying core disciplines, and every time we lose a core discipline from one university it affects other core disciplines and other universities.

It also follows that there has been a lowering of demand for fundamental education, as the mass of the population has not been exposed to its possibilities. This seems to be the situation for a whole generation and its harmful effects are showing. This includes the issue of many students in regional or "unlucky" areas often subject to significant disadvantage in educational opportunities.

A common reply to this sentiment is that we have a market economy and it is driven by demand. I recall a federal politician extolling the positive contribution of a fast-food chain in Australia. They do provide clean efficient service and employ lots of young people at low rates of pay and the demand for fast food is enormous. Now we have an epidemic of obese people. What is the educational equivalent of being obese, through being fed on a diet of poor fundamental education?

At the moment we sit comfortably, importing products to satisfy our insatiable demand for technical gadgets, all paid for by the resource boom. We import manual workers, qualified tradesmen and professionals whilst many good Australian brains have been lulled into a stupor of mediocrity.

We see so many students who are cognitively still at lower secondary level, but they are now at a university completing a degree with meaningless entry and exit standards and an expectation, encouraged by the universities, to think that they should be able to pass in any subject in which they choose to enrol.

Compounding the issue is that the contemporary course of society in Australia has been to move the balance away from education towards legislation. Legislation appeals to politicians and bureaucrats. They understand it, they can partially control it, and they can build their short-term empires, but they also have the power to address the issues, if there is the will.

The will does not seem strong, and it is an inherent weakness in our Australian system. The perceived reasons for the economic success of Australia has changed over time, but there is one common thread – export our large amounts of natural resources, or more recently attract visitors, namely tourists and students. Australia will continue to thrive on a temporary basis with diggers and waiters – the diggers to mine the resources, and the waiters to serve the tourists. What do we do when the resource bubble bursts or in the next major economic downturn?

One has to hang on the slim hope that the current review of Mathematical Sciences in Australia will be more than a political process, as it cannot deal with the broader underlying issues.

3 The University reality

Mathematics cannot justify itself on immediate economic return. It justifies itself in its influence on the long-term cognitive skills of its citizens. The long-term benefits are enormous, but this has often become lost in the immediacy of short-term goals.

Mathematics and all of the core cognitive disciplines have been in decline for some time. Society needs to make major changes in its long-term expectations for the negative aspects of our education system to be reversed.

Many mathematicians in Australia work in universities. Universities are formal organisations subject to the usual influences in any society. Unfortunately the contemporary influences work strongly to undermine the role of universities, and there is no one influence that dominates. However, influential social and financial decision making involve some major players including Governments, and these can act to modify

the situation which they have helped to create.

Consider the following:

- Current EFTSL funding models have caused artificial structural inefficiencies in university education – with each discipline being forced to claim as many students as it can within its own discipline codes.
- The demand for core educational disciplines is subsequently lowered.
- School counsellors partially respond to universities and inform students that the core subjects are now less important, so why not do the easier or "sexier" subjects.
- Hence core disciplines at school become weaker, and so fewer well-educated students complete school.
- Hence universities drop entry standards.
- Hence the demand for the core disciplines becomes less, and subjects become more vocational, meaning based more on process and less on considered thought and deeper understanding.
- The next generation of teachers further the decline in the core disciplines.
- The workforce employs lots of people with "people and communication skills", but many of them do not have deeper cognitive skills, and we are less competitive as a workforce.

We are at the stage in many universities that we have neither the time nor energy to interact with the diverse disciplines or industries which would benefit from some of our skills and knowledge. Because of the decrease in mathematics education in many disciplines, there are fewer members of disciplines or industries who can sense that some mathematical input might be relevant to their considerations. Hence our opportunities for collaboration (direct usefulness?) are decreased. Although it is not always the case, it seems to me that applied mathematics will tend to be driven by the needs of other disciplines or industry, and it is hard for mathematicians to anticipate those needs without a strong desire or guidance from those parties.

I began my tertiary teaching career in TAFE – matriculation maths entry for technical certificates, and compulsory maths for secretaries. It now appears that I will finish my career teaching bridging mathematics or year 9 mathematics to trainee schoolteachers. Luckily there have been periods of joy within the system, provided by many reasonable students whom I have had the pleasure of teaching.

I've never had trouble dealing with students who have difficulties – restating the same basic ideas in many different ways. However, when every basic idea needs restating then the system is moribund, and that's close to where we are now in mathematics education. Our one sad compensation is that we are not as badly off as physics or classics, for example.

The reality of the current system:

- Academically low-level people beginning teacher training (3×10 is unknown to some). Year 8 basic calculations (or less) are being seen as sufficient for teacher training. Trainee secondary mathematics teachers who "don't like surds" – their basic mathematics skills are poor. A large number of functionally innumerate people have graduated as teachers.
- Matriculation mathematics entry were in place for technical certificates 25 years ago, and now there are engineering degrees with no physics or chemistry expected for entry and lower level mathematics entry.
- Year 9 teachers of mathematics simultaneously undertaking bridging mathematics units so that they have some of the basic manipulative skills that they are teaching the next day.
- There are also the teachers with the same skill levels who don't undertake bridging.

- Apprentices unable to do the most basic trade calculations and employers unable to rely upon school reports for an accurate indication of the achieved skills of the their potential employees.
- Contractors preparing tenders who cannot calculate basic quantities (such as the amount of soil needed to fill x cylindrical holes).
- Graduate scientists with no mathematics – ecologists who have never heard of exponential population growth models.
- IT graduates who can't program and who know none of the basic mathematical models/tools essential for intelligent computing professionals.

4 Education not Training

Education should inspire and open the minds of students beyond the simplicity of childhood and pre-abstract understanding. This is necessary to lead to an informed consideration of aspirations. Current education practice often reinforces aspirations – expect to be mediocre and we'll make sure that you are mediocre. Education does not provide all of the answers, rather it provides some answers and poses many questions.

We have removed fundamental principles from education in language, in mathematics, in science, in art (post-modernism) and have replaced it by "self-expression". There are few formal skills now being imparted to facilitate genuine thoughtful expression, and there is a loss of lifetime skills development to deal with the complex, rather than the procedural aspects of modern life and the modern workforce. Moreover, emotional responses are left as the only tools of analysis without the benefit of logic to solve logical dilemmas.

By its very nature, education as opposed to training, can lead to deep or unusual intellectual thoughts, both of which are difficult to measure or control. There is an increasing abundance of intrusive and unproductive measures of control, with reporting and auditing processes being imposed by a bureaucratic system onto an education system already pushed into becoming process-oriented training factories.

There is an alternative, but it is not a simple path, given our national decline in core education. Throw out competency-based learning and outcome-based learning and all of the related processes that not only trivialise but also work to destroy true education. Replace these by education based upon deep and broad understanding of fundamental principles of the diverse core disciplines needed for creative or skilled problem solving. Of course, there is the increasing problem of who is competent to teach this as people significant discipline knowledge is essential.

Unless the notion of core structural principles are reintroduced as central components across a range of core curriculum subjects, it is almost impossible for students to be motivated to learn, or able to grasp the fundamental nature of mathematics as a complex formal discipline – a discipline in which there are few shortcuts in the process of developing the mind's ability to think and reason logically, inductively and deductively.

A comment on teaching

If foundations are not laid then it is almost impossible to build a useful structure in the future – the influence of a good or bad teacher echoes down the generations. I would not like to be a student in the current system. The chances of having a set of suitably educated teachers across the curriculum are too low, at least in the mass public education systems.

We cannot isolate teachers to blame for this. Teachers are a product of a system over which they often have little or no influence, and many of those who care leave the system in despair.

A frequent criticism is that too many people who understand mathematics are poor teachers. I can accept this. However, it is clear that a good teacher who knows

the subject will be a much better teacher of mathematics than one who has little subject knowledge. A good teacher can deconstruct mathematics into its constituent parts and reassemble it into a rich and meaningful experience, building on the natural inquisitiveness of children.

It is easy to enjoy aspects of pop culture, but there can never be a satisfactory pop mathematics. If one doesn't understand mathematics then what is one teaching? It's not mathematics.

It is depressing to see that natural spirit of children being diluted by trivia, and idle minds certainly contribute to inappropriate child behaviour.

It is unquestionably a difficult task to spend year after year with each new group of 15-year-olds trying to extend them beyond their hormones, so it can be partially understood how the education system has taken the easy way out. School teaching is no longer a profession, and soon university lecturing will be the same (if it isn't already).

Current expectations suggest that teaching does not require high-level cognitive skills (and exams of course are not appropriate). Nor is an ongoing professional development based upon discipline-oriented education. Teachers are treated as process workers, managing day-to-day, often meaningless tasks, and distracted by writing copious volumes of lesson documents and reports.

I have fond memories of most of my high school teachers. Their ages ranged from 25 to 65, and each offered unique and interesting experiences when they seemed to be well informed about their disciplines. It was a natural joy and inspiration to learn, and actual learning was a common part of the process – appreciated even more with hindsight. The occasional teachers who did not have mastery of their discipline, stood out as sad and uninspiring.

I find it quite odd that at least some "Education staff" seem to think that current Education graduates are better teachers, despite the fact that current training has significant components of indoctrination into fashionable, narrow and harmful educational dogma and little content. They are trained in process rather than content.

Mathematics is not tactile, it doesn't feel nice, and you can't touch it. Mathematics is an artificial construct based upon abstraction. It is an edifice built on 2500 years of human endeavour, and few appreciate its secrets and beauty. By its very nature each small part may be seen as not being very practical, but as a whole it is essential in our society.

Abstraction is based solely within the brain and it takes years of concerted effort to develop a skilful appreciation of it. Many undereducated teachers have not developed the basis of abstract reasoning and thinking and so they cannot develop the basis of abstract thinking in their students.

On the other hand teachers can be overeducated. I recall a debate in the 1980s at an AustMS conference; I was younger and did not speak at the time, but I knew the proposed resolution was stupid – every mathematics teacher should have an honours degree in mathematics. We need to be more realistic.

How could one spend 30 years teaching 15 year olds the same algebra? There is a need for a balance in teacher training and regular in-service to help teachers refresh, to remain interested and to share ideas and enthusiasm. The AustMS needs to provide leadership.

A comment on university teaching

School education has seen the implementation of structure and processes which are almost meaningless in terms of core education. The same problem is now permeating universities. Many academics have lost the freshness and freedom essential for inspired teaching or research. The best teaching is

an art form. It is being reduced to a poor craft.

University staff are finding themselves in an increasingly frustrating battle. The pragmatic way to solve this social problem is by a significant number of old and irrelevant people retiring, allowing in a new generation who have been indoctrinated into the training industry, rather than into education. The best way to solve this problem is quite different.

Teaching mathematics

Mathematics is a way of thinking and it has precise rules of syntax and semantics. The language aspects of mathematics need to be recognised as a major separate component of learning mathematics. It is not easy and it takes time – lots of time.

Almost all aspects of mathematics are of limited importance in parts but the whole is much stronger than the parts, and the lack of recognition of this is a major flaw in our Australian education system.

Many people see the beauty of pattern and design in the world but few see it with the insight of mathematics. There are so many practical and day-to-day experiences where the mind is needed to solve problems of various complexity, many of the population do not have the reasoning skills necessary to partition problems into their constituent parts and solve them with abstract models.

In this sense each individual part of mathematics is not practical. How many people actually use a quadratic expression at any time in their adult life? On the other hand, how can people deal meaningfully with the notion of ecological models or personal finances (loans, compound interest, ...) when they do not understand the difference between polynomial and exponential growth patterns?

General comments

The language of mathematics is unique and like any highly expressive language it takes significant time to learn. This requires regular appropriate exposure over many years, slowly increasing the complexity and hence the power of the language. The language cannot be absorbed by osmosis or informal exposure. Mathematics suffers from the fact that many undereducated people treat it like other disciplines and therefore understand that it requires proportionately more time than most other disciplines. It cannot be taught in the same way as other disciplines.

There are many people in our society who are naturally gifted teachers, and I am certain that we have lost a large number of them to other more fulfilling jobs. A gifted teacher will have significant subject knowledge, but will also have a strong emotional commitment to their teaching. Entering a classroom is like going on stage, and when we leave the stage we are exhausted. The system does not support this necessary emotional response.

How many of us have been on academic boards, receiving hundreds of pages of documentation with little lead-time, and as a result no serious academic debate occurs? Instead there is a trail of paper and frustration. When do we, as mathematicians, get the opportunity to be involved in a balanced discussion on the importance of mathematics as a provider of core skills for other disciplines? Such interactions have almost disappeared in the EFTSL driven funding model of a mass "miss-education" system.

5 What we need

- Concerted in-service effort for existing teachers.
- Rewards for genuine subject skills upgrading rather than educational theory.
- Replacing many BEd programs so that they are based on the core knowledge of disciplines and their ethos. Education is based upon knowledge. Let teachers gain sufficient discipline so that they can consider how to impart it. At the moment, the "how to" is often being

taught without the discipline knowledge in place. Also don't forget the pragmatics – teachers are often asked to teach out of their discipline or at different levels to which they are trained – hence the discipline training must be comprehensive.

- For most of us the ARC is irrelevant. Instead provide $7000 for each active mathematician to support collaborations (travel/conferences).
- Recent comments from students at an AustMS supported workshop, Dry and Discrete, have provided an interesting insight into possible future activities by mathematicians. The workshop featured some world leaders and open problems in various aspects of discrete mathematics and postgraduate students. Student comment was made that it was very beneficial to see the "gurus" struggling with these problems and they felt the benefit of the interaction with guru or student each making valuable comment as equals. I suggest this as a positive format to be adopted more often, rather than the less interactive but useful "Look what I've been doing" conference paper format.

References

[1] *Defence students to repeat maths,* The Australian Newspaper, The Nation **11 Oct 2006**, page 4. (Statement attributed to ADFA, Canberra)

[2] *Students left behind,* editorial, The Weekend Australian Newspaper, Opinion editorial **7-8 Oct 2006**, page 16. (Quotation attributed to Hon. Julie Bishop, Federal Minister for Education.)

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About this article

This article expresses some ponderings of the author in response to a request for

. . . the regular column "Math Matters" in which a prominent Australian mathematician voices his/her opinion. The subject of this column is entirely up to you, but we would prefer it to be somewhat provocative, stimulating a debate.

Opinions/provocations expressed are based upon 30 years involvement in (Pure) Mathematics, Mathematics Education, Mathematics Research and the perceived views of others. The author has been a student in NSW and WA and has taught/supervised at high school, TAFE, bridging, undergraduate and postgraduate level in the NT, and has been awarded various undergraduate teaching and postgraduate supervision awards. Relevant studies include a research masters in Functional Analysis, a PhD in Combinatorics and a Graduate Diploma in Education. Research/scholarship has been in pure mathematics, mathematics education, or theoretical computer science with collaborators in a range of states and countries.

Working in Darwin has provided a better than average experience of the students from various state systems for the very simple reason that Darwin is a transient city; we are constantly dealing with students from different states and having to assess and respond to their differing educational experiences. Certainly some states rank poorly when it comes to their school mathematics curriculum, and it is getting worse.

The word 'prominent' above deserves a bit of a chuckle, but at least I'm interested and experienced. One of the strategies to succeed in isolation is to be cheeky enough to forge relationships with prominent academics or societies, and so to experience a breadth and depth of experiences that are otherwise impossible in an isolated environment. The advantages of isolation include the ability to deal with educational issues of a much broader nature, to

write and teach a complete curriculum which need not be constrained by the curriculum – inertia obvious in some longer standing mathematics departments, and to enjoy regular relationships with people from other disciplines.

For most of my career I have been a mathematics educator who has also undertaken research, although that balance is changing by personal choice, and partly motivated by the declining circumstances in mathematics in universities.