Australian Academy of Science

transcript

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Driving Australia's economic future through robust investment in science and in science and maths education

Mr Wilson, ladies and gentlemen,
Like AB Facy, I have had a fortunate life. During my early training in Cambridge, I was lucky to have learned from and worked beside some of this century's giants of science, including Nobel Laureates Francis Crick and Fred Sanger.

And in my subsequent career, I have been able to contribute to Australia's rich scientific tradition, alongside my partner in work and life, Jerry Adams.
These opportunities have led me on an exciting and inspiring journey, during which I have participated in important discoveries and met many brilliant individuals, both here and around the world.

Today I have the privilege of speaking on behalf of the Australian Academy of Science, a 440-strong Fellowship of the nation's most distinguished scientists.

One of the most important missions of the Academy is to nurture scientific excellence in Australia. Conscious of this responsibility, I want to share with you today the Academy's thoughts on the state of Australian Science, and Australian Science and Maths Education.

Australia's future prosperity depends on substantially strengthening both.

Australia's proud history of discovery and development

Let me begin by reminding you that Australia has a long history of producing world-changing technology. The examples are too numerous to give you more than a taster here.
Many of the 19th century inventions are icons of Australian history, including the grain stripper[1], the stump-jump plough[2] and the electric drill[3].

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[1] *1843 -John Ridley and John Bull of SA*
[2] *1876 Richard and Clarence Bowyer Smith*
[3] *1889 Arthur James Arnot Union Electric Company in Melbourne*

The 20th century gave us the black box flight recorder[4], the inflatable escape slide[5]; and the plastic polymer bank note[6].

Our medical scientists and technologists have given us the humidicrib[7]; plastic[8] and multi-focal spectacle lenses[9] and, more recently, day/night disposable contact lenses[10]. Countless lives have been saved by Howard Florey's application of penicillin to combat infection; Fiona Wood's invention of spray-on skin for burns patients (*1992*) and Don Metcalf's hormones for white blood cell production (*1960s-80s*).

9 of the 10 Nobel Prizes awarded to Australians have been in Science: starting with physicist William Lawrence Bragg in 1915 (who at 25 is still the youngest ever recipient). More recently we have had immunologist Peter Doherty (1996); Robin Warren and Barry Marshall (2005), who showed that gastric ulcers were caused by infection with a bacterium helicobacter pylori; and Elizabeth Blackburn (2009) for her discovery of the protective cap of chromosomes.

Increasingly, our world-class scientists are bringing substantial international revenue into the country. I'd like to share with you some major recent commercial successes:

1. WiFi

CSIRO scientist John O'Sullivan's pioneering work in radioastronomy led to the invention of WiFi **(**a beautiful example of how 'blue sky' research can lead to commercial success in a totally unexpected area)**.** This technology is absolutely integral to the way people all over the world use computers, printers, televisions and telephones. Indeed it is now hard to imagine a world without WiFi and I.T. specialists predict there will soon be more than one billion WiFi devices worldwide[11].

As of mid-2010, the WiFi patent had already netted CSIRO an estimated 250–million-dollars – which is being ploughed back into research and development via CSIRO's Science and Industry Endowment Fund - and it is predicted to ultimately bring CSIRO upwards of one-billion-dollars[12].

2. Relenza

CSIRO also gave us the influenza drug, Relenza, through the work of Peter Colman, Graeme Laver, Mark Von Itzstein and their teams. Millions of doses of Relenza have been stockpiled and used by nations around the world to protect against bird flu and swine flu, bringing in $63.7 million in royalties for the Melbourne-based company Biota in the 2009-10 Financial Year[13] .

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[4] *David Warren in Melbourne 1958*
[5] *1965; Jack Grant Qantas*
[6] *David Solomon, CSIRO, 1988*
[7] Edward Thomas Both 1953
[8] *1960; Scientific Optical Laboratories in Adelaide*
[9] *1992 Stephen Newman Qld*
[10] *Vision CRC/CSIRO; 2003-now*
[11] CSIRO (http://www.csiro.au/science/wireless-LANs--ci_pageNo-1.html) as at 9 Sept. 2011.
[12] Andrew Collety, *The Australian*, 31 August 2010 (http://www.theaustralian.com.au/australian-it/csiro/story-e6frgakx-1225912084897) as at 9September 2011.
[13] Biota Holding Ltd, Annual Report 2010 (http://www.biota.com.au/uploaded/154/1021687_18annualreporttosharehold.pdf) as at 9 Sept.2011.

3. Bionic Ear
In the 1970s a team of medical scientists and engineers led by Graeme Clark developed the first prototype bionic ear; this Australian invention has now brought hearing to more than 250,000 people worldwide[14].

Cochlear implants are manufactured solely in Australia and more than 95% are exported[15]. They have earned hundreds of millions of dollars in profit for the Australian company that owns most of the patents and manufactures the devices[16]. Bionic ear implants have also earned more than $8 million in royalties for the University of Melbourne and the Commonwealth – each of which owns patents over some of the early research[17].

4**.** Gardasil
The Gardasil story is another great example of Australian innovation that has made a big splash on the world stage.

Cervical cancer, which is caused by certain strains of human papilloma virus, is the second most common cancer in women. It claims nearly 300,000 lives around the world every year, most in developing countries.

I am sure that all of you are familiar with Gardasil, the vaccine developed by Ian Frazer's team at the University of Queensland, in collaboration with CSL. The vaccine prevents infection with the virus, and therefore also prevents cervical cancer.

Already more than 70 million doses of Gardasil have been distributed world wide, and cumulative sales are more than $5 billion, resulting in royalty returns to CSL of around $600 million to date.

We can be very proud that, as a result of seminal contributions by Australian scientists and an Australian company, cervical cancer will ultimately be largely vanquished. We should also celebrate that returns to the University of Queensland are enabling it to invest in further research and development.

5. **Plastic Solar Sheeting**
Looking to the future, an Australian success story in the making is being developed by the Victorian Organic Solar Cell Consortium, a collaboration involving the University of Melbourne, CSIRO, Monash University and four Australian and international companies. This wonderful meeting of minds from industry and academia, which includes my Academy colleague Professor Andrew Holmes, has produced a type of flexible plastic solar cell, much like our polymer bank notes. The cells are printed with a

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[14] Graeme Clark Foundation (http://graemeclarkfoundation.org/About%20G%20Clark/GMC%20FAQs.pdf) as at 9 Sept 2011
[15] Cochlear Pty Ltd (http://www.cochlear.com/corporate/cochlear-wins-export-award) as at 12 Sept 2011
[16] Cochlear, Annual Report 2011 (http://www.cochlear.com/files/assets/corporate/pdf/COH-AR_2011_ED_110831.pdf) as at 22 Sept. 2011.
[17] (http://www.ipaustralia.gov.au/understanding-intellectual-property/case-studies/?doc=patenting-a-medical-invention&view=Detail) As at 16 Sept 2011.

light-sensitive ink that converts sunlight to energy, mimicking photosynthesis. This exciting development can turn just about anything into a solar panel! Hopefully it will increase the use of solar power in Australia and around the world – especially as the cost of producing the units decreases[18].

Success stories such as these are very inspiring. But - as I am sure most of you know - translating scientific discoveries into commercial success is a long and difficult road, requiring:
- collaboration across scientific disciplines.
- cooperation between industry, academia and government.
- strong protection of intellectual property
- far-sighted and patient investors
- and a healthy measure of good timing and good fortune!

Australia's future prosperity will increasingly depend on Science

As these stories suggest, we live in a world where national prosperity is increasingly driven by scientific and technological innovation.

At the time of the Global Financial Crisis, President Barack Obama made a major speech in which he said:

> *At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment, and our quality of life than it has ever been before.*[19]

His words also resonate for Australia. Here we face many big challenges - in the economy, health, energy, water, climate change, infrastructure, sustainable agriculture and the preservation of our precious biodiversity. To tackle these challenges, we need creative scientists and engineers, drawn from many disciplines, and a technologically skilled workforce.

The picture I have just painted for Australian research and development is encouraging. Indeed, the Academy of Science believes that our scientific potential has never been greater.

However, although our past performance is commendable, our ability to improve this performance in the future, or even maintain it, is not assured.

Four things threaten our ongoing R&D performance and, as a consequence, our economic security and ongoing prosperity:

- The level of our investment in research and development

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[18] University of Melbourne Alumni ENews http://alumni.news.unimelb.edu.au/cheaper-efficient-solar-power-sight-funding-boost
Issue 23 August 2011.

[19] President Barack Obama, Remarks at the National Academy of Sciences annual meeting, The White House, Washington DC, 27 April 2009 (www.whitehouse.gov/the_press_office/Remarks-by-the-President-at-the-National-Academy-of-Sciences-Annual-Meeting).

- Our capacity to lever this investment by engaging effectively with the global science effort
- The poor science literacy of our workforce and our community
- The decline of interest in science education in our schools.

I will address each of these in turn.

1. The level of investment in R&D in Australia

First, investment in R&D.

Over the last decade, successive Australian governments have recognised the need to properly invest in research and innovation.

Total investment by the current Government has increased by almost 43 %, and is projected to amount to $9.4 billion dollars over the current financial year.[20] This is very commendable.

It is heartening to see that our business sector is also increasing its investment – although admittedly this boost is coming off a low base compared to many other OECD nations.[21] *(Australia ranks 14th for Business Expenditure on R&D as % of GDP)*

So, we have a good platform to build upon for the future.

But to remain competitive internationally we need even greater investment.

This becomes evident when we look to see where we stand in respect to the competition.

Australia spends around 2.2 per cent of our gross domestic product[22] – or around $900 per person per year[23] – on research and development. This puts us at a rank of 14th among OECD member countries.

We are well behind the next best-ranked country, Iceland – which devotes 2.6 per cent of GDP to research and development.[24] Top of the list is Israel, with 4.6 per cent, followed by Finland and Sweden, each of which spend 3.6 per cent.
(Canada is 1.87% and rank is 17th)

In terms of the people power we devote to R&D, we have around 92,000 full-time equivalent researchers.[25] Again, this is only middle order. According to the OECD, in

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[20] The Australian Government's 2011-12 Science, Research And Innovation Budget Tables (http://www.innovation.gov.au/AboutUs/FinancialInformationandLegislation/BudgetInformation/Documents/2011-12ScienceResearchandInnovationBudgetTables.pdf)
[21] OECD Main Science and Technology Indicators (**eISSN:** 2074-4226) as at 22 Sept. 2011.
[22] OECD Main Science and Technology Indicators (**eISSN:** 2074-4226) as at 9 Sept. 2011.
[23] UNESCO Institute for Statistics, Science & Technology Report (http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?IF_ActivePath=P,54&IF_Language=eng) as at 9 Sept. 2011
[24] OECD Main Science and Technology Indicators (**eISSN:** 2074-4226) as at 9 Sept. 2011.

2008[26] the proportion of R&D personnel in our total labour force puts Australia 16th, well short of Canada, which ranks 9th. To put it further in perspective, China has more than 1.6 million people working on research and development[27], and this number is increasing very rapidly.
(China is ranked 33, with 2.5 R&D personnel per thousand in workforce; total population 1.3 billion)

Worryingly, we rank well within the bottom half of OECD countries *(ranked 20th of 30)* when it comes to the number of university graduates emerging with a science or engineering degree per capita. [28]

These are sobering statistics. As we embrace the challenges and rapid developments of the 21st Century, past success, policies and attitudes are no guarantee that Australia will be able to continue to deliver internationally competitive R&D.

Research excellence is a precious entity that requires constant tending and nurturing. But the environment that researchers find themselves in today is just the opposite: a Darwinian battle for survival, where costs are rising faster than the level of funding and career opportunities are limited, despite recent government initiatives to improve them.

Students contemplating a career in research see how hard it is for their mentors and they are understandably daunted by what they see.

Women in particular feel daunted, when they realise the added degree of difficulty they face when they take career breaks to have children. I meet many young women who have done brilliant PhDs but then either left science altogether or decided to move sideways, into a more stable if less exciting career.
When I started my research training, I was not surprised to find relatively few female career scientists. I am surprised that this is still largely true. That makes me very concerned – we cannot afford to risk alienating half of our potential scientific workforce!

As you can see, both in the case of infrastructure, and in terms of the research workforce, we need to do better.

To be quite frank, we need much greater investment in science in this country, by government – both State and Federal – and by business.

Science is often a long-term investment. But it is an investment that can pay off in spades. Our enormous mineral revenues are a wonderful example of how taking the long view in science investment pays off.

We would not have had any of our mining booms if our geology had not mapped by Government Geological Surveys, at great public expense, starting in 1850.

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[25] UNESCO Institute for Statistics, Science & Technology Report (http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?IF_ActivePath=P,54&IF_Language=eng) as at 9 Sept. 2011
[26] OECD Main Science and Technology Indicators (**eISSN:** 2074-4226) as at 9 Sept. 2011.
[27] UNESCO Institute for Statistics, Science & Technology Report (http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?IF_ActivePath=P,54&IF_Language=eng) as at 9 Sept. 2011
[28] OECD, Online Education database. 2009 data

Today, we are still enjoying the fruits of mining. But this will not last forever. To create the booms of the future, we need to ramp up our investment in research and innovation.

The Australian Academy of Science therefore calls on the Government to create a Sovereign Fund for Science, to secure the future prosperity of the nation.

The goal should be to increase Australia's research and development expenditure to at least 3% of GDP by 2020.

2. Leveraging our investment by international collaboration

I turn now to the second threat to Australia's future prosperity: insufficient capacity for engagement in international science.

By its very nature, Science is a collaborative enterprise that transcends generations, individual scientific disciplines and, increasingly, national boundaries. To paraphrase Sir Isaac Newton, we see further by standing on the shoulders of giants.

Australia produces only 2 per cent of the world's knowledge.[29] To gain access to the other 98 per cent, *we must ensure that our scientists are well-connected internationally.*

> The best international collaborations involve major projects. Getting involved at inception allows Australia to stay abreast of new scientific developments, to have a say in their direction, to take the knowledge further; and to apply it.

International collaborations attract scientists from overseas to spend time in Australia, bringing us new skills and knowledge. Importantly, many are attracted to come back and become part of our scientific workforce.

The Australia Research Council's recent benchmarking exercise, "Excellence in Research in Australia", has noted that much of the best and most innovative research being carried out in Australia involves international collaborations.

Work arising from international collaborations often attracts more attention and gets cited more frequently. Take the recently announced kangaroo genome sequence, which captured even more attention from the media abroad than it did here. This work was done by a consortium of more than 100 researchers from Australia, the US, the UK, Germany and Japan, headed by my friend and Academy colleague Professor Marilyn Renfree. The 'kangaroo' was in fact the Tammar wallaby. As the first Australian marsupial to be discovered, this beautiful creature holds a unique place in our history – and on our Coat of Arms. Its genome is yielding many unexpected insights that may have significance for humans as well as for wallabies – for example the genes that make antibiotics in the mother's milk to protect the tiny newborns from harmful bacteria.

Being part of big international programs opens up horizons that would be inconceivable for Australian Science going it alone.

[29] Venturous Australia: building strength in innovation (2008) (http://www.innovation.gov.au/Innovation/Policy/Documents/NISReport.pdf)

Larger and larger telescopes are allowing astronomers to discover new planets and see the explosions of some of the first stars in the universe, an unimaginable 13.2 billion years ago. Australia does not have the altitude and atmospheric conditions suitable for extremely large telescopes. So, led by the Australian National University, we have joined the international consortium to build the Giant Magellan Telescope in Chile. This ensures that Australian astronomers will stay at the cutting edge of their science internationally.

At the same time, we hope to bring international astronomers to Australia, by winning the bid to build a giant collection of radio telescopes in the Western Australian desert. Known as the Square Kilometre Array, or SKA, this international project will give astronomers huge insights into the formation and evolution of the first stars and galaxies after the Big Bang.

I am pleased to note that Australia's bid to host the SKA has very strong backing from Minister Kim Carr. We should know by the end of Feb next year whether Australia has been successful in its bid.

The importance of staying connected internationally is well-appreciated by our science funding agencies and successive Science and Health Ministers.

Barriers that have impeded the use of Australian research grants for international collaborations are being dismantled. Today many grants, and fellowships provided by the Australian Research Council, National Health and Medical Research Council and CSIRO support projects that include international partners.

Many of these linkages were initially catalysed by the federal government's International Science Linkages or ISL program.

With funding of about $10 million per year, the ISL program has supported bilateral and multilateral relations with many other countries..

One of ISL's most fertile activities was its sponsorship of bilateral workshops, symposia and research exchange programs with the US, Europe, China, Japan, Korea and Singapore. Many benefits have flowed from these interactions. These include the formation of joint centres such as the Australia-China Nanoscience Laboratory, and the Australia-Ireland collaboration, which has resulted in new techniques in microscopy that boost the competitiveness of the Australian dairy industry.

Because Australia is geographically isolated, international linkages and exchanges are vital for Australia's scientists.

Gains from the ISL program extended far beyond the remit of pure science and technology. International Science Linkages also contributed to improved diplomatic relationships between Australia and a range of nations, including many of our neighbours and most important trading partners.

Regrettably, the 10-year International Science Linkages program ended in June 2011. Funding was not renewed in the 2011-2012 Budget.

The absence of the ISL program is creating a lack of continuity and unmet international expectation. Time and again, enthusiastic partners from China, France and Singapore – among others – have come to Australia having funds available for collaboration.

But there are no matching funds on the Australian side. And the danger is that Australian researchers who have much to offer international consortia will become isolated and ignored.

It would be a grave blow if our ability to compete on the international stage were to be diminished.

I strongly urge the Federal Government to fund in its next Budget a new program to provide strategic support for Australia's International Science Linkages.

3. Science capability in the workforce

Let me turn now to the third impediment to Australia's future prosperity: science capability in the workforce.

We are a lucky nation; we have access to immense mineral wealth. But resources are a finite commodity. Even the minerals sector acknowledges that we cannot ride the current boom indefinitely.

Further, the Minerals Council of Australia warns that skills shortages and structural weaknesses in the Australian economy have been masked by the boom.[30]

Given these masked weaknesses, when the end of the mining boom comes, where will Australia be?

There is broad consensus among minds more economically astute than mine that our future prosperity will depend upon

- a skilled workforce;
- innovation;
- entrepreneurship;
- high productivity, and;
- the creation of the kind of knowledge-intensive goods and services that can only result from robust research and development.

This year the Australian-born head of Dow Chemical, Andrew Liveris, published a blueprint for the future of manufacturing in Western economies[31]. It leans heavily upon the deployment of science, engineering and intellectual capacity to revive manufacturing.

The workforce of tomorrow will be drawn from the students of today.

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[30] Minerals Week 2011 Seminar –Minerals Council of Australia (MCA) Chairman's speech (http://www.minerals.org.au/news/minerals_week_2011_seminar_chairmans_speech/) as at 12 Sept 2011.

[31] Arthur Sinodinos,The Australian, 25 August 2011 (http://www.theaustralian.com.au/national-affairs/opinion/libs-would-do-well-to-channel-howard-not-fraser/story-e6frgd0x-1226121530535) as at 12 Sept. 2011.

If we do not equip these students with the right skills, we will find ourselves in the near future with a very lacklustre economy and a dangerous paucity of skilled workers.

Certain skills are already in short supply in Australia[32].

In fact, the No More Excuses report [33] issued by the Industry Skills Council earlier this year points to an alarming deficit in even basic skills.

According to this report, literally 'millions of Australians have insufficient Language, Literacy and Numeracy skills' (the old-fashioned 3Rs) 'to benefit fully from training or to participate effectively at work.'

The Council reports that a recent project[34] looking at the maths skills of bricklaying apprentices at a regional TAFE showed that:

• 75% could not do basic arithmetic; and
• 80% could not calculate the area of a rectangle, or the pay owed for working four-and-a-half hours

The gloomy Industry Skills Report is particularly worrying at a time when the demand for *higher-level* skills is increasing.

It is essential that we act now to break the bottleneck and put in place measures that will create the technologically competent workforce we need for the future.

We can, and should, be 'the clever country'. But this will only happen if we place appropriate emphasis on properly educating our young people in the areas of science, maths and technology.

4. State of science and maths education

And this of course brings me to the final and most important factor for Australia's future prosperity: the quality of maths and science education in our schools.

Without a robust and inspiring science and maths education system, it is impossible to create an internationally competitive workforce.

Researchers, engineers and technologists are not the only workers requiring scientific training. Think about the myriad other jobs which require a basic understanding of science and maths.

- Food handlers need a basic understanding of microbiology to ensure the food they sell is safe for consumers.
- Farmers need knowledge of biology, soil science and meteorology to optimise their production and manage risk;

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[32] (2011) No More Excuses, AN INDUSTRY RESPONSE TO THE LANGUAGE, LITERACY AND NUMERACY CHALLENGE, Industry Skills Council
[33] (2011) No More Excuses, AN INDUSTRY RESPONSE TO THE LANGUAGE, LITERACY AND NUMERACY CHALLENGE, Industry Skills Council
[34] 12 GippsTAFE Trade maths project 2009

- Forestry workers need to be able to operate computer-controlled equipment for harvesting and processing timber;
- Entertainment workers need a broad foundation in basic physics to design and operate stage lighting and sound systems

As a parent, a mentor of young scientists and a passionate advocate for quality education, I know that all children are natural born scientists.

“Why?”, “How?”, and “What happens if…?” are all questions asked frequently by young children, whose natural spirit of inquiry is crucial to understanding the big exciting world around them.

We need to harness this natural curiosity and nurture it with inspiring education.

Of late, however, Australia has been slipping in its duty to inspire our children.

Australian public expenditure on education as a percentage of Gross Domestic Product is just 4.2 per cent – significantly below the OECD average of 5.4 per cent.[35]

A decade ago, a review of Australian science education painted a concerning picture of science learning, especially in secondary schools.[36] Many students were disappointed with their high school science. Traditional ‘chalk and talk’ teaching, copying notes and ‘cookbook’ practical lessons were all too prevalent: these types of lessons offer little challenge or excitement for students.

Indeed, this is the kind of teaching that was around when I was at school – and very nearly put me off science for life. Becoming a novelist seemed much more appealing!

Today, student disenchantment with science continues. This is all too apparent from the declining number of students who choose to study science in senior secondary school.[37]

- In 1991, more than 1/3 of Year 12 students chose to study biology. Now, that has dropped to less than 1/4.
- 23 per cent of Year 12 students studied chemistry ten years ago, compared with 18 per cent now.
- And in the same period, physics has fallen from 21 per cent to 14 per cent.[38]

And that’s not the only bad news.

While Australian students have been losing interest in science, their international peers have been taking it up with great enthusiasm.

The OECD Program for International Student Assessment (PISA) examines the scientific literacy of teenagers in 57 different countries.

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[35] Education at a Glance 2011: OECD indicators (http://www.oecd.org/dataoecd/61/2/48631582.pdf)
[36] Goodrum, D. Hackling, M. & Rennie, L (2001) The status and quality of teaching and learning of science in Australian schools: A research report Canberra, Department of Education, Training and Youth Affairs
[37] (2011) Secondary Science: The Bad News. Data from DEEWR Statistical Collection.
[38] Ainley, J, Kos, J and Nicholas, M. (2008) Participation in Science, Mathematics and Technology in Australian Education. ACER

In 2000, the only nations that performed better than Australia were Korea and Japan. In 2009 – the latest figures available – Australia ranked behind Shanghai, Finland, Hong Kong, Singapore, Japan and Korea.[39]

It is not that our youngsters performed more poorly in science than before. Rather, the Assessment indicated that the performance of other countries has improved while Australia's has remained stationary.

The picture is much worse for mathematics.

Australia's early secondary mathematical literacy scores have significantly *declined* over the last decade and our Year 4 and Year 8 students ranked only 14th internationally in the most recent *Trends International Mathematics and Science Study*, conducted in 2007[40].

This decline in Australia's mathematical literacy is of grave concern because *mathematics is an enabling science.*[41] Without maths it is not possible to make use of other sciences – either in the lab or in the workforce.

Our declining interest and achievement in science in schools is not just of concern for the future supply of scientists, mathematicians and engineers and for the technical capabilities of our future workforce. It is of deep concern for the whole of our society.

The ways in which science influences our everyday existence are too numerous to mention.

Scientific issues pervade an enormous range of the decisions we make – from the everyday decisions about what to feed a child or whether to take a particular type of medication, to the major national decisions about how to ensure food and water security, defend the country or improve the economy.

Major national decisions are rightly taken by parliament, but they should be informed by public input and robust debate. And where science is involved, public input and debate must be based on understanding and scientific evidence, not on misinformation and uninformed assumption.

This is particularly important in politically contentious areas, such as climate change, evolution, gene technology, stem cells or nuclear power.

It is very evident therefore that modern society needs to be scientifically literate.

A recent survey conducted by Science and Technology Australia and the Academy of Science has shown that Australians clearly value science – 80 per cent of respondents

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[39] PISA 2009 PISA 2009 Results: What Students Know and Can Do (http://browse.oecdbookshop.org/oecd/pdfs/free/9810071e.pdf)

[40] TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades. Mullis, I.V.S., Martin, M.O., & Foy, P. (with Olson, J.F., Preuschoff, C., Erberber, E., Arora, A., & Galia, J.). (2008). Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College..

[41] Sadler PM and Tai RH (2007) The Two High-School Pillars Supporting College Science. *Science* 317 457-458 2007

acknowledged that science education is absolutely essential or very important to the national economy.[42]

But it also revealed some alarming holes in the basic science understanding of the average Australian.

- Three in ten believe that humans were around at the time of dinosaurs.
- More than one-fifth of our university graduates think that it takes just one day for the Earth to travel around the sun.
- Almost one-third of Australians do not think that evolution is currently occurring.

So – it appears we understand that science education is important to society and to the national economy. *But, as a nation, many of us do not understand even the most basic science.*

How can Australia improve its performance in science and maths education?

How can we halt this slide in science and maths in our schools and attain an internationally enviable position?

Our situation is not unique. President Obama this month introduced the American Jobs Act. A key initiative is to modernise more than thirty-five-thousand schools, particularly by the installation of science labs and high-speed Internet.[43]

In explaining the need for improved investment in science education he said to an audience at the University of Richmond:
"You're competing now against kids in Bangalore and kids in Beijing, and you've got to -- and you can't avoid those math classes and the engineering classes and the science classes. We've got to focus."[44]

Thankfully, our Government is already investing significantly in school infrastructure and in rolling out a national high speed internet network.

Last December education ministers approved the content for new national curricula in English, history, maths and science. In coming months, they will be asked to sign off on the standards for these curricula. This is an important initiative and the Academy of Science applauds it.

But further investment is needed to ensure that it is properly *implemented*: Investment in teachers, and in inspiring curriculum programs.

This is a responsibility for both the Commonwealth and the States, who must work *together* rather than reverting to the blame game.

Inspired (and inspiring) teachers will be the most important agents for improving educational outcomes.

What saved me from a mediocre writing career and set me on the path to an exciting and successful career in cancer research was the irrepressible enthusiasm of one

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[42] Science Literacy in Australia (2010). Survey performed by Auspoll July 2011.
[43] 8 September Address by President Obama to a Joint Session of Congress, United States Capitol, Washington, D.C. http://www.whitehouse.gov/the-press-office/2011/09/08/address-president-joint-session-congress
[44] 9 September Remarks by President Obama on the American Jobs Act, University of Richmond, Richmond, Virginia http://www.whitehouse.gov/the-press-office/2011/09/09/remarks-president-american-jobs-act

terrific high school teacher in year 9, Miss Laura White. I shall never forget her excitement and wonder in class the day the Russians launched the first satellite. She could see what a giant step forward this was for our understanding of the universe.

We must place a much higher societal value on teachers and do everything we can to recruit some of our brightest and best into teaching. We must support these educators with the best tools and resources available and provide them with stimulating opportunities for ongoing training.

One of the most effective ways of helping teachers to encourage school students to be interested in science is to have the students meet scientists in person, especially *young* scientists. Several innovative programs that do just this – such as CSIRO's Scientists in Schools and Mathematicians in Schools programs - are powerful adjuncts to traditional classroom teaching and are worthy of strong ongoing Government support.

The Academy's programs

The Academy of Science has a very deep and longstanding commitment to programs that enhance Australian science education.

Our web-based program *Nova: Science in the News*, offers a balanced non-technical summary of the science behind topics in the news. It is one of the most popular online Australian science education resources.

Today, however, I want to focus on our two most recent science education programs:
Primary Connections, for primary school; and
Science by Doing, for junior secondary school.
Both have received substantial funding and support from the Federal Government.

Recent reports from the OECD clearly show that the countries making the most rapid progress in education performance have all moved away from traditional content and subject-based curricula, in favour of skills and competencies-driven learning.

This is exactly the type of support offered by the Academy's programs.
Both of these programs are designed to invigorate science teaching. They enhance teachers' skills and emphasise engaging, inquiry-based approaches to guide and enthuse children's learning.

They also draw strong links between science and literacy.

A comprehensive evaluation of the impact of Primary Connections found that 'mainstream' students from Primary Connections classes have a significantly higher scientific literacy than similar students from comparison classes.[45] This includes their ability to reason about and represent scientific data, and their understanding of the processes of science.

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[45] Mark W Hackling and Vaughan Prain (2008) Impact of Primary Connections on students' science processes, literacies of science and attitudes towards science (http://www.science.org.au/primaryconnections/research-and-evaluation/images/irr-15.pdf).

The results that Primary Connections has had with Indigenous students, in particular, have been outstanding.[46]

Indigenous students taught under the Primary Connections program were not only more engaged with science, they were more confident in all aspects of the classroom. Their self-esteem improved, they participated more fully in class activities, and they were more enthusiastic about learning.

Because of this, their attendance records at school also noticeably improved.

Erin, the Aboriginal Education Manager from one of the districts, reflected on her experience with the program. She said:

> *What I've seen going on … is amazing. I've never seen the kids so engaged….. we've … helped them to bridge some gaps. Science is a really powerful way of doing that, because for Aboriginal people it's a way of life; they are very connected to the land and the environment, which are integral to their culture.*

Science by Doing has achieved similarly excellent results.

An independent evaluation showed that junior secondary school students taught using the Science By Doing methods were more engaged, enthusiastic and asked more and higher level questions – all leading to greater learning and improved work quality. Students described the Science by Doing units as '*more fun… better than normal science'.*

Teachers involved in both programs report that the programs improve their own confidence and offer 'better ways of learning'.

Given these outstanding outcomes**,** the Academy was devastated to learn earlier this year that the Federal Government had decided to withdraw its support. This occurred just before the Academy finished developing Primary Connections and immediately after the incredibly well-received pilot stage of Science by Doing.

School Education Minister Peter Garrett wrote to me to explain that he hoped Science by Doing and Primary Connections would continue to help advance science teaching and learning in Australian schools.

But, he said, he had no discretionary funding available to make it possible. Mr Garrett urged the Academy to liaise with "other agencies".

The Academy remains deeply committed to its education programs.

We believe all Australian students deserve access to such proven, quality programs. And so, even though it will take us longer and may not be able to be delivered equitably across Australian schools, the Academy is committed to rolling out Primary Connections and Science by Doing at cost price.

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[46] Robyn Bull (2008) Small Study –Big Success Story Primary Connections Incorporating Indigenous Perspectives Pilot Study Report. (http://www.science.org.au/primaryconnections/research-and-evaluation/images/IndigenousPerspectivesReport.pdf).

I am pleased to report we have made considerable progress toward achieving that goal. Primary Connections is being used in 55% of Australian primary schools. Uptake rates are even higher in Western Australia, Tasmania, Queensland and the ACT. It has now been endorsed for use throughout South Australian state primary schools and we are having very encouraging discussions with Victoria. We hope to hold similar conversations soon with the New South Wales government.

However, the challenge is much greater for Science by Doing, which needs considerable further funding to complete its development.

Mr Garrett announced last Friday that there are new funds available for professional learning and curriculum on-line resources. This announcement has given us hope, but we are still waiting for word on whether the Academy's programs might be eligible.

The Academy urges the Federal Government to use this approach - or another - to restore funding for Science by Doing.

Concluding Remarks

I agree with Prime Minister Julia Gillard that science is one of the fundamental platforms upon which our conception of a modern advanced society is based.[47]

It is science, she says quite rightly, which has created greater progress over the past two centuries than all the previous millennia of human history. And it is science to which we turn for a better understanding of ourselves and the future of our fragile planet.

The whole of our society benefits from knowledge building.

Australia *can* halt the decline in our international rankings for education, investment in science, and economic competitiveness. Let's invest *now* to turn that around and improve our standing on the world stage. Let's ensure we're prepared to fully engage in the booming global science effort.

> *We live in a crucial time for science in Australia and around the world.*
>
> *It is a time demanding strong leadership, from the grassroots to the highest levels of government. Together, we must ensure that science, research and innovation can continue to play their part in shaping our future and guiding our decisions.*

These are not my words. They were spoken by Prime Minister Julia Gillard.[48]

I could not agree more. Thank you.

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[47] Prime Minister Julia Gillard, 17 November 2010, Speech: 2010 Prime Minister's Prizes for Science. (http://www.pm.gov.au/press-office/2010-prime-ministers-prizes-science).

[48] Prime Minister Julia Gillard, 17 November 2010, Speech: 2010 Prime Minister's Prizes for Science. (http://www.pm.gov.au/press-office/2010-prime-ministers-prizes-science).