Making maths matter

Prepared by a working group of the **Smart State Council**

November 2010

Smart State Council

An initiative of the Queensland Government

Dear Premier

Please find attached the Smart State Council working group report on *Making maths matter.*

This report highlights the pervasive applications of maths, be it in the development of new high tech industries or adding competitive value to our traditional ones; providing the tools to monitor, predict and solve environmental challenges; or underpinning our health system and its services.

The message is simple but critical: applied maths research is vital to Queensland's economic, environmental and social prosperity, but we need to guarantee a pipeline of applied maths skills if we are to capitalise on opportunities and meet industry needs.

By establishing an institute for applied mathematics and statistics that focuses on real-world solutions, Queensland will have access to a set of high calibre professionals, tools and technologies that will improve the State's capacity in problem solving and decision making for industry, government and the community.

Such an institute would position Queensland as a national leader in mathematics and its many applications.

I commend this report to you.

Professor Peter Andrews
Queensland Chief Scientist and
Chair, Standing Committee
Smart State Council

November 2010

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Smart State Council

The Smart State Council was established in June 2005. It is a central advisory body that provides high level independent advice to the Queensland Government to help position Queensland as the Smart State.

Since the launch of *Toward Q2: Tomorrow's Queensland* in September 2008, the Council also provides advice on innovative measures to assist Queensland to meet the Q2 ambitions and targets.

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Executive summary

The Smart State Council is chaired by the Premier of Queensland and comprises Government Ministers, the Queensland Chief Scientist and representatives from Queensland's business, community and research sectors.

Key findings

Queensland's economic, environmental and social wellbeing will increasingly rely on applied maths research.

Industry, government and the not-for-profit sectors will all require applied maths and statistics capability, but these skills are dwindling in Queensland and Australia.

Queensland has the opportunity to take a national leadership role by developing an international flagship institute for applied mathematics and statistics.

Maths is the language of science and technology, of engineering and the environment. The power of applied maths lies in its versatility; it provides the conceptual tools with which we can hone in on the microscopic, or visualise the gargantuan. Maths stands behind many of the technologies, such as the internet, mobile phones and GPS systems, which have profoundly changed how and where we do business, communicate and socialise.

The predictive power of maths means that we are able to develop models that assist us to plan for the future and make informed decisions to maintain our quality of life.

To manage contemporary issues and even to prepare for the issues we haven't yet encountered, a significant investment in applied maths research for industry and government will provide a cutting edge advantage for Queensland, nationally and internationally.

"The irony of mathematics is that most people seek to avoid the discipline but seek to benefit from what it delivers: jet planes, broadband internet, the weather forecast, so many things that contribute to everyday life are the direct result of solving mathematical equations!"

David Elston, Professor and Director, Biomathematics and Statistics Scotland (BioSS)

Through modelling and simulation of complex systems, data-based analysis and prediction, optimisation and operations research, the applied mathematical sciences[1] pervade industry, government and business. They are vital for a high functioning and thriving economy, society and environment, now and into the future.

The challenge for Queensland is threefold:

Economic: Research and development (R&D) to spur innovation and increase productivity. Information analysis and modelling to improve the quality of decisions in financial, political, scientific, social, engineering, and environmental fields.

Environmental: Better predictions and understanding of environmental and climate changes and their impacts on ecology, agriculture, water, utilities and the built environment. Management of environmental resources and population pressures based on modelling.

Social: Improving health outcomes and education through the application of appropriate informatics. Using data to inform good social policy outcomes. Understanding and predicting human systems and responses to change.

The risk is that we will not have the required skills to undertake the applied maths research required in the future. The proportion of students studying maths or applied maths is declining at school and university, meaning that a skills shortage – either to undertake applied maths research or to meet the needs of industry and government – is a real concern.

Queensland has an opportunity to take a national leadership role by establishing an institute for applied maths and statistics to develop research-based solutions for industry to improve products, processes, performance and economic outcomes, and grow the quantitative skills that industry, government and society requires for improved analytical thinking and better decision making. Such leadership will mean that Queensland is well placed to benefit from this investment.

Recommendations

Recommendation 1:

Make an in-principle commitment to establish an institute for applied mathematics and statistics that focuses on the needs of end users such as industry, government and the community. The institute will operate as a consortium of mathematics and statistics experts and industry collaborators that together develop and deliver state-of-the-art solutions to complex real-world problems (see Figure 1). The institute will:

Undertake applied research for economic, social and environmental outcomes

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[1] Throughout this report maths is used to refer to pure maths, statistics, and the application of quantitative skills more broadly in engineering, economics, finance, science, information and communication technologies, health and the environment.

[1] Society for Industrial and Applied Mathematics (1998) *Mathematics in Industry*, SIAM, Pennsylvania, accessed 30 March 2010,

- collaborate and partner with end users to transition research into practical application, and to meet end user needs for effective information analysis and improved decision making
- apply its research capacity to solve end user-motivated problems.

Build applied maths capability and leadership

- develop, support and train industry practitioners and researchers in applicable mathematics, statistics, and computational and information sciences
- collaborate with national and international networks in applicable mathematics and statistics innovation.

Develop a pipeline of applied maths skills

- work with policy makers and relevant bodies to improve teacher quality and the quality of maths education at primary and secondary levels
- increase the participation of Queensland industry-based mathematicians in the Mathematicians in Schools program (or similar existing program that is operating effectively but still needs scale and reach to effect a change)
- promote applied maths opportunities and events to students, teachers and parents.

Increase the understanding of the application and value of maths for industry

- work with professional bodies to increase maths content of professional training
- partner with professional organisations, industry and universities to deepen the reach of applied maths internship programs.

Recommendation 2:

Commission a business case for the delivery of an institute for applied mathematics and statistics. The business case will identify:

- funding requirements, options and sources for the building, establishment and ongoing running costs of the institute
- stakeholders and funding partners
- a site and timeframes for implementation
- a preferred operational and governance model.

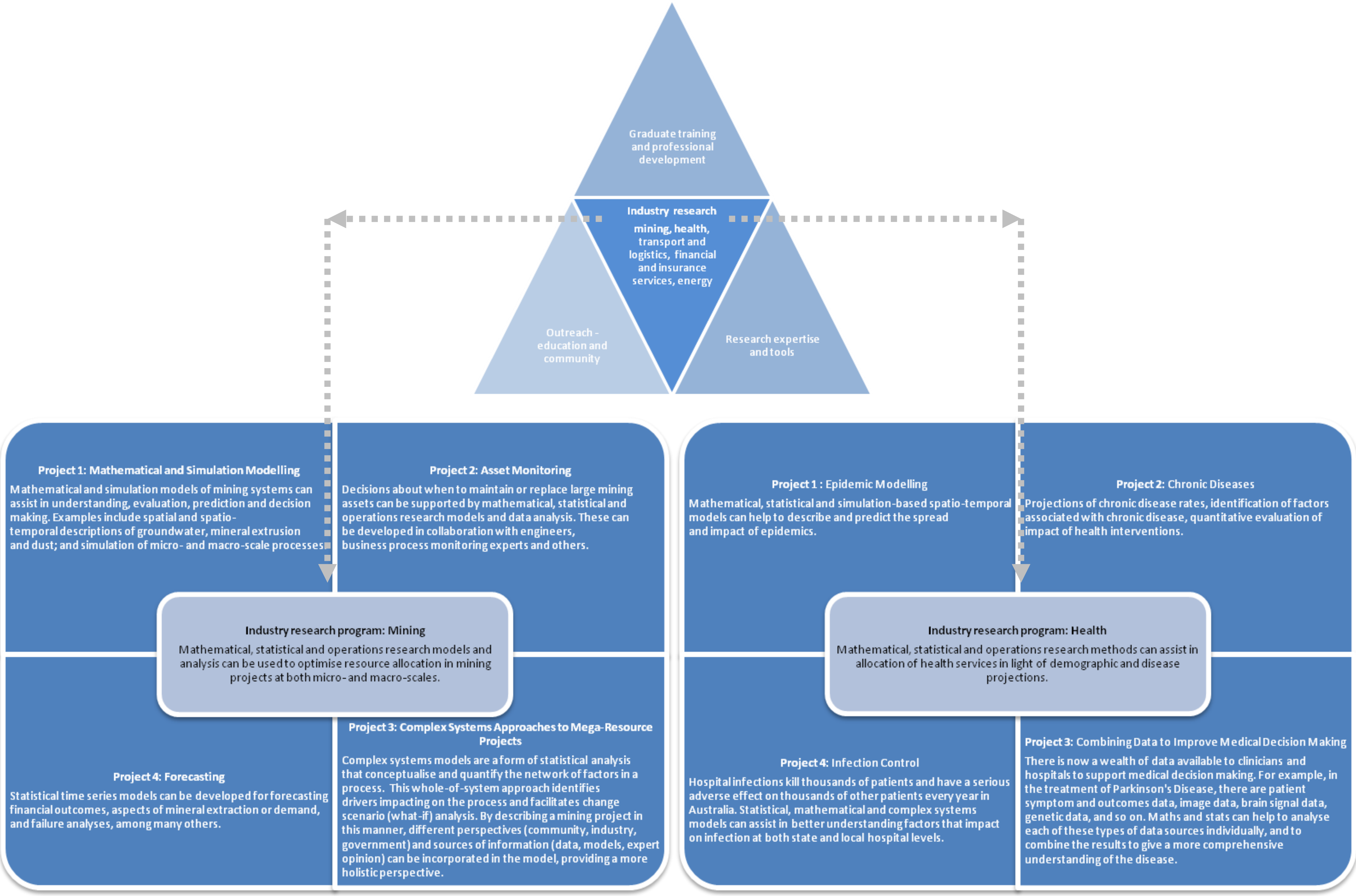

Figure 1: Model of industry led research for the institute of applied mathematics and statistics

Introduction

Applied maths is an ‘enabler’ of future economic, social and environmental outcomes.

Maths is pervasive, working across disciplines and sectors to provide knowledge and skills that are applied in areas as diverse as science, politics, engineering, economics and finance, health, information and communication technology (ICT), and the environment. “History shows clearly that the flow of ideas and inspiration between mathematics and applications runs strongly in both directions.”[1]

Applied maths provides a remarkably versatile set of tools to:

- develop models that predict outcomes (e.g. the weather or demographics)
- analyse the data to inform robust decision making or evaluate the effect of policy decisions (e.g. investment decisions or social policy)
- undertake much of the R&D that leads to innovation (such as technological advances in health and medicine)
- deliver the technology that is fundamental to business operations (e.g. computers and mobile phone technology).

This report highlights the critical role of applied maths in Queensland’s future, and how to continue to build and benefit from maths research and skills.

Section 1 examines why maths matters, and draws out the importance of applied maths research to Queensland’s triple bottom line – economic, environmental and social outcomes.

Section 2 looks at maths skills in Queensland, and highlights the fact that ongoing demand and the declining numbers of graduates in applied maths fields may impact on our ability to undertake the required applied maths research outlined in section[1].

Section 3 suggests that Queensland needs a mechanism to build applied maths research and skills, and to connect end users with the applied maths research. Three options to achieve this are canvassed, with the establishment of an institute for applied mathematics and statistics being recommended.

Section 4 provides a model for an institute for applied mathematics and statistics.

[1] Society for Industrial and Applied Mathematics (1998) *Mathematics in Industry*, SIAM, Pennsylvania, accessed 30 March 2010, <http://www.siam.org/about/mii/report.php>.

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Finally, we give a series of examples throughout this report that outline the ways in which maths matters.

Collectively, they demonstrate that maths matters more and more, yet its importance is not widely recognised. As the 2010 Western Australian Scientist of the Year, Professor Cheryl Praeger observed, "the generality and power of mathematics may unwittingly contribute to the invisibility of the mathematical sciences to the community at large."[2] Put another way, maths is like foundation fitness – a basic capability that is a prerequisite for success in a range of different sports, or in the case of mathematics, a range of disciplines, industries and applications.

[2] Praeger, C. (2010) "Mathematics and Australia." *ATSE Focus,* February 2010: 38 - 39.

1. Why maths matters

Applied maths is essential in dealing with an increasingly complex world.

Applied maths research will assist Queensland to address contemporary and future real world problems that affect the way we live and prosper. These manifest as trends that may be economic (the increasing importance of services industries, greater personalisation of services, and growth in emerging markets and 'developing' economies); social (increasing urbanisation and mobility, greater divides between the demographic trends in the north and south, and greater ICT connectivity); or environmental (including depleted natural resources coupled with increased demand).[3]

Although not exhaustive, the list below gives a taste of the range and complexity of current and future challenges. In almost every case, applied maths research can play a major role in analysing, forecasting and modelling to solve, alleviate or take advantage of the challenge.

Global economic challenges	**Queensland's economic challenges**
asset price collapse	addressing regional disparities
slowing Chinese economy	slowing Chinese economy
globalisation and nationalism	globalisation
sustaining innovation	lifting productivity
developing economies and burgeoning middle classes	sustaining innovation and lifting commercialisation
fiscal instability	conducive environment for business
Global environmental challenges	**Queensland's environmental challenges**
ecosystems demise	ecosystems demise
climate change	reducing greenhouse emissions
increasing urbanisation	population growth
peak oil	water
food security	extinction rates
extreme weather events	

[3] Hajkowicz, S. and J. Moody (2010) *Our Future World: An Analysis of Global Trends, Shocks and Scenarios*, CSIRO, viewed 6 September 2010, <http://www.csiro.au/resources/Our-Future-World.html>; Thirwell, M. (2010) *Our Consensus Future: The Lay of the Land in 2025*, Lowy Institute, Sydney viewed 6 September 2010, <http://www.lowyinstitute.org/Publication.asp?pid=1371>; Bisson, P., Stephenson, E. and Viguerie, S. P. (2010) *Global Forces: An Introduction*, McKinsey&Company, viewed 7 September 2010, <https://www.mckinseyquarterly.com/Global_forces_An_introduction_2625>; World Economic Forum (2010) *Global Risks 2010: A Global Risk Network Report*, World Economic Forum, Geneva, viewed 14 September 2010, <http://www.weforum.org/en/initiatives/globalrisk/Reports/index.htm>; Queensland Government (2010) *Toward Q2: Tomorrow's Queensland*, Queensland Government, Brisbane, viewed 21 October 2010, <http://www.towardq2.qld.gov.au/tomorrow/index.aspx>.

Global health challenges	Queensland’s health challenges
increased prevalence of chronic disease	increased prevalence of chronic disease
pandemics	ageing population
infectious disease	preventative health (e.g. obesity)
Global social challenges	**Queensland’s social challenges**
underinvestment in infrastructure	lifting education levels
migration	Indigenous disadvantage
unemployment	jobless households

This context and these ‘megatrends’ represent both an opportunity and a challenge, and managing them will require research and the implementation of strategies informed by applied maths.

Using maths to predict the future

While maths is important for addressing current global trends, it is also essential in developing models of what these future trends might be. Mathematical modelling and game theory was, for example, used in developing the World Economic Forum’s risk assessment.[4]

Drawing on large quantities of data from the past and taking into account recent trends, maths is used in predicting a whole host of future scenarios, such as rainfall, population growth, employment and disease outbreaks. This information provides evidence to inform policy and expenditure decisions, and thereby limits risks.

Maths also measures the probability of an event occurring. Knowledge of how likely an event is helps us to assess the magnitude of risk. Knowledge of the probability of a plane crash, or winning on the pokies provides us with information that we can use to make decisions in our everyday lives. An assessment of the probability of social and political events affects the stock market, oil prices and currency values – often with international ramifications.

[4] World Economic Forum (2010) *Global Risks 2010: A Global Risk Network Report*, World Economic Forum, Geneva, viewed 14 September 2010, <http://www.weforum.org/en/initiatives/globalrisk/Reports/index.htm>.

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1.1 Economically

Applied maths research and skills will assist us to diversify our economy into one that is more knowledge and technology intensive, while improving our quality of life.

"Throughout the world, innovation and globalisation are the two major sources of economic performance. They directly affect productivity, job creation and citizens' wellbeing, and they help make it possible to address global challenges such as health and the environment."[5] New knowledge, technologies and processes gained through R&D drive innovation.

Recognising this link between prosperity and wellbeing, and innovation and R&D, Queensland has made a significant investment over the past 10 years to increase R&D and innovation. This is very important as developing economies in our region are putting in place measures and policies to do the same. "An economy that does not invest in these areas is destined to be left behind and risks becoming second- or third-world by the end of the century."[6] Germany and Switzerland are two nations ranked highly on the 2009 European Innovation Scoreboard that can also demonstrate positive economic returns from innovation, such as knowledge intensive exports and new-to-market and new-to-firm sales.[7]

> "From the point of view of industry, mathematics is an enabling technology . . . its contributions are rarely visible in the final product that industry delivers. Nevertheless, the economic impact is real, and many companies – old, as well as new – have achieved a competitive advantage through the judicious use of mathematics."
>
> OECD Report on Maths in Industry, 2008.

Applied maths research is at the core of R&D and the development of new technologies which "fuel innovation and growth. Virtually all contemporary technologies, especially those in which Australia is endeavouring to gain a foothold (e.g. bioinformatics and information and communication technology) have the mathematical sciences at their heart. As a result, mathematics and stats are today not just the language, but the culture, of economic development and scientific innovation."[8]

Maths is fundamental to the development, production and marketing of ICT and high end technologies and has been a big part of the innovations we take for granted in our everyday lives, including: the internet; Google; mobile phones; film and animation; and diagnostic medical imaging. With economies, including Queensland, becoming dominated by service industries, once again ICT and its embedded applied maths applications are critical to sustainable economic development.

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[5] OECD (2007) *Science, Technology and Industry Scoreboard 2007: Innovation and Performance in the Global Economy*, OECD, Paris, viewed 17 August 2010, <http://www.oecd.org/document/59/0,3343,en_2649_33703_44198843_1_1_1_1,00.html>.
[6] Beattie, P. (2010) "Super Cities are not just Rocket Science." *The Australian*, 9 – 10 October 2010, p.4.
[7] European Commission Enterprise and Industry (2010) *European Innovation Scoreboard 2009: Comparative Analysis of Innovation Performance*, European Union, viewed 27 October, <http://www.proinno-europe.eu/page/european-innovation-scoreboard-2009>.
[8] Hall, P. (2004) "Australian Maths No Longer Counts." *Australasian Science,* vol.25, no.6, p.43.

The changes in Queensland's economic landscape over the past 19 years highlight the important and ongoing role R&D and innovation will make to diversify the economy. The economic share of services industries has increased, for example, while that of primary and secondary industries has decreased in this time. These changes are in keeping with other advanced economies, and mean that we need to develop new knowledge or technology intensive industries, while at the same time applying that knowledge and technology to existing industries, in order to remain internationally competitive.

The rapid rate of technological change means that industry requires applied maths to maintain a competitive edge. In an industry context, maths assists with managing the:

- complexity of the issues under investigation
- uncertainty of data, or the impact of social and environmental components
- multiple scales (such as size or time)
- increasing role of simulation, enabled by ICT, that replace traditional experiments
- increased quantity of data, and the need to effectively manage this
- need to find ways to transfer maths knowledge into practical outcomes.[9]

Opportunities for industrial innovation driven by applied maths research include improved manufacturing products and processes (digital preassembly and process optimisation), product design (shape and function), materials (less wear and tear), environmental management (modelling hazardous products and processes), and information science (neural networks). [10]

Although Queensland's performance on a number of innovation and R&D measures has increased over the past 10 years, there is still room for improvement.[11] Queensland had the highest proportion of innovating businesses and annual business entry rate of Australian states in 2006-07, but had the lowest levels of R&D expenditure per capita, as well as the lowest business survival rate.[12]

Using knowledge intensive products and services as a performance measure for a knowledge economy, the following measures give an indication of opportunities and areas for improvement:

- The proportion of Queensland's goods exports that are knowledge intensive has decreased from over 5 per cent in 1998-99 to 4.5 per cent in 2008-09. For Australia, this proportion has also dropped from 18per cent to 11 per cent over the same period.[13] By contrast, the OECD average was 56.6 per cent in 2008-09.

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[9] OECD Global Science Forum (2008) *Report on Mathematics in Industry*, OECD, Paris, viewed 23 March 2010, <http://www.oecd.org/document/8/0,3343,en_2649_34319_42626653_1_1_1_1,00.html>.
[10] Society for Industrial and Applied Mathematics (1998) *Mathematics in Industry*, SIAM, Pennsylvania, viewed 30 March 2010, <http://www.siam.org/about/mii/report.php >
[11] Gross expenditure on research and development (GERD) has increased from 1.11 per cent to 1.59 per cent of GSP. In dollar terms, this corresponds to an increase of 140 per cent, from $1.2 billion ($1.6 billion in 2008-09 dollars) to $3.9 billion.
[12] Op cit.
[13] Calculations based on ABS, Foreign Trade, unpublished data; OECD Stan Indicators Database, viewed 29 October 2010, <www.oecd.org/sti/stan/indicators>.

- The proportion of Queensland services exports that are knowledge intensive has increased over the past 10 years; knowledge intensive service exports have increased from 18 per cent of all services exports in 1998-99, to 39 per cent in 2008-09. However, Australian knowledge intensive service exports have increased from 39 per cent to almost 58 per cent in the same period.[14]
- Global economic competitiveness is changing as a number of Asian countries become increasingly competitive on a number of measures. For example, ICT trade has rapidly increased in non-OECD Asian countries (particularly China and India), and manufacturing is increasingly being moved offshore to non-OECD countries. On recent measures, Korea had the highest positive trade balance (5.9 per cent), while Australia had the lowest (-5.4 per cent).[15]

On the environmental front, there is also an economic opportunity associated with the application of maths in developing cleantech technologies, including energy, environmental services and green building and design. It has been estimated that Queensland's cleantech industry generates $1.3 billion revenue annually, and provides jobs for more than 10,000 people.[16]

Environmental innovation now accounts for an increasing proportion of R&D. Leading countries in air and water pollution control technologies (measured by patents) include Japan, Germany, USA and Korea. Of all OECD nations, Australia accounts for 0.4 per cent of the global trade in environmental exports, while Germany, the USA and Japan collectively account for 44.8 per cent.[17] Queensland is well placed to export environmental products to Indonesia, South East Asia, India and the Pacific Islands. Investment in developing environmental products and services will also support the green collar jobs of the future.[18]

Queensland's performance in exporting knowledge intensive products and services points to an underlying need for greater applied maths research to help lift the competitiveness of our industries globally.

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[14] ibid.
[15] OECD (2009) *OECD Science, Technology and Industry Scoreboard 2009*, OECD, Paris, viewed 5 October 2010, <http://www.oecd-ilibrary.org/content/book/sti_scoreboard-2009-en>.
[16] Department of Employment, Economic Development and Industry (2009) *Queensland Cleantech Industry Development Strategy: Issues Paper*, Queensland Government, Brisbane, viewed 20 October 2010 <http://www.industry.qld.gov.au/key-industries/742.htm>.
[17] OECD (2010) *Measuring Globalisation: OECD Economic Globalisation Indicators 2010,* OECD, Paris, viewed 23 October 2010, <http://www.oecd.org/document/50/0,3343,en_2649_34557_45938226_1_1_1_37461,00.html>.
[18] Trade Queensland (2008) *Queensland: Exporting to the World*, Brisbane, Queensland Government, viewed 22 October 2010, <http://www.export.qld.gov.au/publications.html >.

Maths R&D keeps trains running on time

Getting to and from work on time and with a minimum of fuss is not only important for commuters, but also for employers.

Rail systems are already extremely complicated and will be more so in the future as a growing population means increasing demand on rail systems. Trains need to run on the right track at the right time to meet schedules and avoid accidents. One late running train can have a domino effect, causing peak hour mayhem. To keep systems running smoothly, decisions have to be made quickly, and continuously reviewed as conditions change.

Mathematicians from QUT have been funded by the Australian Research Council to develop job shop sequencing (the order in which trains run so as to achieve the best outcomes) and scheduling solutions for Queensland Rail. Using maths, the researchers have developed software that provides the best sequence for trains to run in order to maximise the use of the railway, taking into account the variable times taken on different parts of the track.

The software can be applied to any railway system, and improves the punctuality and reliability of the train network. The software is dynamic and able to respond to unexpected events in order to keep things moving and commuters getting to and from work on time.

The need for applied maths research is further underscored by business' expenditure on R&D (BERD). BERD gives a measure of investment in R&D and therefore in the technology and innovation that improves industry performance and is influential in increasing productivity. Although BERD in Australia has increased over the past 10 years, the BERD to GDP ratio is below the OECD average. Queensland's BERD, as a proportion of gross state product (GSP), in 2008-09 was lower than that of New South Wales, Victoria, South Australia and Western Australia.[19]

> The search for new life-saving drugs, the development of high-performance materials, and the protection of sensitive ecosystems - all of these application-oriented activities, and many others, are strongly dependent on fundamental research, and that research is inextricably linked to mathematics.
>
> OECD Global Science Forum, 2008

[19] Calculations based on ABS (2010) 8104.0 - *Research and Experimental Development, Businesses, Australia*, ABS, Canberra; ABS (2010) 5220.0 - *Australian National Accounts: State Accounts, 2008-09*, ABS, Canberra; ABS (2010) 5206.0 - *Australian National Accounts: National Income, Expenditure and Product*, June 2010, ABS, Canberra.

Business investment in R&D underpins the innovations that can, for example, result in a new software product, right through to improved production scheduling resulting in faster assembly times on the factory floor.

Despite a period of strong growth between 1998 and 2004, Australia's productivity remains below the OECD average and has started to trend downwards in recent years.[20]

Reflecting the importance of applied maths to industry sectors such as mining and financial services, the majority of Australian BERD (80 per cent) was invested in the maths-related disciplines of engineering (54 per cent) and information and computing sciences (26 per cent) in 2008-09, but pure mathematical sciences received only 0.14 per cent of total BERD funding.[21] Of the gross expenditure on R&D (GERD), of which BERD is a component, only 0.088 per cent of business expenditure was dedicated to mathematical sciences.

> We found that a critical mass of internal scientific and engineering capability is required to uptake new technologies, and although that might be less than 10per cent of staff in medium and large companies, small companies are at most risk of not having sufficient critical mass. Undertaking in-house R&D and having internal R&D capacity also positively influences the absorptive capacity of firms wishing to uptake new technology or IP.
>
> Australian Institute for Commercialisation

In key Queensland industries, we are lagging behind Australia in terms of R&D intensity. Of particular concern are two of our biggest indsutries – the maths-intensive financial and insurance services, and transport, postal and warehousing. At 0.4 per cent, the R&D intensity of the financial and insurance services industry is only a quarter of the intensity of Australia overall. Similarly, transport, postal and warehousing has an R&D intensity of 0.28 per cent, in comparison with the national figure of 0.35 per cent. For a sparse state like Queensland, which would particularly benefit from an innovative and effective transport and logistics systems, this is particularly relevant.[22] These two sectors would benefit from increased R&D capability, such as operations research to improve scheduling, or modelling price predictions for good portfolio management.

To utilise maths in new and innovative ways in Queensland's traditional industry base, and expand new technology and knowledge intensive sectors, Queensland needs to ensure that the relevant capability is available, and that industry sectors are able to access and engage this capability to undertake R&D.

Queensland, as a state that has historically relied upon resource-based industries, is well placed to build on the Smart State investment. Applied maths can take our big traditional industries such as mining,

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[20] ABS (2010) 1370.0 - *Measures of Australia's Progress, 2010,* ABS, Canberra; Department of Innovation, Industry, Science and Research (2010) *Australian Innovation System Report 2010*, Australian Government, Canberra, viewed 17 June 2010 <http://www.innovation.gov.au/Section/Innovation/Pages/AustralianInnovationSystemReport.aspx>; Ortega-Argiles, R., Piva, M., Potters, L. and Vivarelli, M. (2009) *Is Corporate R&D Investment in High-Tech Sectors More Effective? Some Guidelines for European Research Policy,* Institute for the Study of Labor, Bonn, viewed 5 October 2010, <http://ftp.iza.org/dp3945.pdf>; Eslake, S. (2010) *Australia's Productivity Performance: Seminar Presentation to Australian Treasury,* Grattan Institute, Melbourne, viewed 8 October, <http://www.grattan.edu.au/programs/productivity.php>.
[21] Calculations based on ABS (2010) 8104.0 - *Research and Experimental Development, Businesses, Australia*, ABS, Canberra.
[22] Calculations based on ABS (2010) 8104.0 - *Research and Experimental Development, Businesses, Australia*. ABS, Canberra; ABS (2010) 5220 - *Australian National Accounts: State Accounts, 2008-09*. ABS, Canberra; ABS (2010) 5206.0 - *Australian National Accounts: National Income, Expenditure and Product, Jun 2010*. ABS, Canberra.

agriculture and even tourism to a more competitive level, and it can help build new industries in energy, health and medical services, and cleantech.

Maths and ICT improving agricultural productivity

In Queensland several cropping sectors including cotton, sugar, grains, rice, turf, vegetables and grapes have led the world in the use of precision Global Navigation Satellite Systems (GNSS) to improve the operational efficiency of agricultural equipment. The Queensland market has been large enough to nurture and sustain the development of several innovative GPS companies.

One of these companies is Hemisphere GPS, built on the engineering nous and foresight of Robert Mailler, an Australian control systems engineer and mathematician, who was determined to develop technology that would make a tractor drive straight and thereby make farming techniques and methods more efficient and productive. This simple idea became the impetus for the development of the world's first application of integrated GPS/INS (GPS with Inertial Navigation) technology for hands-free steering in agricultural vehicles.

By the late 1990s Hemisphere GPS hands-free steering for tractors was a commercial reality and this ground-breaking technology has helped change farming practices all around the world.

The benefits of intelligent machinery are numerous. From an agricultural perspective, production efficiency is maximised through vehicle accuracy. Specifically, there is minimal overlap in field preparation, thereby reducing excess usage of inputs such as fuel, chemical and seed because double treatment is avoided. By eliminating overlap, total cost savings of 10-33 per cent are achievable, although a figure of 10-15 per cent is more commonly used.

The benefits at a Queensland agricultural level have been significant, so too has the development of a new technological product for the global market.

From the Department of Employment, Economic Development and Industry's ICT Business Success Stories (*http://ict.industry.qld.gov.au/ict-qld/204.htm*)

1.2 Environmentally

Maths is vital to manage and preserve our limited environmental resources.

It has been said that maths is the language in which nature is written. It makes sense then to use that language to better understand the natural world. Governments and the public are increasingly concerned about a wide range of environmental issues such a population growth, waste management, human impact on ecosystems, resource shortages, as well as how these interact with social and economic wellbeing.

To highlight just a few: Queensland continues to experience one of the highest population growth rates of all states and territories; we have high levels of greenhouse gas emissions per capita by international standards; 45 per cent of Queensland's ecosystems are classified as endangered or of concern; and on a per capita basis, Queenslanders recycle less waste than the Australian average.[23] But maths can make a major contribution in managing our precious environmental resources by:

- measuring – assessing the environmental impact of industries such as mining, agriculture or tourism
- monitoring – using statistics to order and analyse observations over time to, for example, keep track of at risk flora and fauna
- modelling – predicting the scale and impact of events on the environment.

> Mathematics is a language which transcends national boundaries, cultures, age, scientific fields, industrial sectors – and time. If we were to set out to design a language specifically to harness the innovative diversity in our society, it is unlikely that we could improve on maths.
>
> *Sir David Brown FREng, Chairman,*

Whereas measuring and monitoring build historical data and track changes over time, modelling is the tool that can make predictions based on those historical trends and other contextual factors. Modelling allows us to make informed decisions quickly – vital in our contemporary world.

For example, the importance of modelling the behaviour and impact of tsunamis is highlighted by the 2004 Asian tsunami. Better predictions will mean better warning systems and preparedness. The 2010 explosion and oil spill

[23] Office of Economic and Statistical Research (2010) *Population Growth Highlights and Trends: Queensland 2010,* Queensland Treasury, Brisbane, viewed 9 October 2010, <http://www.oesr.qld.gov.au/products/publications/pop-growth-highlights-trends-qld/index.php>; *Australian Greenhouse Emissions Information System* (AGEIS), Department of Climate Change and Energy Efficiency, Australian Government, Canberra, viewed 21 October 2010, <http://ageis.climatechange.gov.au/SGGI.aspx#>; ABS (2010) 3101.0 - *Australian Demographic Statistics, Mar 2010*, ABS, Canberra; Department of Environment and Resource Management (2010) *Regional Ecosystems Description Database*, Queensland Government, Brisbane, accessed 2 November 2010, <http://www.derm.qld.gov.au/wildlife-ecosystems/biodiversity/regional_ecosystems/index.php>; Hyder Consulting (2009) *Waste and Recycling in Australia: Amended Report*, Melbourne, accessed 4 November 2010, <http://www.environment.gov.au/settlements/waste/publications/waste-recycling2008.html>.

This document does not represent Queensland Government policy.

in the USA also highlights a role for maths in modelling the spread and speed of the oil slick, its possible impact, as well as clean up strategies and costs.

Using maths models to reduce greenhouse gas emissions from agriculture

Managing the greenhouse gas emissions from the agricultural sector is critically important as Queensland looks at ways to mitigate environmental and climate change. Sequestering carbon in the soil via plants, and managing fertiliser use are novel ways of reducing these emissions.

Researchers from the CSIRO and the Queensland Government Department of Environment and Resource Management have used a computer-based program, the Agricultural Production Systems Simulator (APSIM) to model different crop rotation scenarios, use of fertiliser, and their effect on greenhouse gas emissions.

Using historical data, including temperature, solar radiation, how land had been used (e.g. for cropping, pasture or uncleared), and previous farming practices, the model was able to generate sophisticated predictions of the greenhouse gas emissions that would result from a number of planting and fertilisation scenarios. The model is also able to predict the cost impact to farmers of the different scenarios modelled.

Previous research has found that the greenhouse gas emissions resulting from agricultural practices are linked not only to the types of crops planted, but also to the type of soil, and patterns of rainfall and drought that vary by climate and location.

The modelling described above is powerful because it is able to generate predictions specifically for the subtropics. Time and resources are saved by using a model rather than having to conduct experiments *in situ*. Such location-specific information is vital to farmers who wish to identify the best planting and fertilisation strategies to manage greenhouse gas emissions cost effectively. Maths sits behind the modelling and enables the predictions that have practical applications for farming practices.

Because the environmental sciences are data rich, the sheer volume of this data requires maths to manage and utilise it. Maths is increasingly being recognised as an important tool in managing the complex inter-relations between the environment, humans and the economy, and achieving a balance between the needs of all three: “mathematical abstraction and language will be essential to identify the structure needed to organise the large volumes of data in emerging fields, to derive new implications and new predictions to be tested."[24] Maths is a cross-fertiliser in many areas of environmental analysis.

The great versatility of maths is particularly evident in biology, providing the tools to deal with a range of unwieldy problems: "mathematics can help biologists grasp problems that are otherwise too big (the biosphere) or too small (molecular structure); too slow (macroevolution) or too fast (photosynthesis); too remote in time (early extinctions) or too remote in space (life at extremes on the earth and in space); too complex (the human brain) or too dangerous or unethical (epidemiology of infectious agents)."[25]

Recognising the importance of understanding and managing our environment, the Queensland Government has made a significant investment in establishing the Ecosciences Precinct as part of the Boggo Road Urban Village development. The Ecosciences Precinct will focus on climate change, protecting our natural resources and environment, and ways to grow our farming, mineral, forestry, and marine industries so they are competitive and sustainable.

To achieve these outcomes requires the application of maths to manage the vast quantities of data gathered, measure impacts and make predictions to inform policy and practice. Building closer links between the Ecosciences Precinct and applied maths research will not only benefit the environmental science-focused R&D being undertaken on site, but will also improve Queensland's maths capability and application across a range of other sectors.

[24] National Science Foundation (2000) *Mathematics - The Science of Patterns and Algorithms*, National Science Foundation, Virginia, Arlington, viewed 27 July 2010, <http://www.nsf.gov/pubs/2002/nsf0120/nsf0120_2.htm >.
[25] Cohen, J. E. (2004) "Mathematics is Biology's Next Microscope, Only Better; Biology is Mathematics' Next Physics, Only Better." *PLoS Biology,* vol. 2**,** no.12, e439, accessed 22 September 2010, <http://www.plosbiology.org/home.action>.

The maths of conservation

The world is currently in the midst of a mass extinction event – species are becoming extinct at 1,000 times the normal rate. In Australia, recent analysis suggests five kinds of bird have disappeared in the last decade.

The cornerstone of good conservation is having a good national parks system – both on land and in the sea (marine protected areas). Traditionally, decisions about where to place national parks have been ad hoc, driven by scant evidence and the whim of ecologists.

Australian R&D has led the world in mathematically defining the problem of choosing national parks optimally using mathematical optimisation tools – or decision theory. Australian software has been fundamental to the design of Australia's protected area system – in particular the Great Barrier Reef Marine Park in 2004.

The task was to find a set of reefs and other areas (from a total of 17,000 possibilities) that would meet the goal of conserving at least 20 per cent of every habitat type. This would preserve species while having a minimum impact on the fishing industry.

Defining the 'green zones', or no fishing areas, for the iconic Great Barrier Reef sounds straightforward. However, when one realises that the number of options for a reserve system is two to the power 17,000 – a number much bigger than the number of atoms in the universe – one realises that this is much more that a high school maths problem.

To solve this problem an algorithm called 'simulated annealing' is used. Developed (from a mathematical perspective) quite recently (http://en.wikipedia.org/wiki/Simulated_annealing), it finds good solutions fast. This approach is also used for many industrial applications like airline and train scheduling, classifying remote sensing data and military operations (which is where the term 'operations research' comes from).

The Possingham conservation research lab at The University of Queensland has used simulated annealing to develop the Eureka prize winning Marxan software (http://en.wikipedia.org/wiki/Marxan) which assists users to design marine and terrestrial reserve systems. This free software is being used by more than 100 countries around the world, including the USA, Canada, and Papua New Guinea.

1.3 Socially

Applied mathematical research has social benefits that improve community wellbeing.

There is another story to be told about the opportunities we, as a state and as a nation, could miss by not valuing and investing in applied maths for community outcomes. This story is both social and economic.

While R&D is commonly associated with improved productivity and economic performance, and this is a major rationale for investment, applied maths R&D also has a social dimension. Health, for example, is heavily reliant on maths.

> The digital economy and mobile-phone technology rely on scientific breakthroughs in quantum theory and the theory of information that were pursued at the time mainly for curiosity. The basic science behind medical imaging was worked out 60 years before computer technology had advanced to a point where it could be used in practice; now medical imaging saves countless lives and imaging technology has many other applications.
>
> *Chris Budd, Professor of Applied Mathematics, University of Bath*

At the sub-cellular level, combinatorics and statistics have been essential to the sequencing of the human genome, while the development of in silico (computer simulated) models allows for increased knowledge of the whole organism. "Access to such models would, for example, greatly enhance rational drug design, allowing computational testing of hypothetical drugs. It would greatly enhance understanding of 'normal' function in human biological systems and the non-invasive diagnosis of disease states, using computational comparison of subject anatomy and function to template anatomy and function."[26]

The technology behind diagnosis via x-rays, computed axial tomography (CAT) scans and magnetic resonance imaging (MRI) is also reliant on maths, while at the population level, applied maths is a part of epidemiological studies to understand the transmission and effects of disease, and is critical for public health.

The use of maths for medical and social purposes has generated new maths disciplines. Biostatistics, for example, has been developed to design studies and analyse results in biological fields. Bioinformatics has emerged more recently at the interface of genetics, statistics and ICT in order to manage the huge quantities of data that have been produced as a result of the sequencing of genes and proteins, and has been referred to as the "bedrock of current and future biotechnology."[27] Bioinformatics develops databases to manage information, and algorithms to identify relationships between data.

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[26] Sumners, D. (2000) *Mathematics in Molecular Biology and Medicine*, National Science Foundation, Arlington, Virginia, viewed 11 November 2010, <http://www.nsf.gov/pubs/2002/nsf0120/nsf0120_27.htm>
[27] Persidis, A. (1999) "Bioinformatics." *Nature Biotechnology,* vol.17**,** pp.828 - 30.

This document does not represent Queensland Government policy.

The new Translational Research Institute at the Princess Alexandra Hospital will require applied maths skills for biomedical research, and the proximity to the Ecosciences Precinct outlined in the previous section highlights a need for applied maths research capability to service both these maths-rich areas and achieve environmental and health benefits for Queenslanders.

Maths is applied to manage a complex system with major health implications

Blood supplies collected by the Red Cross are in high demand by hospitals and pathology labs. It is vital that hospitals and pathology labs do not run out of supplies, but also that they are not oversupplied which may lead to wastage of blood products.

Mathematicians from QUT have developed a model which enables blood banks to identify the best method for distributing blood products to ensure that hospitals have enough supply and wastage is minimised.

Using the model, blood bank administrators are able to predict where and when there may be shortages of blood products, and the average age and amount of the blood products dispatched to hospitals and labs. The maths-based model has helped develop a system that ensures a cost-effective and efficient distribution of blood products.

Technology, and the R&D behind it, also facilitates broader concepts of social wellbeing. The internet, for example, has made available information and social contact like never before. The Reach Out! website, providing mental health information to young people, is a successful example of how technology has been adapted for social outcomes. Whereas only a relatively small proportion of 15 to 34 year olds suffering a mental disorder use professional services, seven million people have accessed the Reach Out! site since its launch in 2008, and its existence is known to one in three young Australians.[28]

As in other parts of the world, the ageing population in Queensland is anticipated to increase pressure on health and support resources. Gerontechnology – technology that is adapted or developed to keep elderly people safe, well and connected has emerged at the intersection of technological innovation and gerontology, and will require applied maths. Gerontechnology can assist ageing people by, for example, sending automatic health updates to medical professionals (telehealth), assisting with shopping, and improving the design of homes. In the future these technologies could include robotics to undertake housecleaning, artificial muscles to improve mobility, or sensors to provide information about the environment to people with hearing or sight impairments.[29] All of these will require some applied maths component.

[28] Nicholas, J. (2010) "The Role of Internet Technology and Social Branding in Improving the Mental Health and Wellbeing of Young People." *Perspectives in Public Health,* vol. 130, no.2, pp. 86 - 90.
[29] Australian Academy of Technological Sciences and Engineering (2010) *Smart Technology for Healthy Longevity*, Melbourne, ATSE, accessed 23 September 2010, <http://www.atse.org.au/atse-in-action/tackling-issues/health-technologies>.

Increasing rates of chronic disease and lifestyle influenced health issues, such as obesity, as well as an ageing population, will place particular stresses on Queensland’s health and social resources, and impact upon the quality of life of Queenslanders. Applied maths informs the development of technologies that improve prevention and treatment of disease, while the deployment of existing technologies in novel ways builds social capital and wellbeing.

How can maths help recovery from cancer?

“Chemo-brain” refers to a range of cognitive problems that are reported by patients following chemotherapy treatment for cancer. These problems include: reduced visual and verbal memory, poor concentration, reduced motor coordination and slower processing of information. Any one of these impairments impact on the ability to work, as well as everyday living.

Statisticians from QUT have collaborated with clinicians and psychologists at the Wesley Research Institute to find out about the short and long term effects of chemo-brain among women with breast cancer. As the rate of breast cancer is increasing, an understanding of the impact of treatment is important for a growing number of women.

The statistical analysis revealed that for most cognitive domains women's performance remained stable. However for delayed verbal memory, most women declined (55.7 per cent) during chemotherapy, and a subset of women (20 per cent) remained at low levels 18 months after completion of chemotherapy treatment. The analysis also identified the characteristics of those women who had not experienced any change, and those who had not recovered two years after treatment.

The power of statistics lies in the identification of subgroups of women who have different patterns of response to treatment and predictive tools for identifying those women who might be at greatest risk of chemo-brain. The knowledge gained will assist in the development of more targeted management plans for women who have been treated for cancer.

2. Maths capability – applied skills for the future

We need a maths pipeline that will supply the applied high-level maths capability required to undertake research with industry and government.

The previous section shows how the application of maths is critical to technology, research and innovation. Continued investment in R&D to develop innovative solutions for economic, social and environmental issues will require human capital.[30]

This section outlines educational trends in the maths skills pipeline, and suggests that high-level maths capability will continue to be required. There is, however, a potential disconnect between the availability of maths skills and Queensland's future needs, while the increasing economic and technological capacity of Asia and other emerging economies means that demand for quantitative skills in the future could be even more pressing for Queensland.

For a long term supply of applied maths skills we must ensure that we get the basics right:

- quality maths teachers in primary and secondary schools that have high-level content knowledge and ability
- a steady supply of graduates in maths-related disciplines that are industry ready, and
- a pool of talented researchers that industry and government can draw upon.

An important spin-off or spill-over effect will be a mathematically literate community and workforce, and a fairer Queensland overall.

[30] Banks, G. (2010) Advancing Australia's 'Human Capital Agenda'. *Fourth Ian Little Lecture*. Melbourne, viewed 1 June 2010, <http://www.pc.gov.au/speeches/advancing-human-capital>.

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2.1 Future demand

Demand for maths skills in Queensland is predicted to continue, particularly in fields such as engineering, statistics (biostatistics), and ICT. At the national level, demand for applied maths and statistics graduates has been forecast to outstrip supply.[31]

> To understand an entrepreneurial process relies on a similar ability for abstraction and understanding mathematical structures. Therefore, I believe that being a mathematician is very good training for managerial work and the potential talent to become a manager is usually there.
>
> *Achim Bachem, Mathematician*

Calculations undertaken for this report examined the distribution of tertiary qualifications that included some maths component across occupational categories, and used Monash predictions to identify future demand. Between 2006-07 and 2016-17 it is estimated that, in Queensland, of occupations that will be important to the R&D and innovation outlined in the previous section, demand for natural and physical scientists will grow by 98.82 per cent (an increase of 11,820 jobs), information and organisational professionals will grow by 59.3 per cent (or 10,530 jobs), ICT managers by 55.2 per cent (or 3580 jobs), and engineering professionals by 59.1 per cent (or 11,600 jobs).

A survey of 35 Queensland businesses and organisations undertaken by the *Making maths matter* working group reinforced the pervasiveness of maths and its application across a range of industries and sectors – from research to not-for-profit organisations – and highlighted an ongoing demand for maths skills. While not a comprehensively representative sample, the survey results emphasise the importance of mathematical capability not just in maths-based occupations or sectors, such as engineering, ICT or financial services, but also in other roles to support informed and evidence-based decision making in corporate communications or community services.

The majority of respondents indicated that quantitative ability was very important to their sector or business. While about 23 per cent felt that the proportion of quantitatively trained people in their organisation was about right at the time of the survey, more than half the respondents were concerned about a shortage of mathematical capacity in the future. This concern ranged from highly specialised skills (such as hydrology, modelling or spatial reasoning), professional skills (particularly statistics and engineering), through to basic mathematical skills (using spreadsheets or undertaking basic sums). Several respondents also raised concerns about the level of capability coming through schools and universities, which may limit the pool of future workers.

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[31] Department of Education, Training and Skills (2006) *Audit of Science, Engineering and Technology Skills: Summary Report*, Australian Government, Canberra, viewed 26 April 2010, <http://www.dest.gov.au/NR/rdonlyres/AFD7055F-ED87-47CB-82DD-3BED108CBB7C/13065/SETSAsummaryreport.pdf>; Department of Education, Employment and Workplace Relations (2009) *Overview of demand for managers, professionals and technicians: Queensland – June 2009*, Australian Government, Canberra viewed15 April, 2010 <http://www.workplace.gov.au/NR/rdonlyres/37528A5A-6B3C-4A67-96B4-238CA6C2825F/0/QLDmpat0709.pdf>; National Strategic Review of Mathematical Sciences Research Australia (2006) *Mathematics and Statistics: Critical Skills for Australia's Future*, Australian Academy of Science, Melbourne, viewed 15 April 2010, <http://www.amsi.org.au/index.php/publications/238-a-national-strategy-for-mathematical-sciences-in-australia>.

This document does not represent Queensland Government policy.

Almost 95 per cent of respondents indicated that quantitative skills were critical in their organisation or industry, and more than half indicated that they would like to increase the proportion of people with these skills. When questioned about the effect of quantitatively skilled people on their business or industry the majority of respondents pointed to better business outcomes (see Figure 2). Also important were better research outcomes, more informed policy development and decision making, and improved workforce capability. A small proportion reiterated that it was a skill without which the organisation would not function.

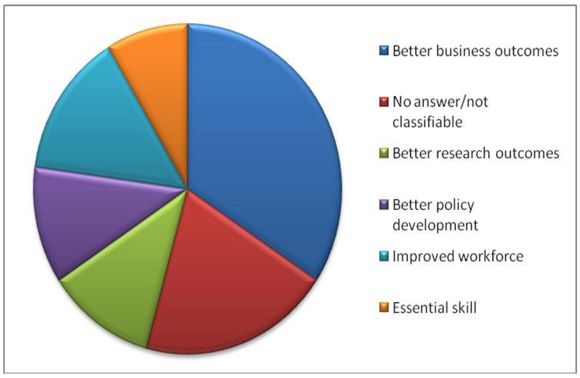

Figure 2: Impact of quantitative skills on business – industry survey

When asked whether our community should emphasise maths skills more than we currently do, most survey respondents agreed. But they pointed not only to high-level skills for employment and industry needs, but also to applied maths for everyday life – managing a budget, keeping a wider range of career options open, being scientifically literate.

Finally, high-level maths skills are required for Queensland's R&D capacity. Underpinning this is the principle that human capital, or knowledge workers, is required to undertake R&D and drive innovation.[32] Economic modelling suggests that if Australia takes steps to pursue an economic structure driven by innovation, a shortage of qualified people for the next decade is predicted.[33] This is of concern to Queensland, which has the lowest proportion of people employed in highest skilled occupations of the mainland states.[34]

> Senior executives from business and the government have warned that a shortage of maths and technology graduates could result in Australia losing its capability to develop and innovate its own technologies, making the country dependent on overseas talent to drive economic growth.
>
> *Julian Baikowski. Australian Financial Review. 13*

By OECD standards Australia has a reasonably high number of researchers, but businesses employ proportionally fewer researchers than comparable high achieving nations, and in comparison with the OECD average (see Figure 3).

[32] OECD (2007) *Science, Technology and Industry Scoreboard 2007: Innovation and Performance in the Global Economy*, OECD, Paris, viewed 17 August 2010, <http://www.oecd.org/document/59/0,3343,en_2649_33703_44198843_1_1_1_1,00.html>.
[33] Access Economics (2010) *Australia's Future Research Workforce: Supply, Demand and Influence Factors*, viewed 26 May 2010, <http://www.innovation.gov.au/Section/Research/Pages/ResearchWorkforceIssues.aspx>.
[34] ABS (2010) 4102.0 - *Australian Social Trends*, ABS, Canberra, viewed 22 October 2010, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4102.0>.

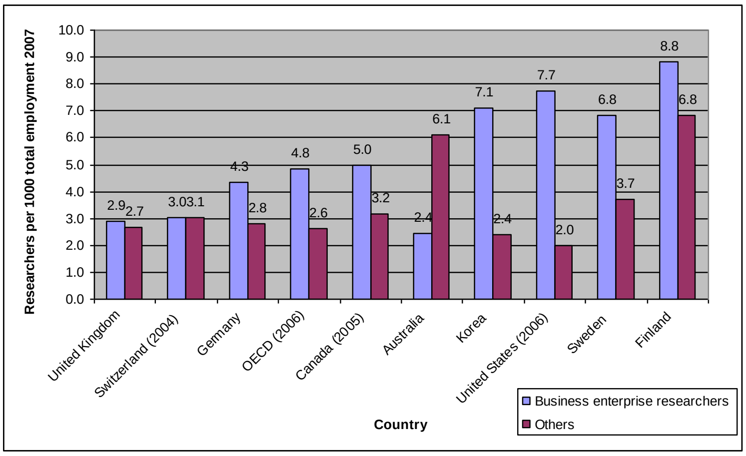

Figure 3: Business enterprise researchers per thousand employment, 2007

This reflects the concentration of Australian researchers in the public system, and suggests that there is an opportunity for industry to better utilise maths skills to increase innovation and economic competitiveness.

From the perspective of applied mathematicians, problems generated by end users offer novel research topics. However, it has been observed that “the single greatest barrier to further success in industrial projects has been a shortage of willing mathematicians and statisticians to participate in the projects.”[35]

A more limited supply of maths qualified people will be compounded by an ageing workforce, particularly in science, technology engineering and maths (STEM),[36] an already reduced mathematical skills base, and worldwide shortages of mathematicians (particularly statisticians).[37]

International education achievement measures are an indication of the future skills in the labour force, and the OECD has used economic modelling to examine the link between these skills and economic growth.[38] It finds that small improvements in the education of a nation’s labour force can have very large impacts on wellbeing, and recommends looking at the long term gains arising from education reform rather than those of a short term business cycle.

Using measures of education quality – the Programme for International Student Achievement (PISA)[39] scores – to examine how increased skills can affect GDP over 80 years in three scenarios, the OECD found that Australia’s level of real GDP would be:

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[35] Shteinman, D. (2010) “Industrial mathematics: Here and now. positive in all directions.” *Gazette of the Australian Mathematical Society,* vol.37**,** no.4, pp.13-219.

[36] Department of Education, Science and Technology (2006) *Audit of Science, Engineering and Technology Skills: Summary Report,* Australian Government, Canberra, viewed 26 April 2010, <http://www.dest.gov.au/NR/rdonlyres/AFD7055F-ED87-47CB-82DD-3BED108CBB7C/13065/SETSAsummaryreport.pdf>.

[37] National Strategic Review of Mathematical Sciences Research Australia (2006) *Mathematics and Statistics: Critical Skills for Australia's Future*, Australian Academy of Science, Melbourne, viewed 15 April 2010, <http://www.amsi.org.au/index.php/publications/238-a-national-strategy-for-mathematical-sciences-in-australia>; Brown, G. (2009) *Review of Education in Mathematics, Data Science and Quantitative Disciplines: Report to the Group of Eight Universities*, viewed 16 April 2010 <http://go8.edu.au/go8media/go8-media-releases/2010/184-group-of-eight-releases-maths-review>.

[38] OECD (2010) *The High Cost of Low Educational Performance: The Long-run Economic Impact of Improving PISA Outcomes*, OECD, Paris, viewed 15 August, <http://www.oecd.org/document/58/0,3343,en_32252351_32236191_44417722_1_1_1_1,00.html>.

[39] PISA occurs every three years and tests competency in reading, science and maths. Each PISA round has a focus on one of these three areas.

- 24 per cent higher in 2090 if the average Australian PISA score improved permanently by 25 points
- 19 per cent higher in 2090 if the average Australian PISA score increased to the current average level of the Finnish PISA test score (the highest current average test score among the OECD countries)
- 20 per cent higher in 2090 if, over a 20-year period, all Australian working age population scored at least 400 points on the PISA test (the current average score for the OECD countries).

What if Australia had implemented educational reform 40 years ago? Modelling undertaken for this report by the Queensland Investment Corporation (QIC) indicates that had education reform to increase PISA scores commenced in 1960, then under all three scenarios, Australian real GDP would currently be between 7 per cent and 9 per cent higher, and the economic growth rate would be about 0.35per cent higher on average.[40] The cost today of low maths achievement is roughly $90 billion.

Applied maths capability has flow on effects – higher levels of human capital translates into lower government expenses on social support, a sufficiently qualified workforce to pursue a knowledge economy, and better social outcomes.

2.2 The maths pipeline

Reflecting national trends, the proportion of Queensland students taking advanced maths (maths C) in year 12 is declining. Of all year 12 students, the proportion doing advanced maths and maths B has decreased, while the number of students taking maths A has increased slightly in recent years (see Figure 4).[41] This is important because maths C is required for tertiary study in applied maths disciplines such as the physical sciences and engineering.

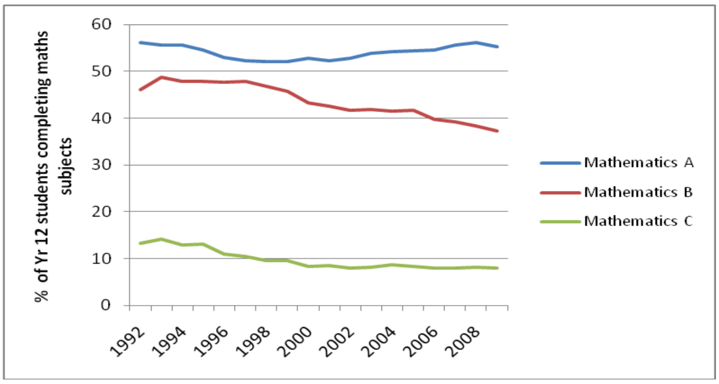

Figure 4: Percentage of Year 12 students undertaking maths by maths type A, B and C in Queensland 1992 – 2009

[40] QIC (2010) Unpublished analysis.
[41] Calculations based on data available on the Queensland Studies Authority website.

This trend continues at the graduate level, where Australia has a relatively low proportion of maths and statistics graduates compared with other OECD nations. More specifically, compared with OECD countries that perform well on ICT trade and high and medium-high technology manufactures, Australia has a relatively small proportion of applied maths graduates (see Figure 5), and has started to trend downwards in recent years.[42]

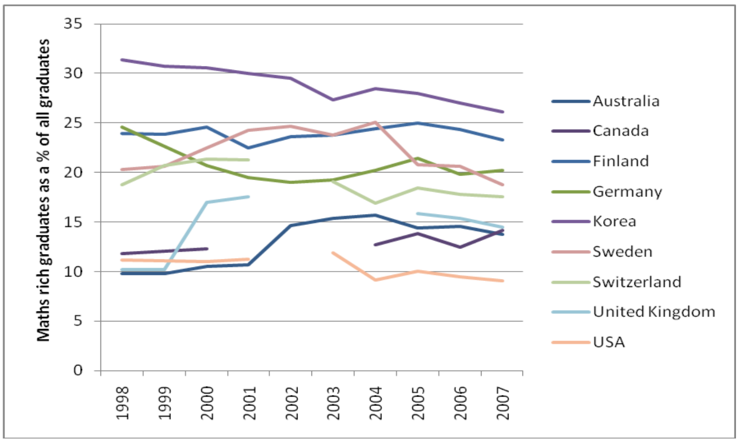

Figure 5: Percentage of graduates with applied maths qualifications, 1998-2007, selected OECD countries

Education is clearly a key part of the pipeline in terms of ensuring that there is an appropriately trained supply of maths skilled people in the workforce, and a numerate population. Because a number of recent reports and reviews (a summary is included at Appendix A) have highlighted the critical role of primary and secondary maths education in engaging students, and the importance of quality teaching, this report does not go over this ground again.

Similarly, reviews of teacher quality and science, technology, engineering and maths (STEM) education and training is being undertaken at both the State and national level, including *A Flying Start for Queensland Children*, the 2009 Masters report, and the development and implementation of the national curriculum (an overview of key developments is provided at Appendix B).

Quality primary and secondary maths education, increased participation in maths at senior levels

> Mathematics has been raised as an election issue only once in living memory . . . when the head of engineering at Google Australia asked three Australian politicians what their parties were going to do to stem the declining number of students studying serious mathematics in Australian schools.
>
> *Nalini Joshi, President, Australian Mathematical Society*

[42] For the purposes of this analysis, engineering and engineering trades, computing, mathematics and statistics, and physical science.

(particularly among under-represented groups such as women), and quality teaching are vital to a supply of mathematically literate workers at all levels, and there is room for improvement in each of these areas.[43]

However, it is worth noting for Queensland, and Australia more broadly, that while our performance is generally above the average on international science benchmarking tests, our average maths performance tends to be lower than for science. This is of concern because maths is the enabling subject for a wide range of science, engineering and technology study and work. On the PISA test, for example, maths scores have been trending downwards, and the Queensland average is below the Australian average (see Figure 6).[44]

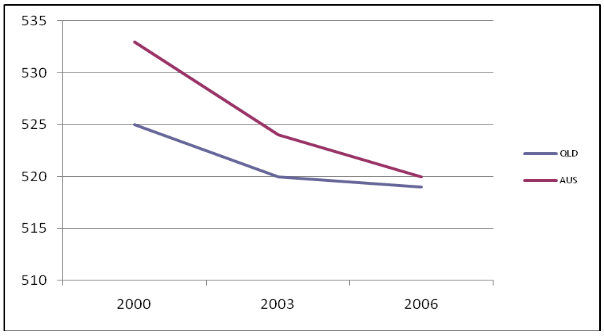

Figure 6: Mean PISA scores for maths, Queensland and Australia 2000 – 2006

Similar trends are evident in the results of the Trends in International Mathematics and Science Study (TIMMS), where Australia's average year eight maths score has dropped below the international average.[45] Queensland needs to maintain not only quantity, but quality of applied maths skills.

The proportion of people with pure maths qualifications in Queensland is quite small. At the 2006 Census only 0.1 per cent of 15 to 64 year old Queenslanders had a maths non-school qualification, compared with nearly 0.6 per cent in the Australian Capital Territory (see Figure 7).[46]

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[43] Harris, K.-L. & Jensz, F. (2006) *The Preparation of Mathematics Teachers in Australia: Meeting the demand for suitably qualified mathematics teachers in secondary schools*, Centre for the Study of Higher Education, Melbourne, viewed 16 April 2010, <http://www.cshe.unimelb.edu.au/research/pubs.html>; Ainley, J., Kos, J. & Nicholas, M. (2008) *Participation in Science, Mathematics and Technology in Australian Education,* Australian Council for Educational Research, Camberwell; The National Strategic Review of Mathematical Sciences Research in Australia (2006) *Mathematics and Statistics: Critical Skills for Australia's Future*, Australian Academy of Science, Melbourne, viewed 15 April 2010, <http://www.amsi.org.au/index.php/publications/238-a-national-strategy-for-mathematical-sciences-in-australia>.

[44] OECD. *Programme for International Student Assessment*. OECD, Paris, <http://www.pisa.oecd.org>.

[45] Thomson, S., Wernet, N., Underwood, C. & Nicholas, M. (2008) *TIMSS 07: Taking a closer look at mathematics and science in Australia*, Australian Council for Educational Research, Melbourne; Mullis, I. V. S., Martin, M.O., and Foy, P. (with Olson, J.F., Preuschoff, C., Erberber, E., Arora, A., & Galia, J.) (2008) *TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*, Chestnut Hill, MA, TIMSS and PIRLS International Study Center, Boston College, Chestnut Hill, MA; Martin, M. O., Mullis, I.V.S., and Foy, P. (with Olson, J.F., Preuschoff, C., Erberber, E., Arora, A., & Galia, J.) (2008) *TIMSS 2007 International Science Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*, TIMSS & PIRLS International Study Center, Boston College, Chestnut Hill, MA.

[46] ABS *Census Data Online,* ABS, Canberra, viewed 9 November, <http://www.abs.gov.au/websitedbs/d3310114.nsf/home/census+data>.

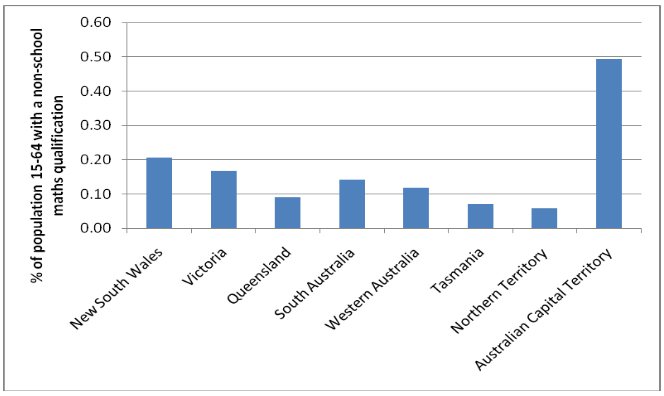

Figure 7: Percentage of state and territory populations, 15 to 64, with a tertiary maths qualification, 2006

The pervasiveness of maths means that it is also relevant to look at qualifications which include some maths component (such as physical and life sciences, ICT and engineering). On this measure, it is estimated that less than 5 per cent of the Queensland labour force has a degree that includes some maths training, which raises the question of our preparedness to undertake applied maths research for industry and government. Of people with a degree that entails some maths component, the majority are employed in the higher skilled and paid professional and managerial occupations (see Figure 8), underscoring the employment and income opportunities associated with maths qualifications.

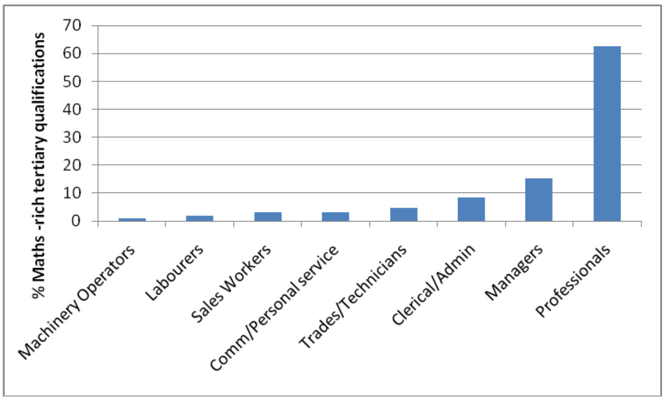

Figure 8: Distribution of Queensland non-school university qualifications with a maths component by occupation, 2006

Maths also matters to a fair Queensland. Overall, people with maths skills have good employment outcomes, including higher median salaries, and high full time employment salaries.[47] Those whose training has included some mathematical or quantitative component tend to be employed in the better paid professional occupations.

Finally, a high proportion of Australians lack maths competency for everyday life and work in a knowledge intensive economy. The International Adult Literary and Life Skills Survey found that approximately 53 per cent of Australians have low numeracy, and only 16 per cent have high-level skills. Applied maths is also critical to analytical thinking. On the problem solving scale, approximately 70 per cent of Australians had low problem solving ability, while only 5 per cent had high-level skills.[48]

[47] Graduate Careers Australia (2007) *GradsOnline, Graduate Careers Australia*, viewed 12 April 2010, <http://www.gradsonline.com.au/GraDSOnline/index.asp>; Bureau of Labor Statistics (2009) *Occupational Outlook Handbook, 2010-11 Edition*, Bureau of Labor Statistics, viewed 12 April 2010, <http://www.bls.gov/search/ooh.htm>.
[48] ABS (2006) *Adult Literary and Life Skills Survey, Summary Results Australia*, ABS, Canberra, viewed 15 April, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/4228.0>.

3. Building mathematical capability for the future

To reap the economic, social and environmental benefits that maths can provide, Queensland needs to take steps to build maths capability now.

Sections 2 and 3 of this report have outlined the vital role of applied maths research for Queensland's triple bottom line.

But to achieve that, we need a pipeline of quality maths education and training to deliver the applied maths researchers and practitioners of the future.

Recognising the escalating importance of maths to industry, an OECD report undertaken by the Global Science Group has recommended ways to increase the connections between maths and industry.[49] Although "Australia and New Zealand . . . have made some steps in this direction . . . much more should and could be done."[50]

Internationally there are a number of organisations and networks that focus on applied maths for industry, and provide models of how to connect maths research with end users. Examples include: the UK Isaac Newton Institute for Mathematical Sciences; Maths in Industry and Study Groups website; the US Society for Industrial and Applied Mathematics (SIAM); and the Canadian Mathematics of Information Technology And Complex Systems (MITACS).

Nationally there are a number of industry focused events, programs or research interest groups (such as the industry internship run by the Australian Mathematical Sciences Institute or the Australia and New Zealand Industrial and Applied Mathematics research interest group), as well as the CSIRO's Mathematics, Informatics and Statistics flagship and Wollongong University's Institute for Maths and its Applications. There is, however, no stand alone institute dedicated to applied mathematics and statistics in Australia.

What is needed is a mechanism to undertake applied maths research and build applied maths skills in Queensland, and to connect the resulting research and skills with end users – industry, government and the not-for-profit sectors – which would benefit from the myriad applications of maths; a mechanism of scale and reach that will:

- undertake applied research for economic, social and environmental outcomes
- build applied maths capability and leadership
- develop a pipeline for future applied maths capability

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[49] OECD Global Science Forum (2008) *Report on Mathematics in Industry*, OECD, Paris, viewed 25 April 2010 <http://www.oecd.org/document/8/0,3343,en_2649_34319_42626653_1_1_1_1,00.html >; OECD Global Science Forum (2009) *Report on Mechanisms for Promoting Mathematics-in-Industry*, OECD, Paris, 25 April 2010, <http://www.oecd.org/document/8/0,3343,en_2649_34319_42626653_1_1_1_1,00.html >.
[50] Wake, G. (2010) "Industrial Mathematics: 'On the Crest of a Wave'." *Gazette of the Australian Mathematical Society*, no.37, pp.88-90.

- increase the understanding of the application and value of maths for industry, government and the not-for-profit sectors.

Three options have been identified to address these areas of need: import skills via migration; create a virtual maths institute; or establish an institute for applied mathematics and statistics. An analysis of the options (Figure 9) demonstrates that an applied maths institute provides the long term and cross-sectoral outcomes for Queensland, has the capacity to undertake applied maths research, and to develop the relevant high-level skills.

	Applied cross-sectoral research	Build capability and leadership	Pipeline	Increase under-standing	Issues	
Import skills via migration	?	✗	✗	✗	+	Skills obtained relatively quickly No or minimal training costs Diverse maths skills and experiences introduced to Queensland
					-	Potential shortage of skills, particularly as emerging economies begin to invest heavily in R&D and wages increase Doesn't address need to establish a mechanism between industry, government and not-for-profit sectors No "go to" point for industry, government and not-for-profit sectors No long term solution to skills needs
Create a virtual maths institute	✓	✓	✗	?	+	Relatively easy to establish International models in existence Builds network of applied maths expertise
					-	Likely to have academic rather than cross-sectoral focus Will not attract talent to Queensland No "go to" point for industry, government and not-for-profit sectors
Establish an institute for applied mathematics and statistics	✓	✓	✓	✓	+	Will attract talent to Queensland Will provide a "go to" point for industry, government and not-for profit sectors Could offer professional development in applied maths Demonstrates national leadership
					-	Cost and time of establishment

Figure 9: Options for a mechanism to undertake applied maths research and build applied maths skills

An institute is able to focus investment and outcomes to achieve key targets. The Australian Institute of Sport, established in 1981, is a case in point. After a poor result at the 1976 Olympic Games the Australian Government made a deliberate decision, backed by funding, to identify and nurture talent. As a result, the proportion of gold medals won by Australia increased substantially at subsequent games (Figure 10). Put crudely, an institute with the capacity to increase and focus research produces more winners.

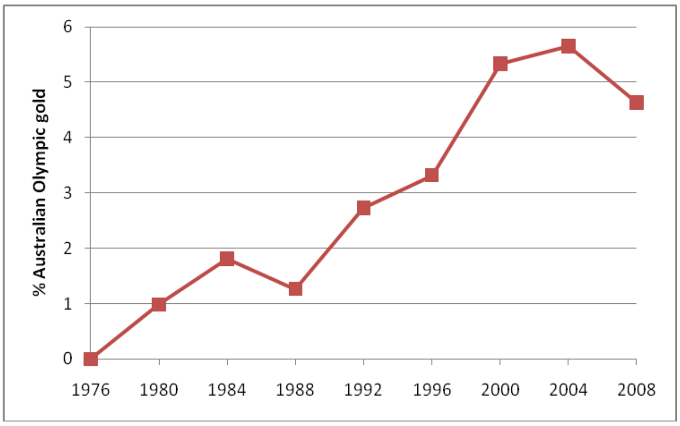

Figure 10: Percentage of total gold medals won by Australia following the establishment of the Australian Institute of Sport

Queensland Smart State investment has demonstrated that bricks attract brains. A return on investment study conducted by Allen Consulting on the Australian Institute for Bioengineering and Nanotechnology (AIBN) found that:

- for every dollar that the AIBN received from the Queensland Government during the period 2003 – 2009 (excluding funds provided as a loan), the AIBN attracted $3.10 dollars in additional investment from other sources, drawing investment to Queensland
- for every additional dollar (aside from Queensland Government investment) invested in the AIBN over the 2003 – 2009 period, Queensland's economic output over the period 2003 – 2029 is expected to increase by between $4.50 and $6.30
- the AIBN entered a total of 43 projects with industry worth almost $2.5 million between 2005 – 2009
- the AIBN has attracted researchers from outside Queensland and research higher degree students.[51]

There is preliminary support from business and research organisations in Queensland for an institute for applied mathematics and statistics, underscoring the importance of applied maths for wellbeing and prosperity.

[51] Allen Consulting Group (2010) *Economic contribution of the Australian Institute for Bioengineering and Nanotechnology to Queensland and Australia*, Allen Consulting Group, Melbourne, Sydney and Canberra; Mather, J. (2010) "State investment a smart strategy, study shows." *Australian Financial Review,* 20 September 2010, p.24.

"Australian business and industry relies critically on strong analytical skills and thinking, which are underpinned by capability in mathematics and statistics. Moreover, maths training teaches people terrific problem solving skills. Training in mathematical sciences also results in superior problem solving skills: from determining the exact question to be answered, to structured analysis, and finally reporting the solution or outcome in the appropriate manner for the audience. Industry is bursting with problems that are well suited to mathematical sciences. Any endeavour to increase this capability through industry-focused research and training in mathematical sciences in Australia would be welcome."

Virginia Wheway, EHS Director, Boeing Australia

"There is a critical need to increase the concentration of expertise and training in biostatistics and the wider mathematical sciences in Queensland. Such an institute would create a concentration of expertise and activity across different domains including health research and practice which are fundamentally underpinned by maths and stats. An Institute of Applied Maths and Stats would be of huge assistance to many stakeholders in the medical research field in Queensland and add substantially to our national and international competitiveness."

Julie Campbell, Director, Wesley Research Institute, The Wesley Hospital

An institute for applied mathematics and statistics will make tangible the critical importance of applied mathematics for industry and the community, function as a magnet and hothouse for highly skilled researchers and practitioners, provide a visible and accessible point for industry and government to access quantitative expertise, and be a place where school students and the community can experience maths in action.

4. A model for an institute for applied mathematics and statistics

Why an institute for applied mathematics and statistics?

Mathematical sciences pervade industry, government and business, through modelling and simulation of complex systems, data-based analysis and prediction, optimisation and operations research. A skilled community of researchers, practitioners and students in mathematical sciences and its real-world application is a state and national priority, indeed a global one.

Advanced mathematical skills are absolutely essential in order to analyse, interpret and convey increasingly complex information, driven by technological and scientific advances, for use in decision making in the private and public sectors. Mathematical and statistical capacity is also critical to the development of an advanced knowledge economy through R&D and innovation.

What will the institute do?

An institute for applied mathematics and statistics, headquartered in Queensland, will operate as a consortium of mathematical and statistical experts and industry collaborators that together would develop and deliver solutions to complex real-world problems.

The institute will:

- be an international leader in collaborative mathematical and statistical research and its application
- partner with industry and business to improve their competitiveness
- partner with government in more effective delivery of policy and programs
- attract national and international research and development leaders, funding and investment
- grow and train maths and statistics researchers
- up-skill industry professionals in quantitative skills to improve analytical thinking and decision making, and
- inspire school students, maths teachers and the community by demonstrating maths in action, including career pathways.

What are the institute activities?

The institute's capabilities and programs will be flexible and adapt over time to meet industry needs.

Mathematical and statistical capabilities

- Description, simulation and visualisation of complex systems
- Data analysis, modelling, computation and prediction

- Data mining
- Services science, optimisation and operations support

Industry programs

- Transportation and logistics
- Finance and insurance
- Mining and engineering
- Environment
- Energy
- Health Sciences
- Social Sciences and Education

Commercial engagement

- Industry led research programs and contract work
- Maths and statistics industry focused forums
- Development of 'smart maths and stats tools' for industry use
- Industry Affiliate Program – access to the institute's resources and expertise as well as comprehensive information on the full range of research and educational activities.[52]

Education and training

- Continuing professional development for industry, government and non-government sectors
- Training industry-ready practitioners, researchers and higher degree students
- Research and industry sabbaticals
- A program transitioning research to industry

How will the institute's research be organised?

The institute will be expressly designed to engage industry and government in addressing their real-world challenges. One possible approach to this is a matrix of core industry and research programs informed by economic, social and environmental needs (see Figure 1).

Industry programs will focus on the application of the institute's core expertise to problems posed by industry partners that will provide them with competitive solutions and know-how. These will be broad ranging. The following program areas are an indication of the types of sectors/partners that may be involved:

- biomedicine, biostatistics and bioinformatics
- mining and mining services
- climate change, biodiversity and environmental management

[52] The institute would develop an industry affiliate program similar to the one in place at Massachusetts Institute of Technology (MIT). For details please visit: <http://ilp-www.mit.edu/display_page.a4d?key=H1>.

- public and clinical health
- transport, energy, and water flows and management
- industrial analysis, modelling and prediction
- economics and finance, and
- other research programs identified by industry and research partners.

The institute will work with its partners to expand its repertoire of application areas as required, adapting known techniques to new areas, and expanding modelling capabilities through new research.

Research undertaken as part of the industry programs will focus on the development of tools, techniques and expertise to address challenges identified by industry. Three potential research programs are identified in the first instance:

- description, simulation and visualisation of complex systems
- data-based analysis, modelling and prediction, and
- service science, optimisation and operations support.

Institute partners

The institute will have national and international industry, research and affiliate partners that will underpin the long term activities of the institute as well as shorter term projects:

- *Industry partners* will comprise industry and government research groups that provide applied research leadership, and subscribe to the institute by providing cash and in-kind support on an annual basis. Industry partners will have privileged access to specialised research capacity that addresses real industry issues.
- *International partners* will include government agencies that can assist the institute with establishing international strategic links. The institute will emphasise a strategic approach to developing partnerships and markets. Underpinning this will be the importance of providing a quality commercial, research and educational experience for our future international business partners. Staff and student mobility will be supported to encourage international partnership opportunities.
- *Research partners* are research intensive institutions with a strong commitment to the application of mathematics and statistics that provide multi-year investment commitments to the institute. Students and staff will have access to innovative research problems posed by industry.
- *Affiliates* will comprise other groups that have an interest in being affiliated with the institute for the purposes of research, research solutions, collaboration, training, policy and communication.

What will the institute look like?

The institute will provide a physical and virtual meeting and collaboration place for researchers from a wide range of disciplines to address the challenges presented by industry and research needing advanced mathematical, statistical, computational and services science techniques and tools to progress their work.

Initially, while a dedicated facility is being constructed, the institute will operate as a virtual network. Having a ‘front door’ will be important in establishing the institute’s identity and a place where industry and government can interact and partner closely with researchers.

Institute establishment

It is proposed that the institute is funded by a three-way split between: industry, universities and research institutions, and government (State, Commonwealth and international).

The co-funding will provide:

- *Coordination:* institute coordination and administration
- *Institute leadership:* senior appointments that will undertake high-level industry-focused research, interface between institute partners, attract new projects, researchers and students to programs, and
- *Institute researchers:* appointments in each of the industry domains according to project/strategic need.

To build an institute of the quality and size that would provide for a world-class capacity in applied maths will require a major upfront infrastructure investment. There is a range of options that could be used to do this, and a staged approach will be necessary to take the concept through development to its final form.

Formation and early years of the institute

During this stage, and while the institute’s building is under construction, the institute will need to provide for a mix of office, meeting and training rooms, and auditorium facilities for:

- researchers, industry and project groups to work
- training and education
- institute staff (minimal in the early stages), and
- meetings (board, research community, industry and government).

It is likely that either co-locating with a participant or renting accommodation would be the most feasible options. During this stage, data and physical connectivity to universities, industry, government and other partners will be vital.

Long-term infrastructure development for the institute

The ultimate form and shape of the institute will depend on the extent of the floor area and facilities required by the institute.

There are several options that can be used:

- capital and operational contributions by all participants
- applications to State and Commonwealth funding programs, and
- private sector funding, with long-term leases in place.

The challenge is to develop a funding/investment model that will ensure excellence in long term applied mathematical and statistical research and skills, while being able to meet the short and medium term needs of industry, government and non-government sectors.

It is proposed to establish the institute through a staged approach as outlined below:

Stage 1
Business plan to be completed by 30 June 2011: stakeholder engagement activities with business, government and industry will be undertaken to gain support, awareness and funding of the proposal.

Stage 2
Start-up of the institute in an existing facility to allow for the design and development of a significant building. It is likely that a university might offer space in a new or suitable building to house approximately 80 to 100 people, rent-free for the first two to three years of the institute.

Stage 3
Development of a **cutting edge facility**: centrally located and dedicated to excellence in maths and applied statistics. One possible site is available land adjacent to the Ecosciences Precinct at Boggo Road.

This document does not represent Queensland Government policy.

5. Appendices

This document does not represent Queensland Government policy.

Appendix A Reviews and reports on maths in Australia

Title	Year	Major findings	Recommendations
Mathematics and Statistics: Critical Skills for Australia's Future	2006	• Maths research in Australia is becoming too narrow and overly reliant on a small group of researchers • The numbers of mathematics and statistics students and lecturers are declining • Maths teaching in areas that require mathematics and statistics is no longer being taught by mathematicians (a cost saving measure) • People with maths training are not entering teaching, or are teaching with inadequate higher level qualifications	• Increase the number of university graduates with appropriate mathematics and statistics training • Broaden the maths research base • Identify and meet industry needs • Maths teachers to have appropriate training • Increase the number of students undertaking intermediate and advanced level maths
The Preparation of Mathematics Teachers in Australia: Meeting the Demand for Suitably Qualified Mathematics Teachers in Secondary Schools	2006	• Maintaining the levels of appropriately qualified maths staff (particularly as most well qualified teachers are older and will retire in the near future) • Recruitment and retention of maths teachers • Ageing of experienced and qualified maths teachers • Attracting new people to maths teaching	• Need for workforce planning and development of a national workforce plan • Develop best practice model for teacher education • Minimum content and pedagogical standards for teachers at each level of secondary education • Bonded scholarships to encourage enrolment in science, maths and education programs
Maths? Why Not?	2008	• Individual factors (including perception of ability and interest in maths, previous achievement, and the perceived ‘usefulness’ of maths) were perceived as the most important influence on subject choice • Students themselves reiterated the importance of individual factors alongside maths’ perceived future uses • Also important are a student's experience of junior school mathematics (including consolidation of knowledge), for senior students less demanding	• Initiatives to improve maths teaching and learning, particularly at the junior and middle school levels • Promote maths career pathways • Implement initiatives to promote transitions between school and university (including reintroduction of university prerequisites) • Further research to investigate and influence students’ participation in maths

Title	Year	Major findings	Recommendations
		subjects are more appealing to maximise tertiary entrance scores, the influence of maths teachers and parents, and a lack of understanding about career pathways • There were differences between the perceptions of careers advisors and maths teachers surveyed • Maths teachers thought that the appeal of less demanding subjects was more influential than careers advisors on students' subject choice	• Setting nationally consistent targets for senior maths participation
A National Strategy for Mathematical Sciences in Australia	2009	• Industry demand for mathematics and statistics graduates is growing • There is an ongoing need for appropriately qualified maths teachers • The quality and availability of maths education (secondary and tertiary) in Australia is declining, and access is inequitable • A reduced maths capacity will impact on the future of Australian science	A national strategy is required that will: • promote the importance of maths (politically, for the community, and among students and teachers) • ensure a supply of qualified maths teachers at each schooling level and across Australia • strengthen maths in the university sector (leadership, staff and students) • fund mathematics and statistics infrastructure via AMSI
Review of Education in Mathematics, Data Science and Quantitative Disciplines: Report to the Group of Eight Universities	2009	• Negative attitudes to maths among students are prevalent • Australia is outperformed by comparable nations on PISA and TIMSS • There are low enrolments in advanced level maths in senior school years • There are difficulties recruiting maths graduates • Teacher quality for maths education is of concern • Maths standards at university level have dropped. • Maths departments are shrinking	• Increased dialogue between maths and education departments to improve teacher training in maths • Increased community awareness of maths and science • Go8 vice-chancellors to review service teaching arrangements • Address social equity and disadvantage through enabling maths programs • National maths research and networking programs (six months to one year) coordinated by AMSI and funded by contributions from Go8 universities

Title	Year	Major findings	Recommendations
			• Renewed attention needs to be paid to statistics

Appendix B STEM education reform in Queensland

Queensland Government	Overview
A Flying Start for Queensland Children green paper – policy in development	A range of reforms that relate to STEM education are canvassed: • teacher quality – a cooperative review of the quality of teacher training courses, including a focus on science and maths education • five teaching Centres of Excellence to be established to give student teachers a solid foundation in their teacher training placement; it is proposed that one or more of these Centres will have a STEM focus.
2009 report by Professor Geoff Masters, *A Shared Challenge: Improving Literacy, Numeracy and Science Learning in Queensland Primary Schools*	Government response to recommendations re science and maths in primary schools include: • additional support for the teaching of science and maths • pre-registration testing for primary teachers in literacy, numeracy and science • monitoring Queensland's performance in the national and international tests in numeracy, science and maths • the Queensland Teachers College will introduce an accreditation process that will quality assure professional development programs for teachers. Education Queensland is introducing a professional development program for state school teachers and leaders, designed to ensure that all state school teachers receive the support they need in teaching literacy, numeracy and science.
Education Queensland is offering up to 160 education scholarships to increase the quantity and quality of maths, science and IT teachers in state schools	Graduate employment scholarships support high achieving, pre-service teachers who are undertaking the final year of their undergraduate teacher education program in STEM curriculum areas. *Step into Teaching Scholarships* are available to high achieving science and maths graduates who are committed to becoming senior maths, chemistry or physics teachers. *Primary Science Scholarships* assist primary teachers to increase their science content knowledge and their confidence to teach the primary science curriculum. *Professional Development Scholarships* support high achieving teachers to undertake a Graduate Certificate in identified priority areas in STEM.

DRAFT

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