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Dear Readers

The Australian Academy of Science and The Australian Mathematical Sciences Institute are currently preparing a Decadal Plan for the Mathematical Sciences in Australia. The aims and scope can be found at the website:
http://www.mathscidecadalplan.org.au
There are seven subcommittees covering: Education in Schools and Colleges; Education and Training in Universities; Research in Universities and Related Institutions; Education, Training and Research in Government Organizations; Education, Training and Research in Business and Industry; Research Centres, Australian Mathematics Overseas.

There have been five national reports covering many of these issues in the recent past. There are many common elements in the reports and many recommendations, a meagre few of which have been implemented. All of this has made me ask myself the question: If you were asked to make just one recommendation on Mathematical Sciences in Australia that would be implemented, what would your recommendation be?

My recommendation is for the federal government to work with state governments in making and resourcing mathematics, with a minimum national standard, a compulsory subject for all students in Australia through to the end of their high school studies. Actually this is two recommendations, one to have mathematics compulsory and another to provide the resources (including appropriately trained teachers) to implement compulsory mathematics. Mathematics is not a requirement for the Australian Capital Territory Year 12 Certificate, the New South Wales Higher School Certificate, the Victorian Certificate of Education, nor the Western Australian Certificate of Education. Mathematics, at varying standards, is a requirement for the Queensland Certificate of Education, the South Australian Certificate of Education, the Tasmanian Certificate of Education, and the Northern Territory Certificate of Education and Training. English is a compulsory requirement for all states and territories except the ACT.

Why compulsory mathematics? To my mind there are two compelling (and not unrelated) arguments. Firstly mathematics, up to or beyond year 12 standard, is required for further training as a professional in a multitude of careers. Secondly, mathematics is the language of the universe; it is extraordinarily useful. Beyond this, mathematics is beautiful.

In 1988 Robert Fulghum published a book titled '*All I really need to know I learned in kindergarten*'. The book, which was concerned largely with social values, became a number one bestseller on the *New York Times* bestseller list. I recall kindergarten mathematics, learning to remember the names of numbers, learning to count, playing with Cuisenaire rods, simple addition and subtraction. I recall kindergarten English too, learning names for days of the week, the seasons and playful stories. A few years out from kindergarten and we had reasonable skills in reading, writing and arithmetic. So why not stop there? We don't all need to be literary scholars or mathematicians. Let those who care for such things take it from there. Mathematics is not something that can be picked up along the way through social interactions and the media. The basics of geometry, linear algebra, calculus and statistics are things that are learned in secondary school from teachers and textbooks. Moreover there is a hierarchy in learning mathematical knowledge. The basics need to be learned before going on to more advanced mathematics that is taught as part of a degree at a university. Let me just mention a random few of these topic areas to give you a sense that there is mathematics beyond kindergarten, and primary school and secondary school. The random few? There are so many, but OK here are a few: algebraic geometry, Bayesian inference, categorical data analysis, differential geometry, Fourier transforms, functional analysis, multi-variable calculus, linear programming, partial differential equations, quasi-Monte Carlo methods, regression, stochastic processes…

At this point you might be thinking that you don't need to know any of this so why bother with mathematics beyond arithmetic. You might concede that mathematics should be studied throughout secondary school by those who know they will need it in their future profession, but surely this is a minority. But there is a growing list of positions in the workforce where mathematical knowledge beyond senior secondary mathematics is required. Examples include the obvious, mathematicians and statisticians, including teachers and researchers in these areas. But the list also includes accountants, actuaries, air traffic controllers, astrophysicists, bio-statisticians, biomedical researchers, chemical engineers, civil engineers, clinical psychologists, climate scientists, computer scientists, cryptologists, data analysts, geophysicists, economists, ecologists, electrical engineers, gaming developers, hedge fund operators, inventory strategists, marine biologists, mechanical engineers, meteorologists, pilots, quantitative analysts, risk analysts, search engine developers, security analysts, software engineers, telecommunications engineers, theoretical physicists,… For almost all professionals, when it comes to mathematics, everything they really need to know they learn in kindergarten; and in primary school, and in secondary school, and in university.

When students leave their secondary schooling they set out on their path to have their own dialogue with the universe. Surely an essential purpose of schooling is to equip them as well as we can for this journey. The following observations of Galileo and Einstein are pertinent here:

> Philosophy is written in that great book which ever lies before our eyes I mean the universe but we cannot understand it if we do not first learn the language and grasp the symbols, in which it is written. This book is written in the language of mathematics without which it is impossible to comprehend a single word of it; without which one wanders in vain through a dark labyrinth. Galileo (1623).

> How can it be that mathematics, being after all a product of human thought independent of experience, is so admirably adapted to the objects of reality? Einstein (1879–1955)

Mathematics is fundamental to the universe. It is the language of the universe. This phrase is a little hackneyed, so let's pull it apart a bit to understand what it is really saying. Mathematics is the only tool we have to reliably understand, predict or improve behaviour. Let's think back a few hundred years to 1642 plus or minus a lifetime. The year 1642 was the year that Galileo died, Newton was born and Abel Tasman discovered Van Diemen's Land. This is not so long ago in the grand scheme of things. This was a period when scientists were fascinated by attempting to understand and predict the motions of celestial bodies, useful for navigation among other things. One of the scientists interested in celestial bodies around this time was Edmund Halley. He spent ten years carefully sifting through observations and carrying out mathematical calculations based on Newton's equations in *Principia* (the publication of which was funded by Halley) to provide understanding and prediction of the motion of comets. Halley famously predicted the 1758 return of the comet that now bears his name. It was the first time that anything other than planets had been shown (indeed predicted) to orbit the sun. The power of mathematics in predictions like this is now taken for granted. But it is a miracle. Mathematical equations are, as Einstein notes, an invention of our mind. They are an abstraction. The solution of the equations is an abstraction of an abstraction. Why should the universe be mindful to respect the integrity of such things? A similar sentiment is expressed nicely by Wigner in his paper 'The Unreasonable Effectiveness of Mathematics':

> The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift which we neither understand nor deserve. We should be grateful for it and hope that it will remain valid in future research and that it will extend, for better or for worse, to our pleasure, even though perhaps also to our bafflement, to wide branches of learning. Eugene Wigner (1961)

The above is bordering on the philosophical and the example of Halley's comet is a little arcane but there is a real pragmatism in the observation that mathematics is the language of the universe. Mathematics is extremely useful. Here are a few quick examples in modern life: online music is a sequence of numbers representing the myriad frequencies that make up the vibrations in the music and the coding and decoding that makes this all possible is based on the mathematics of Fourier transform methods; the ability of search engines to quickly find relevant pages is made possible using the mathematics of linear algebra; the security of financial transactions over the internet is based on the mathematics of cryptography; the pricing of insurance and financial instruments is based on the mathematics of probability and stochastic processes; mortgage repayments are based on the mathematics of discrete dynamical Systems; weather forecasting is based on the mathematics of partial differential equations and numerical analysis; every single keystroke on your computer is based on the mathematics of boolean algebra and binary numbers.

For a mathematician perhaps the most compelling argument for mathematics to be part of a student's education throughout their secondary schooling is that mathematics is beautiful:

> Mathematics, rightly viewed, possesses not only truth, but supreme beauty – a beauty cold and austere, like that of sculpture, without appeal to any

> part of our weaker nature, without the gorgeous trappings of painting or music, yet sublimely pure, and capable of a stern perfection such as only the greatest art can show. Bertrand Russell (1919).

Only mathematically trained people have access to this beauty.

Editor

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