



**Australian Government**

**Chief Scientist**

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**Keynote address**

***Renewing the signals, restoring the continuum***

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Since this is the closing session of a mathematics conference, I'm going to start with a mathematics problem.

Pencils ready? Here is it – and I've been nice, it's multiple choice.

*In the time it takes an unfit runner to cover 60 paces, a fit runner can go 100 paces. The unfit runner has covered a distance of 100 paces before the fit runner sets off in pursuit. How many paces does it take the fit runner before she catches up to the unfit runner?*

- A) 150
- B) 160
- C) 250
- D) 260

Now I'm going to make a confession: I didn't write that problem.

It's from an ancient Chinese text-book that dates back to at least 200 BC, and possibly centuries before.<sup>1</sup>

It's called *The Nine Chapters on the Mathematical Art*, and it's a collection of 246 problems demonstrating the practical applications of mathematics to ancient Chinese life.

What could you do with mathematics in ancient China?

Well, in ancient China there are problems on calculating distances.

There are problems on trading commodities like millet and rice.

There are problems on collecting the right amount of tax.

There are problems on building canals, and ditches, and dams.

There are problems on predicting farm yields.

So, the answer to “why mathematics” in ancient China was “because *without* mathematics our civilisation will collapse”.

And the message to young scholars was clear. If you wanted to climb up the rungs of society by getting an education and joining the civil service, then this was content you absolutely needed to know.

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<sup>1</sup> [http://www-history.mcs.st-and.ac.uk/HistTopics/Nine\\_chapters.html](http://www-history.mcs.st-and.ac.uk/HistTopics/Nine_chapters.html)

Now this insight was not unique to ancient China.

Mathematics has been part of the curriculum for at least four thousand years.

Let's journey back in time to the first known complex civilisation, ancient Sumer, where writing was first developed.<sup>2</sup>

In ancient Sumer there was an elite class of high-skill workers: the scribes.

Scribe school would start with the Sumerian alphabet. Then they'd have to memorise the sign combinations for hundreds and hundreds of words. Next was simple arithmetic, metrology, algebra, geometry and some trigonometry. With that under their belts, they'd move on to accounting, and contract-writing, and law.

Why mathematics in Ancient Sumer?

Again, "because *without* mathematics our civilisation will collapse". And civilisation ticked along all the way to ancient Greece, and a person you might have heard of, named Plato.

At roughly the same time as *The Nine Chapters on the Mathematical Art* was coming together in China, Plato was also educating Athenians in the importance of mathematics.

In his classic work *The Republic*, he sets out very clearly what an ideal education would look like.<sup>3</sup>

Language and literature.

Physical education.

A bit of military training.

And TEN YEARS of mathematics.

Mathematics was so important to Plato that he made it a pre-requisite for entering his Academy.

He had it engraved on a plaque by the door.

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<sup>2</sup> [http://cdli.ox.ac.uk/wiki/doku.php?id=sumerian\\_school\\_texts](http://cdli.ox.ac.uk/wiki/doku.php?id=sumerian_school_texts)

<sup>3</sup> <https://www.thebritishacademy.ac.uk/pubs/proc/files/103p001.pdf>

*“Let no-one ignorant of geometry enter here.”*

Which I interpret to mean a requirement for at *least* intermediate mathematics, with a preference for advanced.

Don't tell me Plato wouldn't have required calculus if it had been invented. *Of course* he would have insisted on calculus. Case closed.

Skip forward 1500 years.

The great universities of medieval Europe are born.

And they look back at what worked in ancient times, and they come up with a three-part structure for the academic curriculum.<sup>4</sup>

First, the trivium: three years of grammar, rhetoric and logic.

Second, the quadrivium: four years of arithmetic, geometry, astronomy and music.

Third, an optional doctorate: in theology, philosophy, medicine or law.

The point is that you don't get to be a master or a doctor of *anything* unless you study mathematics.

So, there's nothing original about the message I'm here to give today: that mathematics is important, and it has to be a priority.

The answer to the question “why mathematics” has been obvious for five thousand years.

But again and again, we seem to forget.

So today I want to reiterate what I mean when I say that the priority has to be mathematics.

I want to talk about the factors that discourage students from taking mathematics at the level of their real ability in their senior years.

I want to talk about the consequences for students who miss out on the mathematics foundations that they ought to be building in school.

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<sup>4</sup> <https://www.irishtimes.com/news/science/quadrivium-the-noble-fourfold-way-to-an-understanding-of-the-universe-1.3153793>

And I want to talk about what we can do to make inroads on what we all acknowledge to be an entrenched cycle that sets up far too many students for disappointment.

Now, as you are a captive audience, and one with a vested interest in the topic, I am happy to give you my answer to your question, “why mathematics”?

Well, in my view, it’s not just about mathematics – but I will get to it.

Students need in their muscle memory four key things:

Most important of all is mastery of, in the context of our community, the English language; the language of discourse, to empower them to discuss politics and philosophy, to read Shakespeare, Charlotte Bronte, Ursula le Guin, and Tim Winton.

It must resonate in their minds to support the development of core communication skills and give them the ability to express themselves with confidence and with reference to history and culture.

To quote Dr Seuss, "Sometimes you will never know the value of something, until it becomes a memory."

And then they will, of course, also need Mathematics, the language of science.

It’s a common comment from students, and their parents and carers, “Why do I have to learn algebra?

Or “Why do I have to be able to estimate weight and distance?”

But when they are learning to drive and need to estimate speeds on the road, or work out the angle of a car park, or estimate the weight of goods, or build a house – or more importantly, pay someone else to build their house – the value of these skills and knowledge will hit them, hard. Or at least a light bulb will go on.

And well-developed basic mathematical skills become the key for students who *do* want to explore mathematics further, as a necessary skill for future studies in fields such as science and economics.

In addition to English and mathematics, we also need Sport, the language of the body. The Greek philosopher Thales had it right – a sound mind is a sound body.

And Music, the language of emotion, a vehicle to express yourself without words. A divine skill. I often wish I had gone down that path ...

What do English, mathematics, music and sport have in common? To be good at them you need muscle memory, which comes from learning and practicing, learning and practicing, year upon year upon year.

Whatever path a student chooses, laying down the core skills of the discipline is vital.

So, if we all agree that mathematics is important – and I am sure that everyone here does – why are fewer students choosing to study it at intermediate and advanced levels?

Many of you may be aware of the work of my Office is doing, along with the Australian Mathematical Sciences Institute and others – to better understand the reasons for the drop off in numbers of students choosing to study mathematics at every level, and in particular at senior secondary school.

We know the issues are complex, including a perception that with computers and smartphones, mathematics is no longer needed!

We know that there are a wide range of factors that influence students' subject choices, and their performance. Parents and friends play a huge role, but teachers have the greatest in-school influence.

For mathematics in particular, there are a number of motivating – or demotivating – factors including: how it's being taught; the capacity of the teacher to teach the subject; and whether there are other more attractive options for students to increase their ATAR.

We know that the majority of students select their courses with an eye to a single number: the ATAR required to get into a particular course. And rightly or wrongly, they absorb the message that the way to boost their ATAR is to drop down a level of mathematics.

Linked to this is the school yard chatter that goes on in years 9 and 10 – although these days it also happens online. The messages get

confused, and inevitably end up being misunderstood by the year 10 students who are trying to decide their best option for subject choices in senior high school.

They are told, and the university course guides confirm through omission, that the higher their ATAR, the best chance they have of getting into their chosen course at university.

But what happens if they attain the necessary ATAR for admission to a university course, but are not competent in the subject content to do *well* at university, often because they haven't stuck with mathematics?

In the past, universities made it clear the subjects that students should study to be prepared for the range of undergraduate courses into which they might want to enrol.

Today, with some exceptions, Australian universities have removed or softened course entry requirements. This trend can be traced back to the 1990s, but it appears to have accelerated with the massification of higher education and the uncapping of places.

In the absence of prerequisites and clear signals of what is required to succeed in a course, the ATAR has been given more prominence than was intended. It is now used as a catch-all representation of student achievement, which it was never meant to be.

The ATAR was originally designed to coexist alongside clear expectations and signals from universities about subject choice. Without these signals, the pressure to study subjects that are seen to maximise your ATAR score has increased.

So while an ATAR score may allow students entry to a course, without a sound understanding of core content, students scrape through, or fail, or drop out. With all the consequences.

A few weeks the Productivity Commission released a report on "*The Demand Driven University System*". It contains some fascinating information on the outcomes of the recent policy changes' impact on under-represented equity groups

It notes that there has been success in achieving an increase in the number of students attending university and improving equity of access.

However, many students are ill prepared when they enter university and they struggle academically. These students are less likely to complete their studies.

While university attendance increased substantially under the demand driven system, growth among equity groups has been uneven.

So with this trend of unpreparedness among a range of students, what changes can be made to try to address some of these issues?

Firstly, like all drive for change, there needs to be leadership in addressing the problems.

Our universities need to indicate clearly to students what subjects are *required* to do well in a given course, and reinstate the expectation of studying mathematics at intermediate or advanced levels, particularly for entry into mathematics-based courses such as physics and engineering, and all of the general science courses, as well as other disciplines that depend on mathematics, such as economics, commerce and architecture.

And medicine. Call me nervous, but I like to think that my treating physician is competent at mathematics.

Those expectations need to be communicated to all stakeholders – students, principals, careers advisors, teachers, parents ...and those online influencers.

Universities need to work together to develop an approach and communicate expectations clearly and consistently in language that is easily understood.

In the United Kingdom, the Russell Group is a grouping of 24 universities from around the country. It publishes a printed guide designed to explain to students 14 years and older the specific subjects that are needed in secondary school to gain entry to undergraduate courses in those universities.

It includes a list of eight core or 'facilitating' subjects that, in addition to English, are more frequently required for entry to undergraduate courses than other subjects. These are: mathematics, English literature, physics, biology, chemistry, geography, history and languages. Students are



advised that including a selection of facilitating subjects at the advanced level will open up a wider range of degree choices.

In May 2019, the Russell Group's Informed Choices guide was re-launched as an online interactive guide. Students can see which subjects are recommended for specific degrees, and also test combinations of school subjects to see which degree paths they open up. According to the Russell Group, the renewed guidance 'is particularly targeted towards supporting less advantaged pupils' who may not have access to high quality advice elsewhere.

Of course, there are other sources of information, but the beauty of Informed Choices is that it is not about how to play the system. Instead, it is about how to optimise one's preparation for future studies without having to guess at the age of 15 what you might want to study at the age of 20, or work on at the age of 25.

It is my hope that a modest number of thought leading universities will agree to develop an Australian Informed Choices.

And I further hope most of those thought leading universities will make it clear to students through prerequisites that they need to study mathematics in school in order to enrol in courses that need mathematics.

Mathematics is not a subject that you can pick up late in one's academic career. The evidence that short bridging courses are effective is slim, the evidence that they are inadequate is much greater.

I would like to complete my remarks on this note. Learning mathematics offers the student core foundational skills for success.

Until universities step up to the plate and send a clear signal to students that if they want to keep their options open they should study intermediate or advanced mathematics in school it is left to principals and teachers to encourage their students.

Mathematics at upper secondary school does not have to be compulsory – but it ought to be compelling.

Compelling by offering lessons set in a real-world context.

Compelling by telling contemporary success stories, such as Jim Simons, who I met briefly last week. He's an American mathematics professor who contributed to the mathematics of string theory and quantum field theory, then in the 1980s decided to apply his mathematics skills to financial trading. He used mathematics to make money, and built his net worth to nearly thirty billion dollars.

Jim Simons, like you, would have worked out in a heartbeat the answer to that ancient Chinese problem that I posed at the beginning of my speech.

The answer is C – 250 paces.

Mathematics encourages logical thought; it allows for the laying out of a problem and working through solutions; it trains you to make deductions from the learned assumptions of those who have gone before; and it encourages you to apply your knowledge to a wider world view.

It's a bit like being a Jedi master.

May the Force be with you.

Thank you