Chief Scientist

AUSTRALIA 2025: SMART SCIENCE

THE CONVERSATION

Optimising the future with mathematics

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AUSTRALIA 2025 – How will science address the challenges of the future? In collaboration with The Conversation, we're asking how each science discipline will contribute to Australia now and in the future. Written by luminaries and accompanied by two expert commentaries to ensure a broader perspective, these articles run fortnightly and focus on each of the major scientific areas. Today, we add mathematics to the mix.

Mathematics is an absolutely critical part of our future – and we can maximise its impact for the public and private good over the next 11 years if we take the opportunity now.

It is the multidisciplinary and universal nature of mathematics which makes this true: multidisciplinary because of its vast scope and universal because of the effectiveness of its processes.

In some fields it plays a supportive role and in others, the lead. I will describe a lead role which will be crucial to achieving the sort of economy we want: the optimisation of public and private sector enterprise.

Charles Darwin summed up the deep importance of mathematics when he said, *"Mathematics seems to endow one with something like a new sense."*

Mathematicians do not have a monopoly on this extra sense. Broad mathematical capability across the community underpins most qualities identified in the aspiration for 2025. Bankers, nurses and engineers competently practise various forms of mathematics on a daily basis.

Today's 12-year-olds entering secondary school will be 2025's young graduates. After the slide in the performance of our 15-year-olds exposed in the latest Programme for International Student Assessments (PISA) results, it's not clear that they will enjoy the same broad mathematical capability as today's 23-year-olds.

The Australian Mathematical Sciences Institute's (AMSI) own aspiration for 2025 is to lift the percentage of secondary maths classes taught by qualified maths teachers from an appalling 66% now to 100%.

We have serious work to do here just to maintain the status quo, but we must also be prepared to deal with the new quantitative and qualitative challenges thrown up by this rapidly changing world – and to do that, we must be more agile than we are at present.

Getting practical about mathematics

Biology is a case in point. The slow uptake of mathematics and statistics in the university biology curriculum hampers our progress despite the demand for mathematically capable specialists at the research frontier.

The lesson here is to connect mathematics and biology in our schools, two disciplines which have not traditionally been close (notwithstanding Darwin's observation). Maths is meeting the biosciences in the 21st century much as maths met physics in the 20th, and we must communicate this through the curriculum – not leave it to Brian Cox, Simon Singh, Facebook and Twitter.

We need our mathematical sense or we risk ending up with The Blind Leading the Blind (Peter Bruegel the Elder, 1568) Wikimedia Commons, CC BY.

The advanced mathematics that the discipline itself practises loosely splits into

1. theoretical mathematics: developed without an immediate view to external application. It is the deep intellectual nature of theoretical mathematics which attracts many to the discipline (think of the Clay Millennium problems).

2. applicable mathematics: focused on practical benefit on various time scales. It is applicable mathematics which most directly, but not exclusively, impacts on our aspirations for 2025.

Many of any of us move freely between the two and history shows that the multidisciplinary capacity of mathematics depends critically on the health of the discipline proper. The use of 19th and 20th century differential geometry in 21st century computer graphics is a striking example. This pointed observation is aimed at the managements of our universities!

The word cloud below shows some public, private and research enterprises, all contributing critically to where we will be in 2025 and all employing or engaging with research-trained mathematicians and statisticians.

Wordle

Mathematicians' roles are increasingly important in a world addicted to progress, and they are multidisciplinary in nature – statisticians work with retailers to refine and analyse their loyalty programs and mathematicians work with banks to manage financial risk and with the hospitals to manage emergency ward workflows.

We make a fundamental contribution to the growth of knowledge based industries and to the smart operation of the natural and primary resource sectors. Unfortunately we don't communicate this very well, especially to students and their parents, but we are making a start.

The practice of this applicable mathematics can be broken into support roles and lead roles. Roughly speaking the support roles involve the practice of existing sophisticated mathematics and the lead roles involve active research:

- computational mathematics plays a lead role in industrial, biological, economic and environmental modelling, such as in the increasing accuracy and sophistication of climate change models
- bioinformatics plays a lead role in genetics, creating algorithms to analyse genomic data to expose genetic markers for disease
- optimisation should play a lead role in both making the Australian economy competitive in 2025 and in improving our national well-being.

Optimising optimisation

Broadly speaking, the mathematical field of optimisation involves determining an optimal scenario (relative to some criteria) among a collection of alternatives.

The determination of the most efficient route between two locations, where "route" and "location" can have many meanings, or the most economical use of resources in production processes. Optimisation problems can involve thousands of variables and minimise or maximise many "objective functions".

It sounds dry, but it cries out "productivity growth!" and "competitive advantage!" and, in times of emergency, "lives saved!"

Adrianne Behning Photography/
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Darwin would certainly agree that optimisation is in his “new sense” category.

Australia is getting better at optimisation, from traffic management to mining to aircraft scheduling, but it’s patchy. The defence forces are very good at it, in part due to the work of the Defence Science and Technology Organisation (DSTO), as well as the CSIRO, NICTA, IBM and some of the universities.

The health sector is not uniformly good at optimisation, nor are our public transport systems.

Small to medium enterprise is not good at it at all. We are babes in the woods compared to countries such as Germany and the US for whom optimisation is worth billions.

The really smart way to optimise infrastructure is to build optimality into the design. We almost never to do this – we usually optimise as an afterthought, if at all.

But one shining Australian example of optimisation in design is the work of business analytics and optimisation company Biarri Commercial Mathematics on the National Broadband Network (NBN) – work so good that they are one of six global 2014 finalists for the prestigious Franz Edelman Prize.

The mandating by government of optimisation integral to design for significant public and private infrastructure projects would have a transformative impact on the Australian economy. It would not only boost productivity but build in competitive advantage and contribute to a sustainable future.

Optimisation would become part of the economic culture at all scales.

By keeping the bureaucracy to a minimum this measure would encourage the growth of dynamic companies like Biarri and draw on the capacity of CSIRO, IBM, NICTA and the universities, all of whom would be able to tender for the design work.

It would strengthen the mathematical sciences and thrust us, sure-footed, towards 2025 and beyond without fear of falling into the ditch of mathematical ignorance.

Nalini Joshi, Professor of Mathematics at the University of Sydney

Mathematics is a universal language that unlocks innovation by abstracting a problem to reveal patterns that answer the crucial questions. The key to Australia’s future competitiveness and security lies in continually creating and adapting mathematical representations of the real world.

Mathematical truths make a complex world more comprehensible and manageable; they are intertwined with efficiency and innovation at all levels of the economy.

Mathematics can show us how to minimise traffic snarls in our cities, cut costs in a complex network of rail transportation, avoid congestion on the internet, produce innovative designs in optical lenses, weigh costs and benefits of environmental policies and optimise a small business plan.

Mathematics can create new and better Australian industries. It is now central to fundamental questions of nature, life and health.

How does genomic information lead to development and better health in early life? How can the resolution of medical images be improved while reducing their file size? How can mathematics be used to create a safer regulatory framework for financial markets?

The more technologically sophisticated a society becomes, the more critical its need for mathematical thinking. The pathways towards economic diversity and opportunity are paved with mathematics.

John Rice, Honorary Professor of Mathematics at the University of Sydney

A smart economy depends on mathematical skills but you would hardly know it. Mathematics in practice is often not recognised as such, and unrecognisable in terms of school and undergraduate mathematics. This is the great failure of mathematics education.

The greatest contribution that the discipline of mathematics could make to Australia's smart economy is to remedy that.

The remedy concerns approach as well as content. Mathematics as it is practised, in research and professional occupations, requires thought, creativity, judgement, questioning and problem solving. An economy based on production lines might not require these skills as a matter of course, but a knowledge and innovations-based economy does.

Current mathematics education, in schools and universities, is satisfied with programming students to carry out certain mathematical processes, and assessment rewards students who can calculate everything even if they understand nothing.

It's more like preparing for a production line than a knowledge based economy.

The mathematics discipline seeks a remedy in improving the knowledge base of those teaching mathematics. However, "upskilling" teachers with "more of the same" will not deliver mathematics in the form that a smart Australia needs.

We need mathematics "to be taught more like it is done" by those engaged in it, in both the innovations economy and research. This is a cultural change that involves the discipline itself, one that must be mainstreamed into school and university systems.

Without this, the connection between mathematics and the economy will remain dubious in the public mind, and mathematics will remain hamstrung in achieving its proper influence and delivering its benefits to a 21st century Australia.