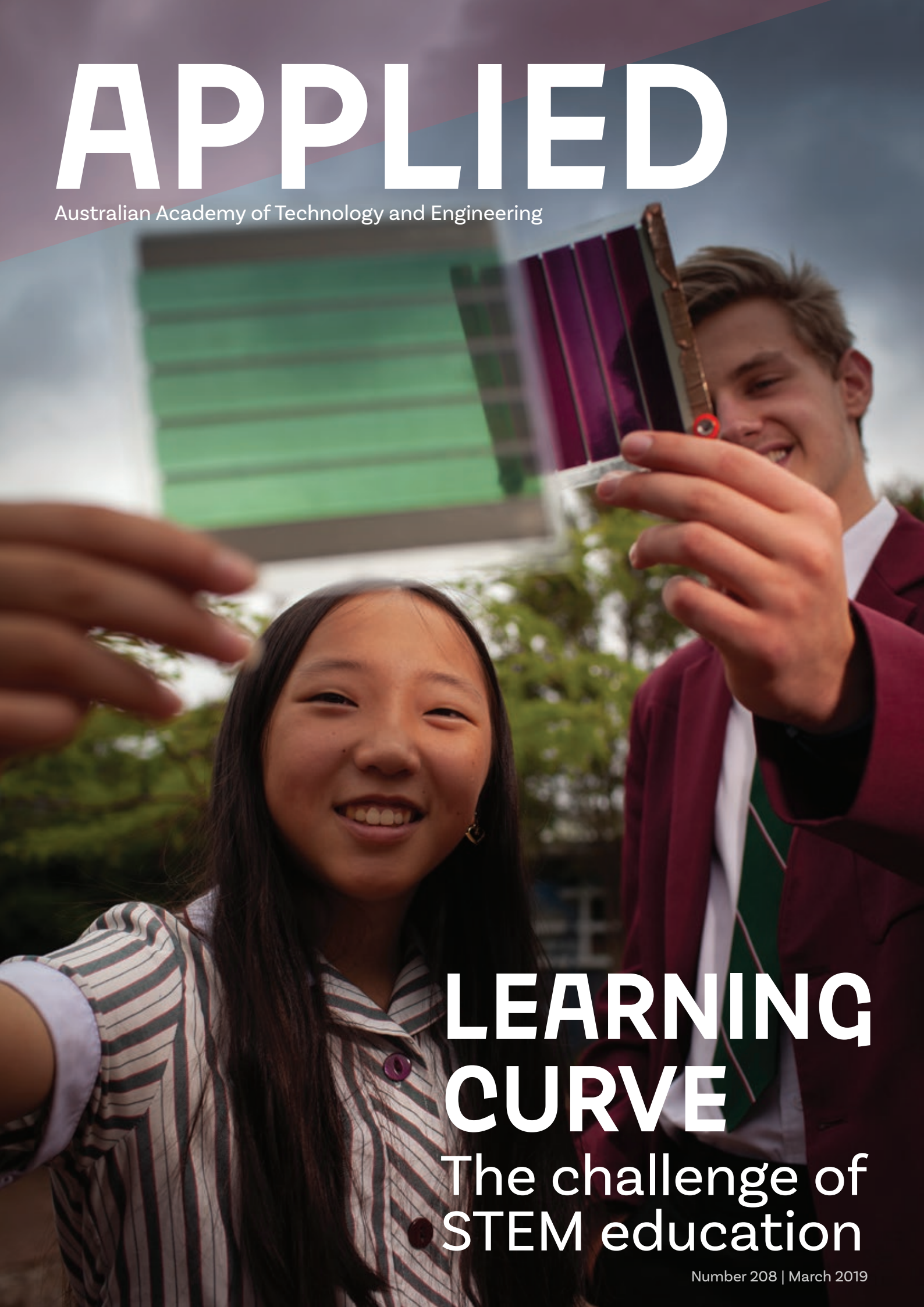
# APPLIED

Australian Academy of Technology and Engineering



# LEARNING CURVE

## The challenge of STEM education

Number 208 | March 2019

# Join us in celebrating **Innovation and Awards Excellence**

## Thursday 13 June in Sydney

### This is an event not to be missed.

Entrepreneurs and innovators will be honoured with the Clunies Ross Awards. The Academy will also celebrate the next generation of innovators with the Batterham Medal, the ICM Agrifood Awards and the Ezio Rizzardo Polymer Scholarship.

Hear Distinguished Professor Genevieve Bell FTSE from the Australian National University talk on "The new cybernetics". Professor Bell is the foremost global leader in applying social sciences and cultural anthropology to technology development and digital transformation.

**VENUE:** **Sofitel Sydney Wentworth, 61-101 Phillip Street**
**TIME:** **6pm pre-dinner drinks for 7pm**
**BOOKINGS:** **applied.org.au/InnovationEvent**
**INFORMATION:** Subscribe to our awards newsletters for further information **applied.org.au/newsletters**





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The Academy acknowledges the Traditional Owners of the land on which we meet and work. We pay our respects to Elders past, present and emerging.



Australian Academy of Technology & Engineering

Read *Applied* online or sign up for a free electronic subscription at **applied.org.au/magazine**

**Front cover:** Two students from South Oakleigh College in Victoria use CSIRO flexible printable solar cells, the latest addition to STELR, the Academy's school STEM program.

PHOTO: EAMON GALLAGHER




FROM THE
PRESIDENT'S DESK

# Education fit for the future

**STEM education is a vexed issue.**

**This is what we know:**

- **Not enough school students are doing STEM subjects, particularly maths at advanced levels and physical sciences**
- **Female students are under-represented in the mathematical and physical sciences**
- **Schools are struggling to find teachers who are properly qualified in their discipline (by which I mean they have a BSc with a major in their discipline)**
- **Without inspirational teachers, students will not be motivated to undertake STEM subjects**

At the same time, the rate of the adoption of automation based on Big Data, the Internet of Things and artificial intelligence is escalating. The latest Future of Jobs report from the World Economic Forum forecasts that the share of human labour (as opposed to machines) will have declined from 75 per cent in 2018 to 48 per cent in 2025. The same WEF report estimates that by 2022, almost a quarter of companies will be using humanoid robots.

So while many job categories are becoming obsolete, demand for STEM-qualified employees is rising rapidly.

With data being the "new oil", employees capable of mining that data are in hot demand. In 2013, an Accenture report estimated that 80 per cent of new data scientist roles could not be filled due to a lack of qualified people. And the demand has continued to grow – it is estimated that it now exeeds supply by 50 per cent.

Beyond the need for STEM-skilled employees, an even bigger problem lurks: the scientific illiteracy of the general population and the rapid escalation of what Yuval Harari refers to as the "useless class" – the people who are irrelevant to the workforce and can't find any employment.

This is a ticking time bomb, not only because of the fundamental divide in society it creates, but because the widespread lack of scientific literacy makes them susceptible to lies and nonsense posing as fact spruiked by populist proponents.

We may ridicule Americans for electing a president who tells 10 lies a day (literally), but even the supposed educated classes are susceptible to scientific fraud.

Take, for example, the case of the PhD-qualified science journalist who set up a bogus experiment that concluded that eating chocolate helped speed up weight loss. Mainstream media around the world believed this absurd conclusion had been scientifically proven without checking on basic issues, like the number of subjects or variables measured.

Okay, so we have a problem – I think we all get that – but what do we do about it?

1. Schools need inspirational STEM teachers
   a. Raise the status of the teaching profession in general and STEM teachers in particular by increasing their salaries and determining their pay based on supply and demand, and performance
   b. Require teachers to be qualified first in the discipline they will teach and make the pedagogical aspects an add-on after a first degree
2. Use problem-based-learning to connect students' understanding of outcomes to the knowledge and techniques they are acquiring
3. Use more simulation (including virtual/augmented reality) to enable students to experience what they are learning
4. Adopt flipped classrooms to put more responsibility on the students for their education while ensuring that they retain peer group stimulation
5. Adopt the new generation of personalised learning systems which uses Big Data, Internet of Things and artificial intelligence to provide a scalable, superior education by personalising each student's learning pathways
6. Use online resources like Kahn Academy to more fully increase the productivity of the teachers and thereby justifying higher salaries
7. Apply 21st century measures to determine the performance of students, teachers and institutions. These measures should be continuous rather than episodic, based on Big Data, and outcome measures derived from machine learning algorithms

I have no doubt these proposals will not necessarily be popular – but do we want to fix the problem or just complain about it while supporting the status quo?

## INSIDE

In this issue of ***Applied*** magazine, you'll find articles and analysis on STEM education in Australia.

Prime Minister's Prize-winning teacher Scott Sleap writes about the benefits of hands-on learning in rural communities.

Read how a mentoring relationship between Alex Atkins and Nazanin Nourifard evolved to a deep friendship.

Learn how we can boost the numbers of girls inspired to study STEM subjects, according to Lyn Beazley.

Find out what next-generation schools might look like in an Industry 4.0 future from a group of forward-looking Fellows.

HBradlow

**Professor Hugh Bradlow FTSE**

# A fresh look at innovation metrics

**The Department of Industry, Innovation and Science is conducting a review of Australia's innovation measurement systems.**

As part of this review, the Academy has been commissioned to undertake a wide-ranging independent study of best practice in innovation measurement, what metrics and indicators are currently used, and how Australia can improve its measurement systems.

A workshop was held with the Academy's expert working group and several other Fellows in late January, which will contribute to the Academy's report.

The workshop focused on gaps in current indicators, mapped against a new conceptual framework of the innovation system developed by the working group.

The Academy will propose a number of new indicators to the Department's Review, which will be discussed with international experts at a workshop in Canberra in mid-March.

## Academies meet in South America

**The International Council of Academies of Engineering and Technological Sciences (CAETS) held its annual meeting in Montevideo last September, the first time the event had been held in South America.**

The Academy was represented by the President, Professor Hugh Bradlow, and the Executive Director, Policy, Dr Matt Wenham.

CAETS admitted its 26th member academy, from Pakistan. Our Academy is supporting our New Zealand colleagues, the Royal Society Te Aparangi, with their membership application.

The annual meeting was hosted by the National Academy of Engineering of Uruguay, whose President, Lucio Caceres, is a former Minister of Transport. He opened the conference by declaring: "Technology without science is craftmanship, science without technology is philosophy."

The theme was forestry. Uruguay has made huge investments in a forestry industry based on eucalypts and the Academy arranged for CSIRO expert, Dr Chris Harwood, to talk about the Australian and Asian experience.

Other topics included sustainability, engineering education and communications with the public.

Professor Bradlow moderated the session on engineering education, which focused on the introduction of problem-based learning and multi-disciplinary projects.


*Professor Hugh Bradlow on a site visit to a vertically integrated forestry and pulp milling operation stretching from the plantations to the port.*

## Workshop builds on decades of Australia-Japan collaboration

**The Academy hosted a transdisciplinary symposium bringing together Australian and Japanese researchers in Melbourne in December.**

It focused on innovative approaches to meeting UN Sustainable Development Goals.

Building on a joint symposium in Fukuoka, Japan, in 2017, it covered the built environment; the natural environment; and health and well-being.

The Academy collaborated with the Engineering Academy of Japan (EAJ) to organise the event. It brought together researchers who had participated in the Australia-Japan Emerging Research Leaders Exchange Program, which has run since 2010.

The Academy has run successful joint workshops with partner academies in north-east Asia for more than 20 years.

Dr Margaret Hartley, Academy CEO, said the event further cemented the strong relationship with the EAJ.

"It was a pleasure to host Professor Hideaki Koizumi, Executive Vice-President of the EAJ, his colleagues, visitors from Hokkaido University, the Japanese Consul-General here in Melbourne and, of course the alumni of the leaders exchange program."

The workshop was made possible by funding by the Australian Government's Australia-Japan Foundation.

# Is Australia's transport industry tech-ready?

**The analysis of the transport sector is being finalised as part of the Academy's three-year research study assessing Australia's tech-readiness.**

Drawing from the pool of our Fellows' expertise, the project is developing a 10-year-plan to ensure Australia can keep up with an accelerating pace of change.

Earlier this month, the Academy held a steering committee, co-chaired by Kathryn Fagg and Drew Clarke.

The committee has begun forming policy recommendations and research questions the transport sector must address to navigate rapidly evolving technology, based on literature reviews, desktop research and targeted consultations.

Australia's health sector is the next industry to be analysed for its tech-readiness.

# Submissions from the Academy

**In helping develop effective public policy across science, technology and engineering, the Academy calls on the expertise of our Fellows to make submissions to Government and Parliamentary Inquiries and legislative initiatives.**

**Here are a few of our recent submissions.**

## NSW Curriculum review

***NSW Education Standards Authority***

The Academy believes firmly that Australia's future prosperity, health, security and well-being will be driven by stronger workforce engagement and performance in areas of the economy underpinned by science, technology, engineering and mathematics disciplines.

As a nation, we are failing to encourage sufficient school students to take the senior secondary subjects that underpin further studies or employment in areas that depend on STEM.

## Cultivating genetically modified crops

***Independent review to the South Australian moratorium***

The South Australian agricultural sector will need to embrace new and emerging gene technology to ensure it can remain globally competitive and maximise its profitability.

The current moratorium denies the SA agribusiness sector access to new and emerging technology that can enhance profitability, increase resilience and provide a safe, reliable and affordable food supply, and environmental sustainability.

## R&D tax incentive amendments

***The Treasury***

To drive greater collaboration and wider benefits for Australia, the R&D Tax Incentive should offer a premium rate for R&D undertaken with Australian publicly funded research organisations.

Among our key points and recommendations are: the outcomes of the R&D Tax Incentive Changes should be monitored to ensure the impacts on companies is minimised; and we welcome the proposed clinical trials exemption, which will support the growth of the Australian clinical trials industry.

Visit applied.org.au to read them in full.

# Connecting globally for the benefit of Australia

International research and innovation partnerships can extend Australia's research and development output and impact, opening access to world-leading expertise, infrastructure, markets, investment and funding programs.

That's the central contention of a new Position Statement released by the Academy, Connect Globally for the Benefit of Australia.

Connecting globally on science, technology and engineering innovation is a key priority for the Academy.

We draw on our extensive networks with sister academies, research organisations and governments overseas to ensure Australian expertise is disseminated to the world and to ensure that leading practice from other countries helps inform policy decisions in Australia.

The Position Statement sets out the Academy's international priorities which underpin the Strategy Plan 2017-2020.

It recognises that Australia ranks highly in quality research production – responsible for some 4 per cent of the world's total scientific output listed on the web, despite having only 0.3 per cent of the global population.

However, Australia is weak on the translation of publicly funded research into commercial outcomes, and the proportion of R&D expenditure financed by industry is low by international standards.

Improving collaboration between Australian businesses and universities and publicly funded research organisations is a national strategic priority and one that is strongly supported by the Academy.

## National Energy Guarantee

***Draft Detailed Design for Consultation, Commonwealth Elements paper***

The Academy supports the introduction of the National Energy Guarantee; however, Australia needs an economy-wide strategy for climate change mitigation, not just an emissions guarantee for a subsection of the electricity generation sector.

The emissions reduction trajectory should be informed by the independent advice of the Climate Change Authority and subject to regular reviews. We strongly recommend that carbon offsets are not permitted in the proposed design of the NEG.

## Soft Power Review

***Department of Foreign Affairs and Trade***

Australia is well placed to use the expertise, networks and infrastructure of our science, technology and innovation sectors to leverage international influence through building and maintaining trusted partnerships. Importantly, these partnerships can outlive political cycles.

To ensure Australia is globally competitive by 2030, the Academy strongly supports the proposed whole-of-government approach and call for bi-partisan support for ongoing stable investment in independent, apolitical institutions.

## Women in STEM Strategy

***Australian Government***

Improving gender equity in STEM fields is essential for creating stronger Australian research and industry sectors.

Among our key points are that there is currently an abundance of misinformation that is impeding girls' feeling of competence in STEM fields, including the general view that girls are not as good at mathematics and science as boys. This false gender stereotype should be dispelled, and governments should ensure correct information surrounding the equal abilities of girls and boys is promoted in schools and to the public generally.

Linked to its Global Innovation Strategy, the Australian Government has nine National Science and Research Priorities and six industry-led Growth Centres, which inform the Academy's international strategy.

As a Learned Academy, we have a unique ability to engage overseas to further Australia's science and innovation diplomacy.

As part of its international strategy the Academy will take steps including:

- Maintain strong relationships with Embassies and High Commissions in Australia and in key partner countries overseas
- Continue to work closely with active technology and engineering academies within the International Council of Academies of Engineering and Technological Sciences
- Leverage the value of its international network of eminent Foreign Fellows

This Position Statement owes much to the work of three Fellows, Professor Kaye Basford, Dr Ros Dubs and Professor Murray Scott, and input from the Academy's International Strategy Group.

***Read the Position Statement in full at applied.org.au.***

# NEWS

Our new Fellows celebrate their night of nights.

# Oration Dinner

The annual Oration Dinner celebrates the election of a new cohort of Fellows. You can find out more about our Class of 2018 at **applied.org.au/new-fellows**.

Guests at the event in Melbourne last November also enjoyed the thought-provoking Oration, delivered by Catherine Tanna FTSE. You can hear it in full at **applied.org.au/Oration2018**.


*Catherine Tanna FTSE delivers the annual Academy Oration.*


*Wurundjeri Elder Ron Jones welcomes guests to Country.*

*All photos: Peter Casamento*


# WE'RE PASSIONATE ABOUT INCREASING THE UPTAKE OF STEM EDUCATION

As the world's largest provider of commercial explosives and innovative blasting systems, we provide expert services to the mining, quarrying, construction, and oil and gas markets.

The STEM disciplines – Science, Technology, Engineering and Mathematics – are critical to the future of a company like Orica, which is why we are committed to increasing the uptake of STEM in schools. With the aim of getting students interested in careers in science and technology, we're proud to be the principal sponsor of the Academy's STELR project, helping more than 700 schools across Australia engage students in STEM through hands-on, inquiry-based and in-curriculum learning.

**orica.com**

ORICA

# A day in the life of a seven-year-old

**What do seven-year-olds want to be when they grow up?**

We asked students at Goodna State School and Good News Lutheran School in western Brisbane before they took part in a six-lesson program called "Day in the Life of a Seven-Year-Old". Then we asked them the same question at the end.

One girl changed her answer from wanting to be a singer to an architect, drawing buildings that save energy. And a boy who originally wanted to work at Dominos now wants to be a YouTuber running experiments about storing electricity.

At Good News Lutheran, the percentage of students wanting to be scientists or engineers went from zero to 45 per cent.

The program aims to create curiosity and awareness of STEM careers and skills in early primary school students by highlighting relatable experiences in the world around a child's day-to-day life. It seeks to develop a common understanding of STEM among students, teachers and parents and its significance for future employability.

The Academy's program STELR and the Australian Power Institute developed the concepts for this initiative and conducted a proof-of-concept trial to test the practical feasibility and curriculum fit.

The program included six lessons structured to:

- Provide interest for the students and value to their learning
- Measure any changes in students' attitude to STEM after six lessons
- Provide the teachers with simple and practical resources that had flexibility for schools to achieve their specific learning objectives

These lessons included:

- Videos from our Women in STEM and Entrepreneurship series highlighting the careers behind the services and inventions students encounter from waking up to arriving at school
- Hands-on team work challenges in engineering
- A visit from male and female undergraduate engineering students
- Parents talking about their careers

Overall, the program proved to be an outstanding success, where we found that the students were actively engaged in the program; their ideas about their future careers broadened to include careers in STEM; and teachers found the content relevant and user-friendly.

**Peter Pentland, Executive Manager, Schools Program**

# Industry leaders dive deep into mentoring

**The Industry Mentoring Network in STEM (IMNIS) recently hosted a series of Leaders Forums on mentoring.**

Experienced IMNIS mentors and Academy Fellows shared their mentoring prowess with industry leaders who mentor PhD students as part of the IMNIS Energy-Minerals and MedTech-Pharma programs.

IMNIS, a flagship initiative of the Academy, brings together PhD students and industry leaders in a one-year mentoring partnership.

Now in its third year, IMNIS has evolved from a small-scale pilot into a prestigious national initiative involving more than 600 participants.

At these recent events, held in Melbourne and Adelaide, mentors shared advice on how to get the most out of mentoring, motivate and inspire mentees, and maintain the partnership over the course of the year.

These events also provided mentors the opportunity to network with each other and guests.

Mentors emphasised the need for trust and respect within the mentoring relationship, working with mentees toward their goals (rather than directing them), and the need for mentors to provide honest feedback and support.

And the results have been outstanding. One IMNIS alumnus, systems engineer Jomana Al-Nu'airat, was mentored during a PhD in chemical engineering at Murdoch University.

"I was able to spend many hours with my mentor talking about my goals and plans. It was incredibly rewarding to be able to get the help I needed to focus and make plans when I started out without much hope," she said.

"The advice and experience have been tremendously helpful throughout these past 12 months. As a result of the expertise and guidance, I landed my first industrial job, and am proud to be the first woman engineer to work at Muja power station."

*In Adelaide, Professor Emily Hilder FTSE and Dr Gordon Frazer FTSE joined IMNIS mentors Kyffin Thompson and Dr Tina Lavranos on a mentoring panel led by IMNIS mentor Tom Melville, Partner at Madderns.*


*In Melbourne, IMNIS Expert Advisory Panel member Dr Jenny Petering led an in-depth discussion with IMNIS mentors Dr Cathy Drinkwater, Dr Tim Oldham and Jürgen Schneider at FB Rice.*

# Ready for the digital revolution?

Deborah Sippitts

Australia is on the cusp of the Fourth Industrial Revolution. Digital transformation will bring challenges and opportunities. The Academy has produced two policy documents to help guide the way.

## MORE COLLABORATION, INVESTMENT AND STRATEGY NEEDED FOR DIGITAL FUTURES

For Australia to drive digital futures and maintain global competitiveness, more collaboration, investment and strategy are needed, according to a recent policy statement by the Academy.

Australia ranks in the bottom half of the OECD index for collaboration. In our vision to position Australia as a leading digital nation, strategies need to be developed to improve peer-to-peer collaboration and grow partnerships between researchers, industry and end users.

Digital technologies are already impacting important national capabilities such as emergency management and advanced environmental management solutions. A number of Australian business areas are successfully using digital technologies to improve productivity, and space technologies offer a unique and important opportunity, as our space and digital futures are mutually reliant.

Australia faces a number of diverse challenges to be internationally competitive in the digital age. We must develop a legislative framework that ensures safety and security while encouraging innovation.

Equally we must develop a globally respected means to operate efficiently and effectively in the digital world, including having a skilled digital workforce, modern digital infrastructure and world-class cyber resilience – all of which are critical for domestic business but also for encouraging global investment.

Australia must also improve its level of digital technology readiness, including improving national digital literacy and encouraging business, industry and government leaders to think more strategically about, and plan for, digital technology uptake.

A key challenge will be to maintain global competitiveness in pivotal research areas such as big data, cloud storage, artificial intelligence, robotics, quantum technology, broadband, the Internet of Things and cyber resilience. Other nations are investing heavily through industry and government funding, so Australia needs to step up to remain relevant and globally competitive.

The Academy recommends that:

- Australia must strengthen its strategic framework to accelerate digital transformation within government, industry and society.
- Australia must expand its digital ecosystem by investing in key projects, developing critical digital infrastructure and encouraging collaboration.
- Australia should both strengthen and better leverage its research and development of digital technologies.

## EMERGING TECHNOLOGIES WILL DISRUPT EVERY ASPECT OF THE ECONOMY INCLUDING EVERY INDUSTRY SECTOR

Digital technologies are having a significant societal and economic impact within Australia. Their use will disrupt every aspect of the economy and every industry sector, consequently this technological advancement need to be carefully considered, according to a second policy statement by the Academy.

We are arguably on the cusp of what is being described as the Fourth Industrial Revolution, characterised by significant advances in, and the convergence of, emerging technologies including artificial intelligence, robotics, autonomous systems, blockchain, big data and quantum computing.

The first three industrial revolutions were underpinned by technologies including the steam engine, electricity, the combustion engine and computing, which, while displacing many manual tasks, still required humans to leverage their cognitive skills to develop, apply and operate such technology. Thinking remained the exclusive domain of humans.

The implications of this new industrial revolution are profound. Humans will no longer have a monopoly over cognitive skills. Machines will be able to assimilate information from a variety of sources, analyse information, apply machine-learning algorithms and make sound decisions without any human input.

The social consequences of increased automation will change employment patterns and, combined with changes in demographics and increased life expectancy, this may mean we need to completely rethink learning, skills and careers.

As more AI-based systems are deployed, what confidence and trust do we have in the underlying algorithms and decision-making processes at the core of these systems? There will be risks in how these systems operate and for safety critical systems the implications could be life-threatening.

We need to do more to understand how these AI-based systems work, as well as consider the ethical and legal issues and the increased risk of cyber-security attacks with the increased use of AI.

The Academy recommends that:

- We need to have robust systems in place to ensure we have confidence and trust in AI systems, particularly those deployed in mission and safety critical environments.
- Australia's education policy needs to address the evolving skills implications of disruptive technology.
- A multi-disciplinary expert group should be established to provide recommendations guidance to the Australian government on the technologies and regulatory frameworks for guarding privacy.

***Read the full policy statements on the Academy website, applied.org.au***

# The future *IS* women in STEM

Deborah Sippitts

**With automation and globalisation set to fundamentally change Australia's workforce, science, technology, engineering and mathematics (STEM) skills are not only important for today's job market but crucial for the nation's future.**

STEM underpins the innovation and creativity needed to develop the technologies to understand and solve current and future problems. But to optimise performance and drive innovation in this critical sector there needs to be diversity.

The problem of gender equity in STEM is well known and documented – women are lost at every stage of the professional ladder in STEM fields. This is due to a range of factors including stereotypes, discrimination, and workplace culture and structure, some of which manifest from early years.

## Complex and multifaceted

The challenge of improving participation and retention of women in STEM is complex and multifaceted.

Yet research shows that diverse teams are more effective and innovative, benefitting from a range of perspectives and approaches. So, a diverse STEM workforce is not only an economic necessity for Australia, but imperative for future national development.

At the request of the Australian Government, the Australian Academy of Technology and Engineering is working with the Australian Academy of Science on a Women in STEM Decadal Plan that will help Australia meet this challenge.

## 10-year road map

The Decadal Plan will provide a roadmap for achieving sustained increases in women's participation in STEM in Australia.

The Plan will identify the barriers and enablers which impact on women's participation, retention and success in all areas of STEM.


This includes issues which impact girls and women in their choices around STEM education in primary, secondary and tertiary education, including both the university and VET sectors.

It will also encompass all areas of the STEM workforce, from academia and government to private enterprise and those at all levels and stages throughout their career journey.

## Expected outcomes

Expected outcomes from the Women in STEM Decadal Plan include:

- long-term improvements in gender equity
- improved quality in STEM skills and expertise in Australia
- increased access for women and girls to participate in STEM
- expanded career and study opportunities for women
- benefits to business from increased access to STEM skills

Developing the Decadal Plan has been a large and complex project involving a core project team, an Expert Working Group, targeted consultations and partnerships with sector representatives.

Last year in September and October, the two Academies held consultation workshops in every state and territory around Australia.

## Broadest STEM workforce possible

Interactive and solution focused, the community consultation forums enabled participants working in groups to suggest solutions to overcome identified barriers for Women in STEM and to refine solutions proposed by previous community forums and interviews.

The forums included a diverse number of stakeholders to ensure the resulting Plan is as effective and relevant to the broadest STEM workforce possible. Online consultations and submissions were also offered to stakeholders.

## Influence real change

Funded for two years – including 15 months of implementation – the Women in STEM Decadal Plan prepares Australia for changes in the future of work, where we will need to think critically and creatively to meet the many challenges of an increasingly complex world.

*Hugh Durrant-Whyte FTSE, NSW Chief Scientist and Engineer, giving the opening address.*

# Towards a prosperous yet sustainable Australia?

**Australia has experienced 27 years of uninterrupted growth. Yet there are warning signs in rising wealth inequality, unaffordable housing, increasing traffic congestion, under-employment and increasingly polarised political opinion.**

To address this, the Royal Society of NSW and the four Learned Academies convened a forum at Government House, Sydney, last November entitled Towards a Prosperous yet Sustainable Australia – What now for the Lucky Country?

It was hosted by the NSW Governor, David Hurley AC FTSE, chaired by Brian Spies FTSE, Secretary of the NSW Division of the Australian Academy of Technology and Engineering, and attended by 130 people.

Hugh Durrant-Whyte FTSE, NSW Chief Scientist and Engineer, suggested that our future prosperity and sustainability would be best secured through comprehensive and joined-up evidence-based policies that addressed the environment, population, energy, and business competitiveness.

That the sustainability of the nation is embodied in its people was addressed by leading social researcher, Hugh Mackay. While Australia had been successful in creating a diverse and (largely) harmonious society, social cohesion was threatened by crisis-level mental health and increasing social fragmentation. "Social isolation is a greater threat to public health than obesity," he said.

Sam Mostyn, a member of the National Sustainability Council, discussed Australia's progress towards meeting the international Sustainability Development Goals (SDG), agreed in 2012. While Australia's position and trends in several areas were not good, he said, the SDGs provided a good framework for leading and tracking future change and transformation.

Graham Turner, from Earth Accounts Consulting, provided trends on population, economic and environmental performance. He showed that the 1972 Club of Rome modelling had been essentially correct. "A sustainable future requires a twofold increase in efficiency, zero population growth and a three-day working week," he said.

Ashley Brinson from the Warren Centre for Advanced Engineering at the University of Sydney argued for a future circular economy, in which product design would consider the material and energy flows from a whole-of-lifecycle perspective.

***An extended report is available at applied.org.au/prosperous***

# Boost for printed body parts research

**A PhD student working with industry on better ways to 3D print body parts is the first winner of an Academy award worth up to $35,000.**

Naomi Paxton from Queensland University of Technology is researching the fabrication of high-density polyethylene, patient-specific surgical implants.

"My research brings together polymer science and engineering in an emerging field called biofabrication.

"I use 3D printing to fabricate biocompatible polymer surgical implants, working closely with Melbourne-based medical device company, Anatomics," she said.

Ms Paxton has already completed two highly successful research projects, melt electrospinning scaffolds for bone regeneration using a promising FDA-approved biomaterial (polycaprolactone) and optimising hydrogel formulations for bioprinting cartilage.

Her work has been recognised with the inaugural Ezio Rizzardo Polymer Scholarship, which acknowledges the potential impact of an outstanding PhD candidate in polymer science or engineering. It provides $10,000 per year over three years, plus a $5000 travel fund. Ms Paxton is already in her second year so will be eligible for $25,000.

The scholarship honours Professor Ezio Rizzardo AC FTSE, one of Australia's pre-eminent polymer scientists and a major contributor to the Cooperative Research Centre for Polymers during its 25-year life.

During 38 years at the CSIRO, he co-invented 44 patents, including Reversible Addition-Fragmentation chain Transfer. He also co-authored 210 journal papers, was awarded the Prime Minister's Prize for Science, and ranked 18th in the Thomson-Reuters' list of the world's top 100 chemists over the past decade.

*Naomi Paxton. Photo: Queensland University of Technology*

*Professor Ezio Rizzardo*

*"These bioactive implants will begin to rapidly regenerate the patient's own tissue while degrading; ultimately, these will completely heal the bone defect."*

Professor Rizzardo is a Fellow of the Australian Academy of Technology and Engineering.

Ms Paxton said: "My research aims to help patients who have lost bone as a result of accidents, birth defects or diseases such as cancer. Currently, grafting is the gold-standard treatment option (taking bone from another site on a patient's body or from a donor and using it as a replacement in the defected area).

"But then you have two surgical sites, which means twice the risk of infection. Grafting is a great solution because the patient's own tissue is used, but tissue availability is limited and there are challenges."

Plastics and metals are other common bone replacements, but Ms Paxton says there are also some risks in using them.

"We are developing solutions to 3D print bio-resorbable scaffolds that contain the patient's own cells. We can design patient-specific 3D designs from medical scans so that the implants perfectly fit the individual patient.

"These bioactive implants will begin to rapidly regenerate the patient's own tissue while degrading; ultimately, these will completely heal the bone defect."

Ms Paxton impressed the selection committee with her academic record and involvement in STEM outreach activities.

Scholarship committee chair, Dr Peter Coldrey FTSE, said he and his committee were delighted that someone of the calibre of Ms Paxton was the inaugural winner of the scholarship.

"She has excelled in her undergraduate degree and presented a research proposal with the potential to make a high-impact contribution to polymer science and engineering.

"Naomi also clearly demonstrated her ability to communicate her scientific ideas and accomplishments to a broad audience," he said.

Ms Paxton said she was honoured to be the first recipient. "Combining polymer science and engineering innovations in biofabrication research has the potential to revolutionise how we treat tissue loss and improve the quality of care for patients all around Australia.

"This scholarship will make it easier for me to work on these biofabrication solutions and I'd like to thank the selection committee, including Professor Rizzardo."

At QUT, Ms Paxton has been a committed STEM ambassador and science communicator, involving herself in STEM engagement activities since 2012, including high school workshops.

In one of her interactive biofabrication workshops she shows students how to use smart phones to create a 3D visualisation of model bone defects. From these, the students can design their own patient-specific implants and have them printed on in-house 3D printers.

Ms Paxton paid tribute to her role model, supervisor Professor Mia Woodruff. "She is absolutely incredible. She has very much empowered me to succeed in research, which can be very challenging, particularly for females."

The scholarship, funded by a generous donation by the CRC for Polymers, is administered by the Australian Academy of Technology and Engineering. The selection committee comprises Academy Fellows who are polymer specialists.

**Academy Senior Communications Manager Dr David Glanz**

# CHANGING LIVES ONE AT A TIME

Lyn Beazley

## "Bio-mechatronics".

One day, more than a year ago, I was among a dozen or so STEM supporters mostly but not exclusively women, on a Techtrails incursion. We were headed to a state secondary school on the south coast of Western Australia.

The aim was to inform and inspire students, influencing them to stick with STEM subjects, especially the girls who traditionally tend to drop them.

We started with a brief and hopefully energy-inspiring welcome from me to the students. In this co-educational school both girls and boys were involved, because research shows that the message hits home better to both genders.

On this particular visit, a Year 11 student had just worked with a robotics expert and their Nao robot, and seemed particularly happy. When I asked why, she replied:

*"I have always known what I want to do but I didn't know if the subject existed. And if so I didn't know its name or where I could study it. Now I know it is real, it's bio-mechatronics and I can study it at Universities right here in Western Australia".*

One life changed.

The visit was organised by Women in Technology WA, the largest networking organisation in the State and described as "women focussed, men friendly". A group of dedicated women run the industry-sponsored program, recently propelled forward by a one-off Federal Government Grant.

> Australia is on track to boost girls' participation in STEM, but we need to move much faster. It's a matter of both equity and pragmatism.

Groups of around 10 students sequenced through workstations predominantly led by women, who were living examples of "if I can do it, so can you".

These stations vary from visit to visit, but have included students interacting with robots, becoming a forensic scientist at a mock crime scene, and testing Nobel Laureate Barry Marshall's latest invention – his diagnostic Noisy Guts device.

Students have said they were "blown away" by the opportunity to hear first-hand from an RAAF pilot and a Royal Australian Navy meteorologist who, for good measure, was in full uniform and eight months pregnant at the time. What a great message!

### STEM in school leads to informed grown-ups

There are many such examples across the country of programs, some female-focussed, that help build a STEM-savvy generation of Australians. I will not attempt to cover them all but I thank all industry and community groups involved.

The Academy's STELR program and Primary Connections of the Academy of Science are splendid examples.

Australia needs to stress STEM to girls and boys as a matter of both equity and pragmatism. It isn't right to leave people out and we can't afford not to make the most of our entire talent pool, irrespective of gender.

*Lyn Beazley with the **Herpetology** collection in the Western Australian Museum's wet store, which holds approximately 2.5 million wet specimens. Part of her research has focused on the regeneration of the nervous system in frogs to provide insights into restoring function after neurotrauma in humans. Photo: Frances Andrijich.*

> I hope I was a role model for the class in Brisbane, in fact one young lady asked a question that sadly I still hear far too often: Can women become scientists?

We must prepare every young Australian for the jobs of the future – 40 per cent of existing jobs are due to disappear and 75 per cent of new jobs are predicted to require STEM skills.

Beyond the career aspect lie wider issues of an informed community. We must equip the emerging generation to make informed decisions on ethical and practical questions, including "Do I vaccinate my children?", "Do I support genetic modification of crops, the environment or even people?", and "Where do I stand on climate change?".

When young people are making subject choices in their final years of schooling, surely STEM subjects should be among them.

Indeed, I have yet to see an argument why mathematics should not be compulsory throughout schooling, like English. This is already the case for many of the countries that our workforce and economy will compete against in the future. But even when students choose maths, the girls more often favour the easier options.

My view is that STEM is vital for whichever direction secondary students plan to follow. It is easy to argue for students with aspirations for a university education, but it applies equally to those selecting a vocational route.

STEM underpins many vocational courses including those traditionally popular with girls (veterinary, nursing, beautician and so forth) but also the traditionally male-dominated ones (electrical trades, carpentry or plumbing). These, thank goodness, are increasingly attracting young women.

I welcomed Western Australia's Trade Up mentor program and the State Government-backed scholarship scheme. I apologise if this and other examples I give here reflect my local experience but I am convinced they are applicable far more widely.

## It's never too early to smash stereotypes

Ideally we need to engage students earlier than secondary school.

Research shows clearly that we can never start too early to overturn stereotypes about gender and STEM. Unless we engage kids before they leave primary school, we are unlikely to do so later.

Parents, caregivers and educators can all play a part. Parents and caregivers, for instance, can arrange visits to museums with science sections and to centres such as Questacon. They could put a chemistry set or a microscope in the Christmas stocking, and above all, they can prioritise discovering new things together. I know the Scout and Guide movement are highlighting STEM, which is great.

Teachers also play a pivotal role. I would argue that building a teacher's confidence to teach science well across primary and secondary sectors is the single most important thing, augmented by a science facility in every school.

I have also witnessed the value of providing equipment and a great example is the Microscopes in Schools Rotary Clubs-driven program. It has already provided microscopes to every Grade 5 and 6 student in more than half of all WA primary schools, including one with just eight students deep in the Tanami Desert. I hear that even the kindergarten kids borrow the microscopes, reinforcing the "start early" message.

At a Federal level I cheer for the recent appointment of a Women in STEM Ambassador. And what a great choice in astrophysicist Professor Lisa Harvey-Smith. It is a huge job and I am sure we can help Lisa in so many ways. I suggest two here.

1 **Connecting Fellows with classrooms**

One of these would build on an existing Academy program. The recently introduced initiative for Fellows to connect by Skype with a primary school class was an eye-opener for me.

I hope I was a role model for the class in Brisbane, in fact one young lady asked a question that sadly I still hear far too often: Can women become scientists?

It is an easy program to rollout and costs only one's time. I would love to see this grow into an Australia-wide program with Fellows and others, especially women in STEM, reaching out to schools particularly those in rural, regional and remote areas.

2 **A School Science Patron scheme**

I have recently become Patron of a local secondary school. It has been a great success with students now invited to professional workshops and conferences.

I also organised a QandA at the school with Professor Gretchen Benedix, a cosmic geologist from Curtin University, showing in real life that science is for girls. I hope that many reading this article, especially women, will be inspired to contact a local school and establish such a relationship.

## STEM in practice makes memories

Ultimately, it takes hands-on, meaningful and exciting science to keep students engaged in STEM.

I remember with pleasure far more of my school practical classes than the theory lessons. Watching a flame change colour to help identify an unknown substance, monitoring plant growth in response to directional light, or witnessing tadpoles as they metamorphosed into frogs.

And now, teaching STEM reaches beyond the school classroom and into the laboratory, the terrestrial and marine environment, and local science-based industries. It embraces long-term school-based activities such as aquaculture and horticulture, astronomy, and building, such as the solar car that raced across the Nullarbor.

Students have even planted vineyards and made wine. One team even came third in the Perth Royal Show wine competition, even though the students were too young to savour their produce.

We also need well-trained school laboratory technicians (themselves mostly women). A recent initiative – that I hope will be established long-term – is the highly successful ASSIST web-based information program designed for technicians but valuable also for teachers.

So in 10-years-time, where will Australia be placed in terms of girls' participation in STEM?

Gender issues might have become a distant memory, but with current rates of progress, there is still a way to go.

**If you'd like to take part in the Academy's program connecting Fellows with primary classes, email communications@applied.org.au.**

*Lyn Beazley inspiring girls on a Techtrails incursion.*

## Lyn Beazley: Ensuring girls study STEM

- STEM integrated into teaching from kindergarten to Year 12 with suitably trained and appreciated teachers, women and men
- Mathematics being studied by every student throughout their school education
- All students gaining hands-on science experience, with school laboratory technicians being given appropriate support and recognition
- A nation-wide register being compiled of STEM-outreach programs
- Every school having a Science Patron, with many being women
- A Skype-style program bringing STEM experts into classrooms, especially to those in rural, regional and remote areas.

The career of **Professor Lyn Beazley AO FTSE** as a bio-medical researcher in the field of neuroscience was followed by her appointment as Chief Scientist of Western Australia from 2006 to 2013 advising the State Government on science, innovation and technology. She continues to promote STEM within the WA community and beyond, a goal boosted when Lyn was named as the WA Australian of the Year in 2015. Currently Professor Beazley is particularly concerned to promote women in STEM and pursue her passion for every young Australian to learn and love science.

STEM EDUCATION

# Next-generation schools

Doreen Thomas, Robin King, Jan Van Driel and Lachlan Blackhall

## With a long tail of underperforming students, Australian schools must make changes to develop students who can meet future global challenges head-on.

Students who graduate today are entering the workforce at a time of increasing global uncertainty. They will need to navigate threats of climate change, and ongoing speculation about the changing nature of work and the number of careers they will have in their lifetimes.

In this context, it is vital that schools adequately prepare students to excel in this environment. So how should next-generation schools prepare students for the future, dynamic world?

Schools of the future will need to increase their emphasis on STEM teaching and learning so that students are better prepared for tertiary education and STEM-intensive professions.

A well-designed curriculum will embrace educational technology so that students will be motivated to study in a personal way, fewer students will be left behind and more students will achieve their true potential.

In 2013, the Australian Council of Learned Academies compared STEM education internationally. Their report stated that governments around the world want to lift the overall scientific literacy of their populations and to draw most or all school students into senior secondary studies in STEM.

For Australia, STEM skills are seen as essential for future economic and social well-being with most occupations requiring more STEM skills and knowledge.

But the small numbers of graduates in mathematics and information technologies tell a different story. And the number of Australian students enrolling in engineering is declining – it's a major concern in the face of the many complex technological challenges for society.

Australia is falling behind many countries who are improving their school-level STEM provision, participation and performance, placing both our absolute and relative positions at risk. Australia's wide distribution in school student achievement is a particular issue, with a long tail of underperforming students.

Australia needs to provide these students with opportunities to participate in the economy of the future, where STEM will be critically important. The many excellent educational initiatives in schools must be available to all.

## Australian Schools of the Future: All students will be educated in STEM

In Australian schools of the future, the study of mathematics and at least one science-based subject will be compulsory to the end of Year 12.

Senior students will take the level of mathematics that best suits their ability and aspirations.

The current four senior mathematics subjects (Essential, General, Mathematical Methods and Specialist) in the national curriculum already accommodate the required range. And all states and territories offer a range of science-based subjects, including in engineering, digital technology and design.

The challenge, however, is not to devise more subjects. It is to increase participation in higher-level mathematics and science subjects.

To receive an ATAR for eligibility to enter university, students should gain an acceptable grade in at least General Mathematics on par with the current requirement of English.

For the more strongly quantitative disciplines, such as science, engineering, IT, economics, health sciences, architecture and design, students should complete Mathematical Methods (often termed intermediate) or Specialist Mathematics.

However, a greater push for the study of STEM should not detract from the study of culture and the arts, as jobs of the future will require intuition and good interpersonal communication skills.

## Australian Schools of the Future: Mathematics and science teachers will inspire students through a deep knowledge of their discipline

Research has shown that highly effective teachers have a deep understanding of the subjects they teach. They make mathematics fun and exciting and hence inspire, through first studying mathematics themselves and then learning to communicate it.

Many of the countries that are strongest in STEM education are those with a commitment to discipline-based teacher qualifications and professional development.

> “It is easy to be fearful about what the future holds for students today, but it is important to realise that times of great uncertainty are often also times of great opportunity.”

But the 2013 ACOLA report highlighted capacity gaps in Australia’s STEM teaching, with a clear indication that the supply is insufficient, particularly in rural and remote communities.

This results in a large “teaching out-of-field” problem, especially in the critical years’ of late primary and early secondary schooling.

A recent report from the Australian Mathematical Sciences Institute indicates that out-of-field teaching in mathematics continues to pervade Australian secondary schools.

Out-of-field teachers teach an estimated 21-38 per cent of Years 7 to 10 mathematics classes, depending on the definition of “out-of-field”.

Replacement of these teachers with fully qualified mathematics teachers will be a major task. It will require increasing both the numbers of students taking mathematics degrees (or majors) and the proportion of these graduates choosing to undertake teacher training.

Immediate action should also be taken to raise the expertise of current teachers teaching out-of-field in mathematics and science, through specific programs such as the Primary Mathematics and Science Specialists Program, with 200 participating teachers per year, provided by the Victorian Department of Education and Training.

Similar programs are needed for secondary teachers, and across Australia.

## Australian Schools of the Future will deliver STEM knowledge and skills from within the curriculum with less reliance on extracurricular activities

In the national school STEM curriculum, children are already expected to be digitally literate and to have understanding and skills in coding. Future primary school teachers – not just secondary teachers – must have confidence and knowledge across the STEM spectrum.

All next-generation schools will be well resourced. The curriculum framework will allow teachers flexibility to teach contemporary topics within their subject areas, and expose the connections between science, engineering and technology underpinning many modern systems.

The curriculum framework will also require senior students to undertake authentic, creative and collaborative projects. They’ll develop motivation in STEM, and skills in teamwork, communication and self-confidence – attributes often lacking in senior students today.

Currently, extra-curricular activities develop these attributes, many with industry support, but these are not available to all students nor are devised to link directly into the formal STEM curriculum subjects.

Next-generation teachers will have more systematic and more frequent professional development in integrated-STEM pedagogy and in their discipline.

Some of this may be acquired through short courses or other interactions delivered by university science and engineering schools, and industry. This means the apparent need for extra-curricular STEM activities will be reduced, and the value of many of these activities will be mainstreamed into all schools for the benefit of all students.

That said, as today, input and support from STEM professionals and industry partnerships will continue to be very valuable.

Industry will increasingly be willing to invest the time and effort to deeply engage with schools and ensure the brightest are attracted to STEM careers.

## Students solving authentic problems in the real world

Effective STEM education initiatives around the world typically share a common aspect: Students work on and become engaged with authentic real-world problems.

One excellent example is a program based in The Netherlands, called Technasium.

The core of this innovation is the implementation of a subject called Research and Design, alongside the regular school subjects. It aims to focus on acquainting students with STEM professions, and students work on up-to-date and authentic STEM questions. This is in order to stimulate them to develop skills as competent researchers and designers.

Research and Design is taught four to six periods per week from Years 7 to 12 and is entirely project-based.

The projects are negotiated with parties that aren't related to the school, such as local businesses. Typically, these organisations initiate the projects, acting as "clients" to provide students with real research and design problems. Students work in teams of three to five on these projects.

Currently, about 100 schools across the country have adopted this approach and are certified as Technasium.

Local industries have committed to working with these networks of schools on an ongoing basis, providing input and expertise for the projects and supervision for groups of students who do their projects mostly at school and partly on-site.

A schoolteacher supervises the groups of students, and a training and certification scheme for teachers, recognised by the government, supports the implementation of the program.

## Australian Schools of the Future will teach creativity and entrepreneurship, preparing students for solving interdisciplinary problems

In addition to the strong STEM focus outlined above, a beneficial way to prepare students for this changing world is to ensure they are taught and encouraged to apply creativity.

Creativity is typically defined as new or original ideas or ways of doing something. Encouraging a focus on creativity in the classroom, including in STEM subjects, will yield students who are equipped to respond to the many and varied challenges that they will face throughout their careers.

It is frequently argued that creativity can be cultivated in tertiary and school classrooms by developing critical thinking and problem solving; using activities that cross disciplinary boundaries; by challenging students; and by encouraging them to be reflective on their learning.

We also believe that a focus on creating impact through entrepreneurship and entrepreneurial activities is important.

Although entrepreneurship is most often associated with starting and growing a commercial business, here we take a broader view of entrepreneurship to mean identifying and solving important problems and the creation of business, operational or organisational models with a proper ethical framework, ensuring the solutions have a broad based, beneficial community impact.

While some schools in Australia have started to experiment with new entrepreneurship programs, there is yet to be a national focus on how to include these vital skills in a modern curriculum.

## The challenge

It is easy to be fearful about what the future holds for students today, but it is important to realise that times of great uncertainty are often also times of great opportunity.

Students with STEM knowledge and an appreciation for creativity, who have been well taught by inspiring teachers with expertise in their disciplines, will be well placed as graduates to develop interdisciplinary solutions to complex societal problems.

With support from the broader community, schools must rise to oncoming challenges with an ambition for their students to have the know-how to lead the rest of the world.

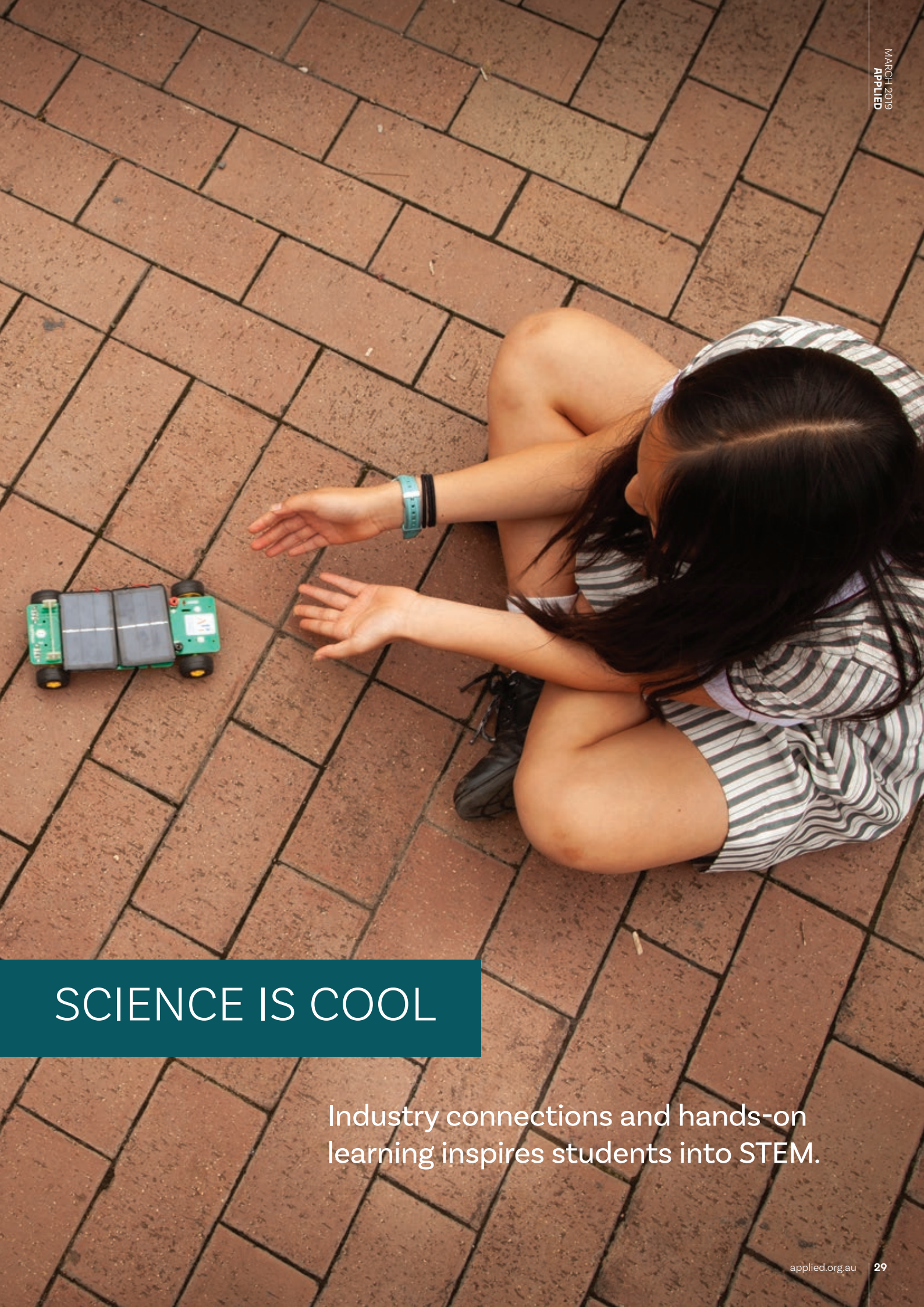
**Emeritus Professor Robin King FTSE** was Pro Vice-Chancellor of the University of SA's Division of IT, Engineering and the Environment during 1998-2007. Since then he has led national engineering education projects for the Australian Council of Engineering Deans. He is a past chair of Engineers Australia's Accreditation Board and of the Academy's Education Forum.

**Emeritus Professor Doreen Thomas FTSE** was Head of the School of Electrical, Mechanical and Infrastructure Engineering at the University of Melbourne. She holds a DPhil (Mathematics), University of Oxford. She was a founding director of MineOptima, through which her mining software has been commercialised. She has been recognised with a national teaching award for her contribution to engineering education and mentorship.

# FROM SKIPPING SCHOOL TO

Scott Sleap

*Photo: Eamon Gallagher*



# SCIENCE IS COOL

Industry connections and hands-on learning inspires students into STEM.

# STEM EDUCATION

**Jordarna, a Year 8 student from Cessnock Academy of STEM Excellence (CASE) in NSW, disclosed to a local state politician that she had once wanted to be a beautician, but would now like to be a pilot after working on interesting projects with CASE.**

This shows the influential power a hands-on learning approach can have on young minds.

With more than 20 years of experience as a public school technology educator, I have worked with both industry and educational organisations on partnership programs that have long-term sustainable and measurable success.

Kyle, an Aboriginal student at CASE, was unsure of his future direction until he became involved in number of its activities. He is now enrolled in Aerospace Engineering at the University of Newcastle and is in the running to receive a scholarship from Boeing Australia.

In my passion for promoting widespread STEM uptake, I led the development of the STEM Industry School Partnerships (SISP) program for the NSW Department of Education, which was piloted in three regions of NSW in 2018.

The SISP program is a contemporary education model matching primary and secondary schools with region-specific industry partners and provides industry-specific technology programs and equipment to make classroom learning relevant and motivating.

There is a major emphasis on inquiry, problem and project-based learning, providing authentic and practical learning activities.

SISP is delivered in partnership with "Academies of STEM Excellence" in regional NSW, an initiative I helped develop, leading with the Cessnock High School Learning Community, to form CASE.

SISP collaborates with Regional Development Australia (RDA) offices across NSW. Networking extensively within their communities, RDA delivers insights into the industrial base, economic conditions, workforce requirements and skills gaps in their regions, acting as a conduit between schools and industry.

They foster mutually beneficial partnerships, which underpins the SISP program.

> Cessnock High has reduced suspensions by 50 per cent, Year 7 enrolments are up, the school is winning or placing at regional, state and national STEM competitions, and students are now aspiring to employment in emerging STEM areas.


*Students from the Cessnock Academy of STEM Excellence.*

## Results speak for themselves

Cessnock, in the Hunter Valley, has been steadily declining from the mining boom of 2013, leading to the local government area ranking in the lowest 30 per cent in Australia. Youth unemployment is stubbornly high and students from the region did not recognise that jobs in the emerging STEM sectors are for them, despite chronic skill shortages in the region.

But the benefits of introducing real-world, hands-on learning approaches has made immense changes and created new opportunities. And the results speak for themselves.

Cessnock High has reduced suspensions by 50 per cent, Year 7 enrolments are up, the school is winning or placing at regional, state and national STEM competitions, and students are now aspiring to employment in emerging STEM areas.

Last year we established Australia's first All-Girl Aboriginal F1inSchools team. With significant assistance from our industry partners Boeing Defence the girls designed, manufactured and raced a miniature Formula 1 car.

The team has been so successful in the regional and NSW state finals that they will compete for the national title at the world's largest STEM competition later this year.

Academy students who worked on designing, constructing and racing electric bikes for the Hunter Valley Electric Bike Festival led the school to be the overall winner in its first attempt at the competition in late 2018.

## From strong beginnings ...

There has been a long history of Australian businesses and industries assisting schools, as it is in their best interests that students have the skills and knowledge required for their future workforce needs. Schools have enthusiastically embraced such partnerships, but long-term sustainable success in this area is, indeed, rare.

The success of the SISP program began with initial, measureable triumphs of the Regional Development Australia's ME Program. Since 2012, the ME Program successfully implemented a whole-of-region approach to industry-school partnerships.

We were credited with dramatically turning around falling STEM enrolments in Hunter Region schools. STEM participation in senior studies in program schools increased by more than 19 per cent while the remainder of NSW's enrolments declined during the same period.

Much of the success of the ME Program, through to the state-wide SISP initiative, can be attributed to the development of highly effective partnerships with organisations like Google, Boeing Australia, the Australian Academy of Technology and Engineering, PwC, Jetstar and more.

Other evidence that this hands-on approach is having a major impact on student engagement has been observed in Cessnock High School's Year 9 iSTEM class.

Integrated STEM (iSTEM) is a curriculum that I developed in partnership with Industry and RDA-Hunter and is taught in more than 250 schools across NSW.

Students in the iSTEM class were regularly truanting, were late to class and were not at all engaged in the work being presented.

A change of head teacher and classroom teacher, who embraced the practical approach of the course, meant all this has changed.

Now, the students want to stay back at lunchtime and after school to complete work on their projects, they are competing at regional competitions and are placing in them for the first time.

## Crookwell students get hands-on

Crookwell Academy of STEM Excellence and RDA-Southern Inland made renewable energy their main industry focus to develop hands-on learning through the SISP Program. The area is home to the largest network of renewable energy stakeholders in Australia.

They chose to invest in STELR Renewable Energy equipment packs and educational resources to undertake their hands-on inquiry-based learning activities and to solve real-world problems.

Through locally developed partnerships with the Gullen Range Wind and Solar Farm, Taralga Windfarm, and Crookwell 2 Wind Farm, students were immersed in the renewable energy technology sector with excursions, incursions and mentoring.

Combining hands-on inquiry based lessons with real-world activities has had a major impact on student learning at the academy. Students use STELR renewable energy equipment in their projects, and the site tours meant they could get up close to one of the 130-metre-tall wind turbines.

They have worked with a number of local wind farm representatives, who have helped the students solve problems identified in the agriculture sector.

And the feedback has been outstanding. Eighty-eight per cent of the students said they had better knowledge of STEM careers; 73 per cent said they were now more motivated to consider further study in STEM; and 48 per cent were more interested in pursuing a career in the renewable energy sector.

The SISP program in operation in Southern Inland is an outstanding example of how industry, schools and organisations such as the Australian Academy of Technology and Engineering working together can provide real-world learning opportunities that engage students in the STEM professions and greatly increase the likelihood of these students following a STEM career pathway.

This year, the NSW Department of Education committed to more than $1.3 million to expand the SISP program from three regions to five, with plans to expand further to the whole of regional NSW.

*Students from South Oakleigh College use STELR equipment in the classroom. Photo: Eamon Gallagher.*

**Dr Scott Sleap** is an educational leader with more than 20 years' experience with various roles in the secondary and tertiary education sectors as well as industry workforce development. In 2018 he was awarded the prestigious Prime Minister's Prize for Excellence in Science Teaching for his work in STEM education. He is currently employed by the NSW Department of Education as the leader of the STEM Industry/Schools Partnership (SISP) program. Formerly the Director of the internationally recognised ME Program at Regional Development Australia – Hunter, Dr Sleap has built a reputation as being a leading expert in STEM education and workforce development.

**Science Technology Education Leveraging Relevance (STELR) is a flagship initiative of the Academy that makes science relevant for students and teachers in more than 710 schools across Australia and internationally.**

> "We use STELR equipment and curriculum to engage students across genders and cultures through its innovative, tactile, hands-on equipment packs that are purpose built, Australian designed and manufactured. It is vital that the STELR program continue to provide STEM leadership for Australian Schools. Students can solve authentic real-world problems and learn the way that STEM professionals do."
>
> **Scott Sleap, Winner of the Prime Minister's Prize, Best Secondary Science Teacher 2018.**

# ‘We’ll be friends forever’:


*Alex Atkins and Nazanin Nourifard have both grown from their mentoring relationship.*

# Beyond industry mentoring

*Professor Paul Wood FTSE chats with Dr Marguerite Evans-Galea at the IMNIS National Launch, 2018.*

## How we're bridging the gap between academia and industry

IMNIS Directors Paul Wood, Tony Radford and Ronnie Wood

**The Industry Mentoring Network in STEM (IMNIS) initiative was developed in 2014 in response to concerns about the gap in Australia between academia and industry.**

OECD data shows that Australia consistently has one of the lowest levels of academic-industry engagement, while only 10 per cent of current PhD students in STEM will end up with long-term academic careers.

The reality, however, is that the skills students learn through their PhD training are indeed transferrable to many careers outside of academia. Problem solving, creative thinking, communications and analytical skills are critical for emerging industries. What the graduates often lack is an understanding of the needs, drivers and operating mechanics of the non-academic environment.

It was with this in mind that we began exploring various options that might help, and discovered Australia did not lack endeavor to address the gap. The government invests around $9 billion a year in R&D, but it seldom persists for long enough or at a scale that would really make a difference.

The team began to expand, and we developed a vision: 500 industry professionals mentoring 500 PhD students in STEM each year, for 10 years. Could we develop a new type of PhD graduate who was academically talented, had the skills to engage with industry and the networks to develop their careers?

After finding IMNIS a home at the Australian Academy of Technology and Engineering, and appointing an Executive Director, Dr Marguerite Evans-Galea, we rolled out successful programs in the biotechnology, minerals and energy sectors.

The number of sponsors, supporters and university partners continues to grow each year. Now, there are almost 330 students from 17 universities enrolled in programs across five states.

All of us at IMNIS continue to be grateful for the dedication of the hundreds of mentors who readily donate their time to give back to their industries. Many of these mentors have now been with the program for three years, and often continue their contact with their original mentees as they move into new career paths.

# IMNIS


*"We had a great bond from our first meeting and, over time, this mentorship evolved to become a great friendship."*

TESTIMONIES

## Mentee: Nazanin Nourifard

**In today's competitive world, it is quite hard to gain trust from an employer before they know you. It's always more reassuring if an industry professional introduces you to a company or gives a recommendation.**

Alex always wanted me to practise my networking skills at events, where she would introduce me to people. Later she recommended I attend events without her so I could try to make the first impression. Those solo events were usually a great opportunity to practise networking.

But one time, when the attendance was only about 20 people, I felt awkward because I was the only student there and other guests were from one or two companies, and they already knew each other. I didn't make a single connection and found myself alone most of the time – even in the long lunch break. I was quite disappointed with myself.

When I described the situation to Alex, I hoped she would give me advice on how I could improve. To my surprise, she told me the issue was with the event. They weren't welcoming to new arrivals and it had nothing to do with me.

Alex made me think differently and the amount of self-confidence I gained was enormous. Later, at other events, I had the mindset that if it doesn't work it's not always my fault. This had a great impact on my communication skills because I learnt that rejection is acceptable and nothing personal.

But it's not only about the introductions or referrals, the most important aspect is to get to know industry before applying for the position. You need to have a clear vision on what they expect and how you can transfer your skills.

I always had this belief that once I entered my PhD I would have to stay in academia for the rest of my life. I always wanted a more vibrant environment yet had no hope to shift. The IMNIS program broadened my career horizon.

Once Alex introduced me to people from industry who were interested in my research, I became confident to re-plan my future. I even discovered an industry that does what I do, but I had no idea about beforehand.

Alex is a genuine person and I knew I could trust her from day one. We had a great bond from our first meeting and, over time, this mentorship evolved to become a great friendship. She is a high-profile professional who empowers you to be yourself and I have received nothing but honesty and motivation from her.

I think the best advice from Alex was "to be true to yourself and your values". That is surely a lesson for life. She always emphasises authenticity and putting your heart in what you are doing.

I feel so blessed that I joined IMNIS and met Alex. I learnt wonderful lessons and would like to share them with other research students who feel isolated or have self-doubts; perhaps as a small thank you to this wonderful chain of kindness I received over the course of the program.

> We had a great bond from our first meeting and, over time, this mentorship evolved to become a great friendship.

**Nazanin Nourifard** is a PhD candidate in geophysics in the Department of Exploration Geophysics at Curtin University and her research is on "static and dynamic study of stress induced anisotropy on the reservoir rocks". She holds two Masters in mining engineering and engineering geology with a focus on rock mechanics.


# Mentor: Alex Atkins

**The first time I met Naz, we clicked. It has been a beautiful experience from the start.**

Early in our mentoring relationship I took Naz to a few networking events, introduced her to a few people then walked off to let her "do it alone". I think she was initially a bit annoyed with me for leaving her, but she soon realised she's got to be able to stand on her own two feet and network confidently.

It was tough love, but Naz was fine!

I shared key learnings from my own experiences in the mining industry and I have a few regular sayings that highlight systemic issues. This way my mentees can identify the issues as they experience them and know when it's the system's fault, not theirs. That's important for their self-confidence.

I explored Naz's values and helped her more clearly define her life's purpose so it aligns with her strengths, passions and values so she can be truly happy, enjoy her life's work and shine in the long term.

I enjoy mentoring STEM women who have experienced enough to understand what I'm talking about, but are still young and optimistic enough to take my tips and tricks with them and keep breaking the mould; to be humble learners with compassion and integrity; to be their unique authentic selves; and to be unapologetically awesome at what they do.

> Knowing that someone sees something special in you, believes in you and trusts you to do a good job is a huge self-esteem boost, which is much needed when you are hard on yourself.

Watching my mentees take the baton from my generation with gusto makes me so proud.

My purpose is to make mining better and to ensure mining women are involved in that process, including in the digital transformation of mining.

I believe that a healthy innovation ecosystem requires strong, long-term trusting relationships between industry, academia and government to solve real-world problems in a practical and holistic way.

Problems cannot be solved without understanding, which comes from time spent together, learning and listening. Industry mentoring lets PhD students gain insights that can fine-tune their research, adding real value to industry, answering their questions and solving their problems.

I have had sponsors and advocates throughout my career who took risks to put me in mining leadership positions where women had never done so before.

Knowing that someone sees something special in you, believes in you and trusts you to do a good job is a huge self-esteem boost, which is much needed when you are hard on yourself.

Naz has been a pleasure to mentor because she is so humble, grateful and gracious. It's not often you get to meet a person so beautiful inside as Naz, so it's an honour to be able to help her. She was a little tentative to begin with but now she's a tiger! We'll be friends forever.

With a diverse mining career spanning more than 25 years, **Alex Atkins** is a Non-Executive Director of Ausdrill Limited and Founder of her own consultancy. Alex holds Bachelor of Engineering Degrees from the University of Queensland and WA School of Mines (qualifying her as a Mining Engineer, Geotechnical Engineer and Geologist) and an MBA (Finance).

# Deakin Engineering
## Strength from diversity

DEAKIN UNIVERSITY

### Did you know that industry-focused R&D is a core activity at Deakin University's School of Engineering?

Industry-specific problems provide context, drive, innovation and challenges for our talented staff and students. Utilising our state-of-the-art facilities within the Centre for Advanced Design in Engineering Training (CADET), we are able to tackle the toughest challenges of Australian industry and create work ready graduates.

We have specialists in many areas of engineering and take a holistic, end-to-end approach to problems. Working with industry, we can address the concerns that are of greatest importance to our community and assist in providing the solutions that will help to advance our society and strengthen our economy.

Email us at: **hos-eng@deakin.edu.au**

Find out more

**deakin.edu.au/engineering**



# It's never too late

Karen Hapgood

**Mature-aged students are often left out of conversations about women in STEM. We need to promote the diverse pathways available to them.**

Conversations around women in STEM tend to focus on inspiring girls in high school to study maths and physics, take a STEM university degree and then remain in that field. This pathway is important in boosting Australia's STEM diversity – but why are mature-aged students so often left out of these talks?

Statistics show that the online postgraduate market is predominantly female, but we're not tapping into this for STEM, like we do for the MBA. There seems to be a group of women who wish in retrospect they had studied STEM – perhaps they were discouraged at the time – and think it's now too late.

At Deakin University, the online "cloud campus" is our fastest growing campus, attracting a different cohort of students including in engineering and IT degrees. Almost half of our engineering students are mature-aged, working around the country with jobs, mortgages and kids.

They typically study remotely and part-time. Some of them are even posted overseas on projects for their employer and can still continue their studies uninterrupted.

In our engineering courses, for instance, only about 10 per cent of our undergraduate students are female, but a number of these have truly diverse stories.

One woman trained and worked as a nurse for several years before studying engineering at Deakin. Another enrolled in chemistry about 20 years ago before getting a chemistry technician job and deferred her degree for a year. She got married, had children, and when her kids left home she enrolled in mechatronics engineering. Now, she has graduated and is working as an engineer.

It's important that we better promote the many options available to mature-aged students, particularly women, who are interested in pursuing STEM at university without stopping work or having to move.

The fact that an engineering degree can be achieved with online, part-time study and one trip to campus per trimester is not widely known and consistently missing from "women in STEM" discussions.

The trend is not just at Deakin – University of New England has a strong online science degree for example, and USQ and CQU offer online engineering degrees as well.

Each woman had to overcome the barrier of feeling like they would be the only mature age student in the class. This is likely to be true in some universities, but several universities have significant resources and infrastructure to support a cloud education.

And statistically the mature-aged students do better on average than school leaver students in their studies. In my experience, they are super motivated and generally well organised. The biggest stumbling block is usually their rusty maths skills, which can be managed with bridging courses if required.

Many mature age students already have a job and need the formal STEM qualification to advance their career. Sometimes their companies are supporting their studies in some way. However, those seeking to switch into a STEM career commonly report that they find it more difficult to get a job interview than the cohort of fresh school leavers that most large company graduate recruitment programs have in mind.

So what can we do to encourage more mature-aged women to consider studying STEM without putting their lives on hold?

If I could wave a magic wand, I would create a raft of special scholarships for mature-aged students – particularly women – to upgrade or retrain in STEM by studying remotely and part-time around their existing work and family commitments.

I would also launch a massive advertising campaign in unorthodox places like the Australian Women's Weekly and Jetstar and Qantas magazines – places where we might reach women who are not currently in STEM.

We also need to get industry and government on board, with companies offering internships for high school leaver students and "returnships" for mature-aged women.

This would have two major effects – it would raise awareness of mature age study in STEM as an option for women and employers, and it would signal to the women that they are not alone. Imagine the power of a whole connected cohort across Australia.

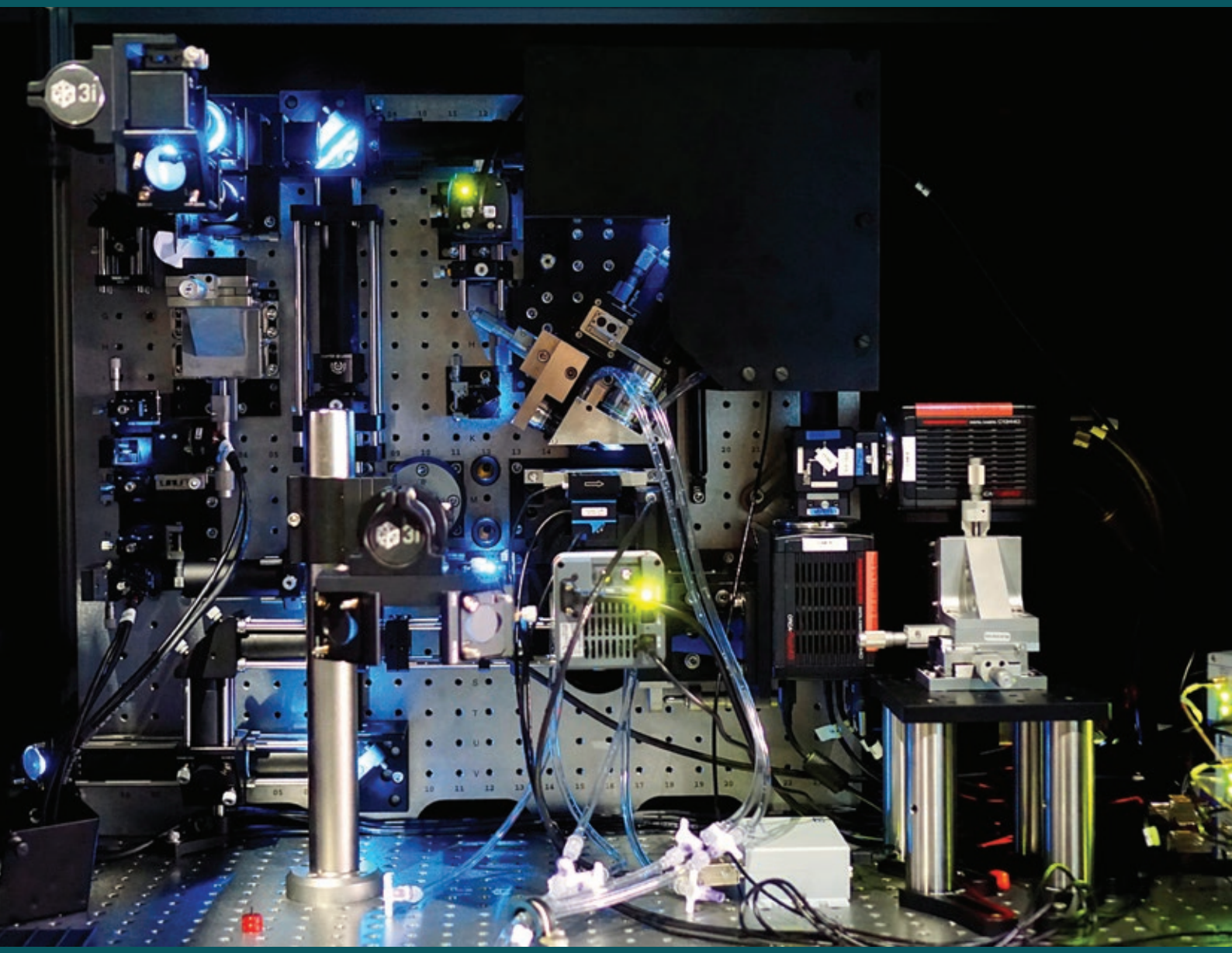
So with their broad life experiences and enthusiasm, mature-aged graduates are of enormous value to STEM in Australia. We should try to make this route more prominent to policy makers, employers and prospective students.

**Professor Karen Hapgood** is the Executive Dean of Science, Engineering and Built Environment at Deakin University, with a passion for diversity and STEM. She is an industry-focused engineering researcher with expertise in granulation and agglomeration of powders, including five years of pharmaceutical R&D and manufacturing experience.

*A mature-aged student at Deakin University. Photo: Deakin University*

# SUPERCOMPUTING COMES OF AGE

David Abramson



*Supercomputer Wiener is installed at UQ's Queensland Brain Institute. Photo: Dr Nick Hamilton*

# Wiener, a next-generation supercomputer, is cutting research time and revolutionising laboratories.

**Capturing images at the smallest scales with the highest resolutions takes an enormous amount of data. Using contemporary computers that haven't kept up with new microscope technology means researchers have been forced to process the data over days and weeks.**

This inhibits their ability to rerun failed experiments and interpret experimental results.

The University of Queensland's Lattice Light Sheet Microscope (LLSM), for instance, images live cells or specimens in 4D – three-dimensions plus time. Acquiring moving images in real time at high resolution generates up to three terabytes of raw data per hour.

A typical research microscopy workflow involves booking time on an appropriate instrument, setting up the experiment, capturing and storing images, and subsequently using an advanced computer system to enhance and analyse the data.

This whole process could require multiple days. For example, our LLSM alone is capable of generating 360,000 images per hour, which on a moderately sized supercomputer would take around 12 hours to process.

Thus, one hour of laboratory time is stretched to a couple of working days for a single result, and repeating this could take weeks.

But this is set to change, thanks to our new special purpose supercomputer, called Wiener.

Wiener reduces this process to just 30 minutes, enabling researchers to interpret their data within a single laboratory session. This supercomputer is disrupting workflows and practices at the University and the project won a gold award in the 2018 Australian Computer Society Digital Disruptor's awards.

Wiener delivers the image improvement (deconvolution) capacity needed for analysis and represents an essential new component in the high-performance computing infrastructure supporting cutting-edge microscopy-based research.

The machine is named after Norbert Wiener, the mathematician who devised the first deconvolution algorithms to remove noise from a signal or image.

Traditionally, supercomputers on campus have been built from commodity central processing units (or CPUs), coupled in large numbers to allow the solution of the most demanding problems in fields like weather modelling and aeronautical engineering.

But in the past few years, designers have been able to achieve unprecedented levels of performance using chips originally built for accelerating computer games graphics.

These so-called graphics processing units (or GPUs) can provide much more cost-effective and energy-efficient ways to perform repetitive numeric computations compared to equivalent CPUs. GPUs underpin the graphics capabilities of every laptop and desktop computer so they are now also extremely cost-effective.

While early versions targeted graphics operations, modern GPUs have extremely powerful numeric processing capabilities, propelling them into a much wider range of applications.

In fact, half of the 10 fastest computers in the world now use GPU chips.

GPUs are ideal for implementing image deconvolution algorithms, leading a number of third party image processing software companies to take advantage of them.

Wiener combines a judicious mix of conventional CPUs and GPUs in a small, relatively inexpensive package, targeting very fast image deconvolution, and has become one of the fastest computers of its type in the Asia-Pacific.

Researchers have been quick to apply Wiener's speed and GPU-enhanced supercomputing characteristics to research problems other than microscopy with outstanding success.

One novel application underpins a new approach to treating Alzheimer's disease, based on the use of ultrasound energy to displace particular protein fragments in the brain. The work is currently undergoing commercialisation and holds great promise.

As part of the project, researchers from the Queensland Brain Institute needed to determine the optimal amount of energy and its delivery vector – too much energy can be fatal and too little is ineffective.

Rather than relying purely on wet-lab laboratory experiments, researchers augmented their approach to use Wiener to solve the complex numerical equations that model the distribution of ultrasound waves in the skull.

This approach has decreased the time from experiment to translation and has generated a superior treatment regime.

In other research, scientists in the University of Queensland's School of Chemistry and Molecular Biosciences aim to achieve large-scale validation of biomolecular force fields – the forces acting on atoms.

This work will help understand the dynamics of a critical process in rational drug design called "protein folding". Initially, running jobs on the National Computational Infrastructure in Canberra, the team could simulate the action of 20 nanoseconds of atomic force fields in one day of computation for a typical protein; it took weeks for realistic modelling periods.

Using Wiener, the rate of simulation increased to around 80 nanoseconds per day and the team has now simulated a set of more than 50 proteins for 400 nanoseconds each.

And in a third example, Institute of Molecular Bioscience researchers are addressing variability in skin cancer diagnosis by automating the analysis of skin cancer biopsies to assist pathologists.

They are using artificial intelligence algorithms first to classify and distinguish images with cancers in them and to identify the type of skin cancer. Second, they use machine learning to segment and select the regions in the image that include cancer.

These can then guide a pathologist in deciding whether further surgery may be required.

The group has used Wiener to "train" a neural network to classify images based on a previously tagged image set. This means the network can perform classification without supervision.

Wiener makes training models extremely efficient, and delivers results in minutes rather than the weeks, unlike conventional supercomputers. For instance, researchers trained a model using 30,000 images in only 15 minutes.

This work has the potential to transform not only cancer detection but also many other types of pathology based on histology slides.

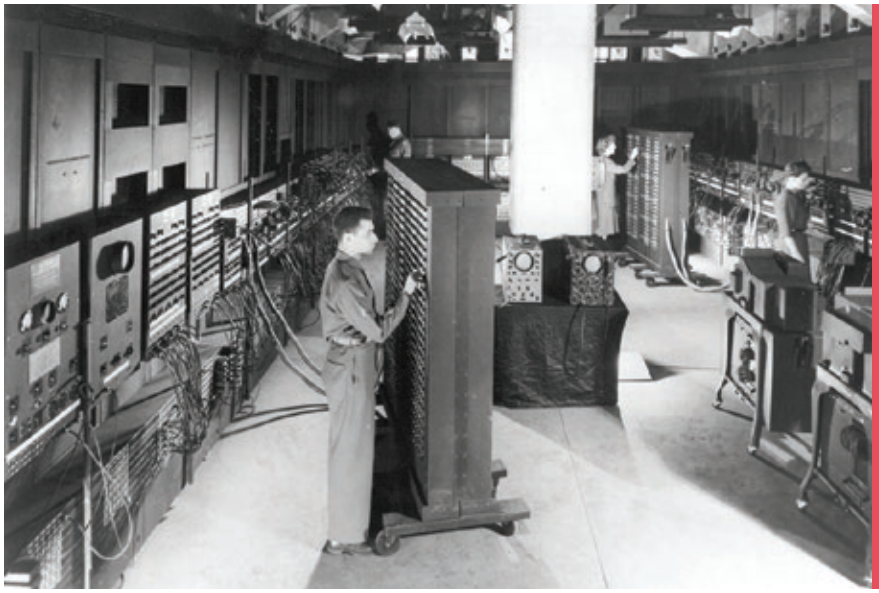
Weiner, a key capability in the research-computing infrastructure at UQ, underpins an exciting range of core research projects and we're excited to see what lies ahead for the future of supercomputing.

**Professor David Abramson FTSE**, Director of the Research and Computing Centre at the University of Queensland, has been involved in computer architecture and high-performance computing research since 1979. Before joining UQ, he was the Director of the Monash e-Education Centre, Science Director of the Monash e-Research Centre, and a Professor of Computer Science in the Faculty of Information Technology at Monash. He has produced more than 200 research publications and some of his work has been integrated in commercial products. One of these, Nimrod, has been used widely in research and academia globally, and is available as a commercial product.

*Wiener computer. Photo: Jake Carroll, QBI*

# It takes a village

Genevieve Bell



The world is not prepared for the scale of new technology in our future unless we bring diverse voices from a vast range of disciplines to the table.

*Electronic Numerical Integrator and Computer (ENIAC) in the 1940s. It was the first large-scale computer to run at electronic speed without being slowed by any mechanical parts. For a decade, ENIAC may have run more calculations than all humankind had done up to that point.*

**Let me tell you a story about a time when the power of computing seemed limitless. When the first question everyone asked was: Would these computers be intelligent and think, like us?**

It was a time when more and more data was being generated every day; when the conversations were about what to do with all that computing power and data; and about what this would mean for how the world could – and should – be.

It was a time when governments, universities and companies were all competing to take advantage of recent innovations. Everyone worried about the future, but also they wondered about it.

That time was 1946.

Every month brought new breakthroughs. Things that had been theoretical were suddenly possible. The world's first general-purpose computer, the ENIAC (Electronic Numerical Integrator and Computer) had just come online.

Alan Turing create the design for the first stored-computer program. Vannevar Bush had recently published "As we may think" and asked readers to: "Consider a future device ... in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory."

A mathematician and philosopher named Norbert Wiener pioneered the idea of the feedback loop, helping shape systems engineering and developingd the core theories in systems and control theory. He is well remembered for this work.

In 1946, though, he coined a new term – "cybernetics" – and created a whole new area of study and a whole new way of looking at the world. Wiener believed the world would mould to become a whole new kind of feedback loop of biological, technical and human systems. We would make new, smart, thinking systems.

Making cybernetics real, however, required more than just a name. It required conversations, champions, and framing questions in such a way as to reveal the edges of the cybernetics potential.

From 1946 to 1953 a series of conferences took place to try to do just that. Created and curated by anthropologists Margaret Mead and Gregory Bateson, in collaboration with Wiener, these conferences, later known as the Macy cybernetics conferences, took place in New York.

And the participants were strikingly diverse – there were mathematicians and philosophers, physicists and psychologists, anthropologists and historians, hailing from North America including Mexico, Europe and Asia. They were at different points in their careers and they had different lived experiences.

What Mead, Bateson and Wiener knew was that building something new like this was not a task for one scientific discipline. It could, in fact, only be built in the intersections between fields and existing ideas.

In 1953 the Macy Conferences came to an end but the conversations didn't.

And in 1956, 10 years after Wiener had coined the term cybernetics, a new term would come to take its place: "artificial intelligence". This, too, was born at a conference of sorts, the Dartmouth Summer Research Project.

The future was being built, again, but this time with fewer voices, and fewer questions. This group, it seemed, already knew the answers – make a machine that can think like a human!

Indeed, many ideas were lost in the transition from cybernetics to artificial intelligence, such as the idea of dynamic systems that included technology, people and ecology; the idea of feedback; and the idea that the world you were making should be subject to critical inquiry.

The thing about ideas, though, is that they move, grow and adapt. Your ideas will always end up in someone else's hands and, when they do, you hope you gave them enough grace and enough shape to hold up.

> “What Mead, Bateson and Wiener knew was that building something new like this was not a task for one scientific discipline. It could, in fact, only be built in the intersections between fields and existing ideas.”

Mary Catherine Bateson, daughter of Gregory Bateson and Margaret Mead, wrote of the moment cybernetics gave way to artificial intelligence:

> “*The tragedy of the cybernetic revolution, which had two phases, the computer science side and the systems theory side, has been the neglect of the systems theory side of it. We chose marketable gadgets in preference to a deeper understanding of the world we live in.*”

## So why is this story important to engineering and its possible futures?

Well, because right now we are living in a time when the power of computing seems limitless.

We are still gobsmacked by the volume of data generated every day. Our conversations are still about what to do with all that computing power and all that data.

Right now, governments, universities and companies are all competing to take advantage of recent and forthcoming innovations. And everyone is worrying about the future, and also wondering for it.

I believe engineers and engineering offer us a way to navigate that future. But to do that successfully, we will need to change and adapt.

An historical analysis of cybernetics and the Macy Conferences reveal that the early conversations were characterised by a systems approach to how society should integrate and develop artificial intelligence, focusing on how humanity might be enhanced. Economic benefit was a secondary consideration, in stark contrast to how AI applications are positioned and employed in the majority cases today.

This lesson tells us about innovation and impact on society, and about the need to keep everyone in the loop. Not just the technical loop, but the societal one, too.

The good news is that engineering has always been about precisely this. The whole history of engineering is about a body of knowledge that grew up around the need to keep humans safe as technical systems achieved increasing degrees of scale and scope.

***So really, engineers have never been more relevant or more necessary.***

Some 200 years ago, the rise of trains and railways required engineers to help ensure steam engines could get to scale safely; we need engineers and their allies to help bring artificial intelligence safely to scale.

The world is moving at the speed of light towards a more technologised state. We can call it the digital revolution, the fourth industrial revolution, or the computer age (if you’re of a certain vintage).

I imagine this is a future where artificial intelligence goes to scale. I am not talking generalised intelligence and singularity. I’m talking about that time in between, where AI engines are sophisticated enough to get put into lots of machines and autonomous systems, and into the world around us. And start – inevitably imperfectly – making decisions that affect people’s lives.

That is a very complex future.

If we translate the skills we have today onto that future, we come up short. We have lawyers who are trying to regulate configurations of technologies they don’t understand. We have computer programmers who are coding algorithms for machines they are not sure how will act in response to algorithmic output. And we have engineering teams trying to put autonomous vehicles on roads who don’t understand the social and political context of transport.

I believe that the world needs a new way of thinking to tackle these coming challenges.

I think the answer lies with a re-imagining of cybernetics and re-capturing the systems theory core of that nascent conversation. This new body of knowledge would be more closely tied to Wiener’s notion of cybernetics, which, for all its madness, can be re-interpreted for the 21st century in ways that we desperately need.

The practitioners in the new field will have to be able to ask the right questions. They will integrate scientific insights across disciplines examining intelligence, including computer science, systems theory, psychology, anthropology, the law and so on.

And they must use them in a practical decision-making framework that will assist them to design, build, scale, manage, regulate and decommission cyber-physical systems (autonomous systems super-charged by AI and the Internet of Things).

When we build, every step of the way is a decision with real-world impact. We must equip our engineers with the skills they need to bring in diverse voices and make good decisions at every point.

We need thinkers who see the whole.

Genuine, society-wide innovation is different to making gadgets. It is hard work. And it is better with more voices than fewer. It is part luck, part hubris. A willingness to fail a little, to be reborn as something else. It is also persistence and purpose.

I hope we are up for the challenge!

**Distinguished Professor Genevieve Bell FTSE** from the Australian National University is the foremost global leader in applying social sciences and cultural anthropology to technology development and digital transformation. With a background in cultural anthropology, she has an unparalleled reputation as a leader at the intersection of technology and social sciences, and the impact of digital transformation. Her combined industry and academic impact are creating new fields at the intersection of social and technology sciences. She has been a globally recognised champion of diversity and gender equity, and a practical mentor and supervisor to colleagues and students.

# Are we using nature for urban water management? Not even close ...

Ana Deletic

> Australia is not only one of the driest countries on Earth, but the country with the most weather extremes. While droughts are destroying crops and emptying water reserves in NSW, severe floods are rampaging through Queensland, destroying people's lives. And with ongoing climate change and rapid urbanisation things are going to get worse.

**Nature has been dealing with these issues for millennia, so why not learn from it, why not start sprucing up our concrete jungles with greenery and harvesting all its benefits? But you might say: "Where are we going to find that much water to irrigate all those plants if you just said that droughts are the problem?" The answer is, water is everywhere around us, we just need to learn how to effectively use it.**

Green infrastructure researchers around the world have been passionate about transforming green, vegetated infrastructure into systems that can use and treat what is considered common urban waste water sources, such as stormwater and greywater. This involves the use of plants, soils and natural processes to treat water.

In Australia, research teams from UNSW in Sydney and Monash University in Melbourne have done extensive work on developing both horizontal and vertical vegetative water technologies. For example, Monash has developed rain gardens that retain and treat stormwater run-off that otherwise would pollute our bays and waterways.

This work resulted in practical design guidelines for the adoption of rain garden technologies, published in 2009 and updated in 2015. In inner Melbourne alone, more than 10,000 raingardens have been installed to protect the lower Yarra from stormwater pollution.

More recently, Dr Veljko Prodanovic, currently at UNSW, developed Blue-Green walls – vertical biofiltration gardens in urban areas that, instead of using tap water, use and treat household greywater.

Imagine living in an apartment on a higher floor of a building. Every time you shower or wash your hands, the water you used goes to irrigate a beautiful green wall just outside your building instead of entering the sewerage system. What's more, that "waste" water gets treated and could be used again for toilet flushing or garden irrigation.

The water we produce while showering is rich with soaps and shampoos which act as fertiliser for plants, so we should harvest these resources. Otherwise, nitrogen and phosphorus from these products can create algae that choke our rivers and bays. The practical recommendations for the blue-green wall design was published in 2018.

## Multiple benefits of nature

While using nature for water treatment was the initial driving force for researchers in this field, this is not the only benefit of green systems. Green walls are already valued for their beautifying presence and are highly used architectural features in cities where trees and other greenery can't fit.

One Central Park building in Sydney, an award-winning structure, shows off its lush green walls across the whole Sydney CBD. Standing close to a green wall, or other vegetated system, it is not hard to understand their unique cooling benefits either. If you are in the street surrounded by green walls, the temperature drop can be as much as 12C.

While this highly important for human comfort, it also reduces temperature stress, which can lead to death. This is especially true across sensitive communities where every heat-wave represents a health risk. With Sydney's western suburbs being on average 10C warmer in summer compared to eastern suburbs, application of green technology could be highly beneficial.

*Ana Deletic. Photo: University of NSW*

Using greenery to reduce temperature has another positive side-effect – it reduces energy consumption in buildings. Researchers have found that using vegetation to shade building walls can reduce cooling costs in Miami, USA, by almost 60 per cent and, incredibly, almost 100 per cent in Brasilia and Hong Kong.

Real estate prices are a hot topic nowadays. The University of Western Australia conducted a research on the effect of rain gardens on property value in Sydney and found that a rain garden within 50 metres of your home can increase its value by 6 per cent.

So here is a tip on how to increase your property value in this falling market – convince your local council to build a rain garden next to your property. However, the amenity value of green systems is usually hard to quantify and not a convincing indicator.

Did you know that nature-based technologies can be used to reduce flood damage? Climate change and urban growth has increased the pressure on drainage infrastructure. Completely removing flooding from cities is not feasible as total flood control is usually more expensive than the value of infrastructure and buildings in the flooded area.

Major flood events can cause severe and expensive damage but they do not happen frequently. Smaller floods on the other hand cause less damage but they happen more frequently. The cumulative damage of smaller but frequent floods can exceed that of big floods.

Nature-based technologies, such as rain gardens and wetlands, can reduce the risk of smaller floods. The latest work by Dr Behzad Jamali, a flood researcher from UNSW, has estimated that flood damage in a small (270-hectares) catchment in Melbourne can be around $10.3 million per year.

By installing rain tanks in every household for indoor and/or outdoor water use, the expected annual damage bill could be reduced by 30 per cent. Integrated use of rain tanks and rain gardens could cut that even further.

While we recognise the water recycling, cooling and amenity benefits of nature-based systems, it might be time to start considering green infrastructure as a cost-effective and environmentally friendly flood mitigation solution, too. Unfortunately, current Australian drainage practice does not give any credit to nature-based systems for their flood mitigation benefits.

## Not just in Australia ...

Backed by research and multiple benefits, green infrastructure is not hard to sell. In Australia, these nature-based systems are known as Water Sensitive Urban Designs (WSUDs) and are starting to be widely implemented across the country, especially in Melbourne.

In Europe, these are "nature-based solutions" and are heavily used for rain water capturing, while in the US they are named Low Impact Developments (LIDs), a popular solution for road run-off treatment and urban cooling. China has recently launched the "Sponge City" concept, which relies on green technology to hold water during wet periods so that you can "squeeze a sponge" during dry periods and use water where it's needed.

Adoption of green technologies is happening around the world and this concept is not new. Recent technological advances in the development of green water treatment technology have popularised this sustainable water management practice, but two new issues arose.

For a long time, green technology development was the primary concern of engineers. The pendulum has recently shifted towards delivering widespread adoption, with a focus on planning and regulatory issues.

While these are crucial for the roll-out of green technologies, they shouldn't be seen in isolation. We need to balance this pendulum and have technology development and system adoption happening hand-in-hand.

The green technology systems are not robust enough for unrestricted implementation, and we need coordinated effort and investment from researchers, state governments, councils, water corporations, developers and households to achieve desired results.

Keep in mind that these are nature-based systems which are specific to different climates, soils and water conditions. They can't be mass-produced.

This leads me to a second issue which is even more concerning. Some companies have started to "blindly" use green technology guidelines developed in one climatic region in other, incompatible regions. This can be seen in countries like China, where there are significant investments in this field and business are selling Australian designs for a quick profit.

However, this leads to system underperformance and, in some cases, plant death, which gives rain gardens and other green technologies a negative reputation. For the best results, these systems need to be tailored, tested and validated to local conditions.

## What does the future hold?

Now we all must work towards more research-industry partnerships as well as to educate the public about nature-based water treatment systems. Engineers should be working with urban planners, landscape architects and ecologists to build capacity for wide-spread implementation of water and life-saving greenery throughout our cities.

So, are we using all the benefits that nature provides? No, not yet, but let's keep working towards that goal.

**Listen to Professor Deletic talk on this topic at applied.org.au/green-walls**

**Professor Ana Deletic FTSE** is Pro Vice-Chancellor (Research) at the University of New South Wales. Until mid-2017, she was Associate Dean of Research Engineering Faculty and the Founding Director of Monash Infrastructure Research Institute at Monash University. Professor Deletic leads a large research group working on multi-disciplinary urban water issues, focusing on stormwater management and socio-technical modelling. Earlier she led the development of a number of green nature-based water treatment systems which are now widely adopted in Australia and abroad. She is a Fellow of Engineers Australia and is Editor of Water Research.

*One Central Park in Sydney is globally recognised for a number of its unique features, including its cantilevered heliostat, low carbon tri-generation power plant and internal water recycling plant.*

# Engineering diversity

Leeanne Bond reflects on her experiences as a woman in engineering.

*Using the dimensions of average males as an engineering standard can have catastrophic effects for women and children.*

**Like many female engineers I've met, my first priority as a young engineer was to feed my interest in science and maths. I wanted to "make things happen" by contributing to our world through a career in engineering.**

Entering university in the early 1980s I was mildly aware engineering was a non-traditional field for girls in Australia, but I had the support of my parents and brothers who studied engineering and computer science, so it seemed natural.

But as I began my career, I became increasingly aware I was unusual in the profession, often being asked with surprise and genuine curiosity: "What's it like to be a female engineer?" And I would reply: "I don't know, what's it like to be a male engineer?"

I did occasionally have to reinforce my right to be in this profession – not just to others but also to convince myself.

A male colleague once commented to me that "it was okay I was a chemical engineer, as that's not a real engineer". He was a mechanical engineer with similar years of experience – but I was glad I didn't threaten his sense of self.

Around the same time, my supervisor told me he liked to have a balanced gender mix as it created a better work culture. I thought he was kidding, or slightly crazy, but now I understand he was ahead of his time and I often remind myself that gender balance supports an inclusive culture appreciated by both men and women.

In the late 1990s, about 10 years into my career, the Queensland Government invited me to join the Smart Women Smart State Taskforce for the Office of Women. We were tasked to give advice to the Minister for Women on encouraging the entry, promotion and retention of women in Science, Engineering and Information Technology.

I found the concept curious, but enjoyed my career and felt the need to give back and encourage others to join me in my profession. It was really the first time I came across gender equity as an issue and I learned a lot in a short space of time – and it was ground-breaking work conducted over four years.

I slowly realised that by being immersed in a male dominated environment I had closed my eyes to all gender issues, explaining away any comments on my gender and focusing clearly on my skills and experiences.

Only a few years later I was asked by colleagues to be the Queensland President of Engineers Australia in 2002, which was a wonderful honour and opportunity, but it also made me nervous since I was the first female president (and only the second in Australia).

I decided I needed to get over my discomfort and be the role model engineers were asking me to be, to highlight the desire for gender equality. Female participation in engineering was 8.5 per cent in 2001 compared to 13 per cent in 2015.

As President, I focussed on engineers becoming leaders and the value of engineering to our society, business and governments.

All this time I believed the scarcity of women in engineering was a pipeline issue and that we just needed to be evangelical, sharing the opportunity with more girls.

Later I realised it was not just a recruitment issue, but that promotion and retention were also an issue for women, in engineering and across the business community. Just look at politics and the gender conversations.

This experience, and my increasing awareness of structural issues facing women in engineering, has allowed me to look at gender equity as a system issue. I can identify and assist more women to access a fulfilling and rewarding career and gain greater financial independence.

Years later, here I am writing about the benefits of gender diversity again!

And as well as my board portfolio, I'm currently actively creating a more inclusive culture in construction and asset services in my role as Executive for Diversity and Inclusion for Downer's Mining, Energy and Industrial division to improve business performance with innovative solutions.

So why is gender diversity important in engineering, and how does gender diversity improve development?

In an attempt to crystallise an answer based on research, rather than purely my own opinion and personal experience, I spoke to Juliet Bourke.

Juliet Bourke is a Partner of Human Capital at Deloitte, an author and a TEDx speaker who has written many papers and books on diversity and its contribution to diversity of thought. Juliet steered me to the following four prevailing thoughts on gender diversity that she outlines in depth in her book *Which two heads are better than one.*

1. Men and women think differently (not her view)
2. Men and women have been socialised to see their environments and behave differently
3. Men and women may bring different life experiences which are relevant to the task
4. Gender diversity improves collective intelligence because it changes conversations

Bourke concludes that while there may be some inherent gender differences, the similarities are much stronger. She agrees with the latter three thoughts - particularly that gender balance brings out more views that are diverse from group dynamics.

Perhaps that's what my supervisor noticed 20 years ago!

Bringing together different life experiences and socialisation seem to be supported by many anecdotes, often used to call for greater gender diversity in development of technology.

For example, I recently participated on a gender diversity panel with Dr Sue Keay, the former Chief Operating Officer of the ARC Centre of Excellence for Robotic Vision and now Research Director Cyber-Physical Systems at CSIRO's Data61.

I was fascinated to hear her recounting the story of crash test dummies and airbag development.

Between 1973 and 2011, crash test dummies were exclusively made to represent the height and weight of average males, showing shocking thoughtlessness about the diversity of users. It resulted in 47 per cent higher rates of serious injuries for seat-belted women and children over many decades.

So it's not just a good thing to be more inclusive of your users, it may be imperative.

And these stories are widespread, including in early voice recognition systems not recognising female voices, and of technology companies being slow to realise the benefit to women of including menstrual cycles in their otherwise comprehensive health apps.

**Leeanne Bond FTSE** has 30 years corporate experience including more than 14 years as a professional company director. She helped establish WorleyParsons' business in Queensland, NT and PNG. Leeanne is currently the independent non-executive chair of ASX listed Synertec Corporation Limited and a non-executive director of ASX listed Liquefied Natural Gas Limited (LNG), Snowy Hydro Limited, the Clean Energy Finance Corporation, The University of Queensland's JKTech Pty Ltd and QADO Services Pty Ltd. In addition to her board portfolio, Leeanne is also Executive for Diversity and Inclusion at Downer Mining Energy and Industrial, advising the CEO on improving gender diversity.

I slowly realised that by being immersed in a male dominated environment I had closed my eyes to all gender issues, explaining away any comments on my gender and focusing clearly on my skills and experience.

# 60 NEW SUPERSTARS TO LIGHT UP STEM

**Science Minister Karen Andrews has named 60 Superstars of STEM following the selection of some of Australia's most inspiring scientists, technologists and educators.**

The women will smash gender stereotypes by being public examples of the diverse range of people working in STEM, and being role models to encourage girls to consider a career in these fields.

Professor Emma Johnston, President of Science & Technology Australia, said the women would no longer be hiding their scientific superpowers, and would share them with as many Australians as possible following the launch.

"When we launched the program last year, I said that the stereotypical scientist was an old man in a white coat," Professor Johnston said.

"Thanks to the first 30 Superstars this is starting to change, and with 60 more, we will be well on our way to permanently smashing the stereotype."

The program is continuing until 2022 thanks to Government support.

"Women represent 50 per cent of the intelligence, skill and creativity of our nation's population, and yet recent figures show less than 16 per cent of Australia's university and VET science, technology, engineering and maths graduates are women," Minister Andrews said.

"We know that by 2030, workers will spend 77 per cent more time using science and maths skills. With the demand for STEM know-how higher than ever, women have to be part of the solution."

Hundreds of applications were received, and the successful Superstars of STEM are now in the midst of a year of training and support before they actively engage with their communities and the media in 2020.

The women chosen to take part do exciting and varied work in science and technology. They include a researcher working to develop a "key-hole surgery" inspired approach to mining and a conservationist on a mission to train reptiles not to eat cane toads.

"Each Superstar will connect with hundreds of school children; feature in local, national and international media; and serve as a representative for their work, their discipline and their sector," Professor Johnston said.

# NHMRC adopts Gender Equality Strategy

**The NHMRC has adopted a Gender Equality Strategy to 2021 with the aim of achieving a gender-equal health and medical research workforce.**

The aim is underpinned by the central principle of "50:50 – if not, why not?"

The strategy, developed with advice from NHMRC's Women in Health Science Working Committee, is focused on achieving an increase in the retention and progression of women.

Its vision states: "That all researchers have equal opportunity to participate in NHMRC funding schemes and are supported to reach their full potential. This requires environments which are free from bias, discrimination and sexual and all other forms of harassment.

"NHMRC considers that gender equality will have been achieved when similar numbers of women and men apply for, and are funded through, all NHMRC funding schemes. The outcome will be an improved health and medical research sector that will aid in building a healthy Australia."

Initiatives to support gender equality in the health and medical research workforce include:

- Establishing the Women in Health Science Committee to gain a better understanding of the issues that women researchers face
- Taking career disruption into account during peer review and in determining eligibility for funding
- Improving gender balance on peer review panels
- Introducing the Elizabeth Blackburn Fellowship to recognise outstanding female research fellows
- Annual publication of funded rates by gender to ensure transparency to the research sector.

# Meet Dr Collette Burke – Victoria's first Chief Engineer

Deborah Sippitts

*Dr Collette Burke at work on Victoria's Metro Tunnel project*

**At the age of 16 Dr Collette Burke, Victoria's first Chief Engineer, had her first real taste of engineering.**

Some of her extended family members were working on construction sites and she would go and spend time with them.

"I was absolutely amazed with the dynamics and pace of work on the sites. Each day was completely different and each site was transformed very quickly into something better than was there previously," said Dr Burke.

"After a couple of weeks, I decided I wanted to work in the field and this only grew in my final years of high school."

Dr Burke was appointed Victoria's first Chief Engineer one year ago – so what has her role involved so far and what's planned?

## Expert advice and support

"The role provides expert advice and support on design and engineering aspects to the Victorian government on major infrastructure projects.

"We've been strongly focused on addressing the many opportunities that engineers can provide to the Victorian Government.

"For example, the state-wide use of digital engineering, performance-based specifications and fit-for-purpose assets; increasing the visibility of the profession; and improving gender and cultural diversity," she said.

Dr Burke is particularly interested in driving strategies on Future Cities, Industry 4.0 and connected environments.

"This is really where society needs to head and I think engineers are in the driver's seat to make this happen – the sky really is the limit," she said.

## Unprecedented infrastructure investment

Established by the Victorian government, the Chief Engineer role complements the unprecedented level of infrastructure happening across the state.

By way of example, since March 2018, the Victorian Government's annual infrastructure investment will average $10.2 billion over the next four years – more than double the average during the previous 10 years.

"My role will also look at how we can raise the profile of the engineering profession to safeguard Victoria's future growth," said Dr Burke.

"As part of this, a prime opportunity is addressing the gender inequality of the engineering workforce – less than 14 per cent of the career engineering workforce is female.

"This means we are effectively missing half a workforce, and that only half of our community are represented in the things that engineers do," she said.

## Working closer together

Dr Burke will also continuously be asking how Victoria can bring various bodies closer together – to be able to share knowledge and current and future issues and challenges, and to work towards providing benefits for everyone.

"We need to forge these partnerships because each of the different entities are essential in the successful delivery and development of our future infrastructure, assets, cities and regions.

"Collaboration is imperative as many of these stakeholders have developed solutions to many problems and challenges that we all face.

"It's a totally wasted opportunity if we don't make the most of those existing efforts," she said.

Dr Burke is a good example of how a young woman can have a successful career in engineering.

When she was younger and entered the profession, she was quite oblivious to the fact that gender was an issue in engineering.

"I was just so excited to be in the industry, that I didn't see being female as a barrier.

## Actively advocating for women

"I was quite fortunate that I didn't feel impacted in the early days but, as you move on in your career, you realise the importance of continuing to develop and retain more young women engineers," she said.

"With less than 14 per cent women in engineering, they are a vital proportion of the industry and provide diversity in ideas, solutions and capabilities".

Dr Burke has always actively advocated for women within the industry across the wide range of organisation types and different career paths she has worked in.

"It should be a common and high-level priority across the whole sector to raise the bar and, until the engineering profession reaches equality, we still have lots of work to do".

Dr Burke is very excited about being Victoria's Chief Engineer – just as excited as when she was 16 and visiting construction sites … which is a great way to be.

# Lisa Harvey-Smith: Smashing galaxies and gender stereotypes

Bianca Le

## Australia's first Women in STEM Ambassador discusses the future of astrophysics, the importance of science communication and what it takes to boost STEM diversity.

Not many people have the skill to draw an entire room full of everyday Australians – scientists, science-enthusiasts and the science-illiterate alike – to a two-hour talk on complex astrophysics.

Professor Lisa Harvey-Smith did this in theatres around Australia for the launch of her book *When Galaxies Collide* and managed to keep the audience on the edge of their seats from start to finish with vivid metaphors and humorous anecdotes of day-to-day life as an award-winning astrophysicist.

This ability to capture and communicate the universe with such vibrancy is among many reasons why she was last year named Australia's first Women in STEM Ambassador.

In her two-year appointment, Professor Harvey-Smith will focus on accelerating the cultural and systematic changes already underway in Australia to keep women in the STEM workforce.

She said women in STEM were often driven out of science by a lack of work flexibility or a toxic workplace culture. So to boost their numbers, she is tackling gender stereotypes that form at a young age.

Smashing stereotypes herself, Professor Harvey-Smith's research focuses on an intergalactic event that will change our night sky forever.

Every hour, the Milky Way moves 400,000 kilometres closer to a neighbouring galaxy, Andromeda. In 3.8 billion years, these two galaxies will collide, causing brilliant bursts of star formations, the fusion of supermassive black holes and the ignition of fiery gas streams that will tear through space at almost the speed of light.

But before we worry about that, she explains that in half a billion years, humans will need to think about leaving Earth to get away from our hot, expanding sun.

**Do you think humans are more likely to move to another planet or to live on a floating space station once the Earth becomes uninhabitable?**

The human body doesn't do too well in space. Although we've grown quite good over the past 20-30 years living in space stations, after a couple of years humans come back weak, with diminished eye sight.

Our bodies have adapted over hundreds and thousands of years to live in gravity, so we'll have to develop spinning space stations to create artificial gravity – otherwise our bodies will waste away.

Alternatively, when the Earth is too hot we could move to the outer solar system on an icy moon like Saturn's Enceladus. I think either way, we have some big problems to solve here on Earth today.

We're destroying our own planet and it's such an imminent problem. There's no way we can possibly live on Mars, or another planet or moon, if we can't control climate on our Earth now.

**You've played a key role in developing the CSIRO Square Kilometre Array (SKA), which will not only expand our understanding of the universe but also drive technological developments worldwide. What are some examples of these technologies and why is this important?**

It's very exciting working in astronomy because we not only discover things in the universe, but also all of the money spent on space research is also spent for things that help us on Earth – that's something people need to remember when you hear billions of dollars being spent on astronomy research.

The technologies we take for granted come from the most unexpected types of research that often seem unrelated.

Medical technology and imaging were also developed through fundamental leaps in astronomy and other sciences. Some of the medical technologies used to look at changes in moles to check for melanoma growth stem from astronomy research, for instance.

And the SKA helped developed faster, more reliable wi-fi because of a project at CSIRO to look for exploding black holes.

For the SKA, we're developing cameras with multiple pixels for radio imaging. In radio astronomy, cameras previously just used one pixel to take images of space, which sounds weird, but it's true.

We hope that these developments can be translated to medical technologies, for example medical imaging of the body to detect and treat cancers. That could be a very important spin-off.

**How and when did you know you wanted to become a science communicator and educator?**

It's really about the way I got into science myself – through some amazing science communicators I grew up with in the UK. My key influencers were television and books.

The BBC had a program called Tomorrow's World. It imagined the world of the future, but it wasn't all silver foil, monorails and hovercrafts! It explored how the world can change with technology – that was so inspiring.

I always had this passion to teach but I didn't want to be a teacher like my mum because, frankly, it's a very difficult profession. I have the greatest respect for teachers in schools, but I knew it wasn't for me.

I wanted to use my creativity rather than teach in a confined setting – that's what I love about science communication, the creative aspect. The challenge of breaking out of my science niche and cutting through the jargon and explain these cool concepts. I find it challenging and engaging and I love watching people's faces as the penny drops.

**How do you think new technologies like machine learning, automation and quantum computing will affect the field of astrophysics over the next 50 years?**

Machine learning and the automation of every part of astronomy research is definitely coming – we need it.

We have so much data coming from our new telescopes – going from taking images of just one pixel to multiple pixels and from one telescope to the 130,000 telescopes planned in Western Australia – we will need to use one giant supercomputer brain to study the sky.

Astronomers used to just go through data and images to study space but we can't do that anymore. There isn't enough human capacity in the world to do that, so we have to teach computers to be the new scientists.

That's a very difficult thing to do because humans are surprisingly intelligent compared to computers – computers can only follow specific rules, whereas we have a bit more agency. These new technologies will be massively important and game-changing.

Research will not only be faster, but we will be able to find things we didn't expect.

When we take a picture of the sky for a whole night using a camera on a telescope, we analyse every millisecond of that picture. Every millisecond the sky changes – there are things flashing and exploding, disappearing and appearing. Those are the flashes of light from a distant universe created by things we've not discovered yet.

And those are what bring in the game-changing discoveries. That's a fundamental shift in the way we do science, because now the computer is alerting us to the things that we don't expect to see.

**Sounds like a great time to be in astrophysics!**

It's brilliant!

**What did you wish more people knew about astrophysics?**

Astrophysics can be done by anyone.

We have so many citizen science projects where anyone can take part. You can go online and look up *Galaxy Zoo*, or *Citizen Science* and you can take part in classifying galaxies, look at how the sky is changing and discover supernovas and star explosions.

And the findings will be used in real research, so I wish people would get involved. It's really exciting and a great opportunity to be a real scientist in your own home.

**Congratulations on being appointed Australia's first Women in STEM Ambassador! There's currently a lot of funding pouring into initiatives aimed at increasing girls and women's participation in STEM – why do you think Australia needs a Women in STEM Ambassador?**

My role really is important because it works on a national scale to raise awareness of issues that create roadblocks to girls studying STEM in school at advance levels and progressing into STEM jobs and careers.

Once women are in science, they're driven out by bad workplace culture and a lack of work flexibility, particularly around the time when they may have caring responsibility. There are many different issues, but really I'm trying to accelerate the cultural change that's already underway in this country.

In particular, I want to tackle some of the stereotypes that form from a young age and, this year, I'm focusing on early learning facilities. We want young people to understand that STEM is for girls and boys, and it can lead to amazing, exciting, fun, world-changing careers.

I really want to go to primary schools and drive this message home, and work with education departments across the country to help young people make the most of their education.

**What have you learnt in this role so far and what do you hope to achieve for the remainder of your time as Ambassador?**

I've learnt that the education system in Australia is very complex. Targeting young children is really a good way to make change before they start forming stereotypes and before they start making decisions about their future study.

Talking to 14-year-olds is actually too late – they've already formed a lot of those opinions. Although girls actually outperform boys in many maths and science tests, they have a lower opinion of their ability to do those subjects.

It's really about breaking stereotypes, building confidence and boosting the understanding of young women about what STEM really means.

**Bianca Le is a PhD candidate at Monash University. She was a STEM Graduate Policy Intern with the Academy.**

WOMEN IN STEM

# SAGE Bronze Awards – a leap forward for gender equity and diversity

Fifteen Australian institutions were recognised for efforts to improve gender equity and diversity at the inaugural Athena SWAN Bronze Awards Dinner, held in the Great Hall, Parliament House, in Canberra in December.

The awardees are:

- Australia's Nuclear Science and Technology Organisation (ANSTO)
- Baker Heart and Diabetes Institute
- Charles Sturt University
- CSIRO
- Curtin University
- Edith Cowan University
- Griffith University
- Monash University
- Queensland University of Technology
- Swinburne University of Technology
- University of New South Wales
- University of Newcastle
- University of Technology Sydney
- University of Wollongong
- Walter and Eliza Hall Institute

SAGE Cohort 1 members are the first group of the 45-strong institutions from the higher education and research (HER) sector to complete the Athena SWAN Bronze process – with the remaining institutions due to complete accreditation this year.

## Positive impact already emerging

With 50 per cent of Australian's HER sector institutions participating in the SAGE Pilot, evidence of positive impact is already emerging.

This includes increased career satisfaction and opportunities; improved working practices to support career progression; increased visibility of women in science; and an increased proportion of women in STEMM – science, technology, engineering, maths and medicine – departments nationally.

Find out more about Science in Australia Gender Equity (SAGE) at **sciencegenderequity.org.au**


*Members of the CSIRO team at the SAGE Awards Dinner. Photo: Bradley Cummings.*


*Award-winning ABC TV journalist and presenter, Del Irani, hosted the inaugural SAGE Awards Dinner. Photo: Bradley Cummings.*


*From left: Dr Margaret Hartley, CEO, Australian Academy of Technology and Engineering; Alison Johns, Chief Executive, Advance HE, UK; Dr Wafa El-Adhami, Executive Director, SAGE; and Anna-Maria Arabia, Chief Executive, Australian Academy of Science, at the Dinner. Photo: Bradley Cummings.*

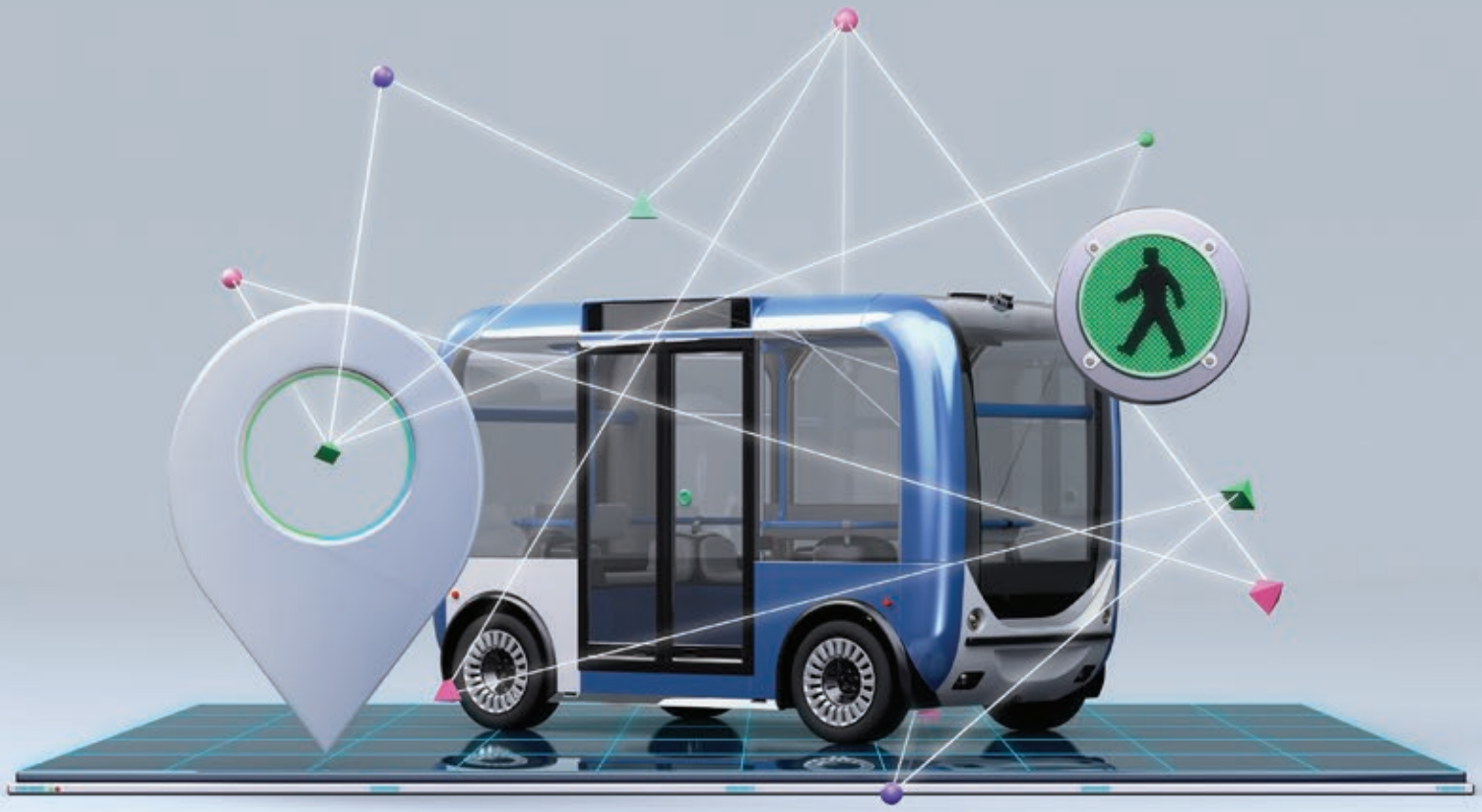

*Members of Edith Cowan University team with Professor Cobie Rudd, Deputy Vice-Chancellor Strategic Partnerships, holding the award. Photo: Bradley Cummings.*

THE UNIVERSITY OF MELBOURNE

# THE FUTURE OF TRANSPORT:

# AUSTRALIAN INTEGRATED MULTIMODAL ECOSYSTEM (AIMES)

## Intelligent transport technology for smart cities



AIMES is a world-first living laboratory based on the streets of Melbourne. AIMES was established to test highly integrated transport technology with a goal to deliver safer, cleaner and more sustainable urban transport outcomes. The University of Melbourne is taking a leading role in testing and implementation, working closely with government and leading local and international industry sectors.

FIND OUT MORE **eng.unimelb.edu.au/industry/aimes**

CRICOS: 00116K

*Brian Walker recently won Japan's Blue Planet Prize for his pioneering work in ecosystem and societal resilience.*

# Meet a Fellow: **Brian Walker**

Anthea Batsakis

**What do the French Revolution and dryland salinity have in common? For Dr Brian Walker, it's a matter of resilience.**

Dr Walker is a global pioneer of resilience science, the ability of a system to absorb disturbances and keep functioning. But systems – both environmental and social – can only endure so much before they break down.

For instance, salt brought to the surface by a rising water table can build up until particles of clay in the soil disperse and rain can no longer soak in.

"And that's the end of agriculture there, unless some massive interventions are made, but it won't come back on its own," said Dr Walker, who is a Fellow of the Australian Academy of Technology and Engineering.

When the people of 18th century France could no longer endure hardship from decades of poor harvests, heavy taxes and a widening disparity between the rich and poor, it led to revolution – an example of a society that reached massive inequality leading to transformational change.

"In systems of people and nature there's this tight connection back and forth between the social system and the ecological system," Dr Walker said.

"You cannot really look at either one alone when you're trying to think of global problems because it affects both in a linked social-ecological system."

Dr Walker, who headed CSIRO's Division of Wildlife and Ecology for 15 years, has been at the forefront of resilience science, blending social and ecological systems.

His world-leading expertise on the subject was forged from the ideas of Canadian ecologist Professor Buzz Holling, the "godfather" of resilience science, in the early 1970s.

"I'd been doing some research and bumped into this problem of not being able to fathom why things changed so suddenly and irreversibly. Then I came across the ideas about non-linear change put forward by Professor Holling."

In 1999, he helped launch the Resilience Alliance, an international, multidisciplinary research organisation exploring the dynamics of social-ecological systems.

And he has authored a cache of scientific publications, edited and co-edited 10 books and written three books on resilience – one of which, *Finding Resilience*, will be released in March.

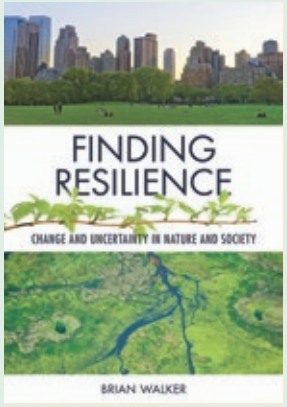
"I still hadn't got across to people who aren't scientists, and so I had this archetypal reader in mind, which is a member of a book club. My wife belongs to a book club, and I keep imagining them; would they be interested in this?"

He said one of his hopes is that the word "resilience" doesn't become diminished by overuse and misuse.

"Resilience is the capacity to keep functioning in the same kind of way and absorbing all sorts of changes, both externally and internally driven. It's important to recognise that resilience is neither good nor bad. Salinised landscapes are very resilient, but bad. Evil dictatorships are very resilient, but they're not good either."

One of the proudest aspects of his career, he said, is the people he has influenced and worked with.

"If I look at all the graduate and postgraduate students and scientists that I've worked with and helped, that has always given me great satisfaction."




Dr Brian Walker's latest book on resilience, *Finding Resilience*, is an analysis of how ecosystems, societies and people cope with disturbance and adversity, written in plain English. The book is international in scope, with fascinating stories of resilience from around the world, and provides understanding necessary to navigate dangerous global trends.

*Finding Resilience* is available from CSIRO Publishing.

# ACADEMY PEOPLE

## Judy Raper wins Ada Lovelace Medal

**Professor Judy Raper has been named Australia's top female engineer, winning the prestigious Ada Lovelace Medal for Outstanding Woman Engineer – the third Fellow in consecutive years to do so.**

With expertise in air and water pollution, and as a former senior official in the US National Science Foundation, the University of Wollongong chemical engineer has championed engineering and diversity throughout her career.

"I am thrilled to be recognised by my peers with this award, especially as it is named for Ada Lovelace who was a true innovator and a truly inspirational woman," Professor Raper said.

"In terms of diversity, engineering has come a long way since I began my career in the 1980s, but we still have a long way to go.

"We have gone from six per cent of engineers being women then, to around 18 or 20 per cent now so there is still a lot of room for improvement, and we in the university sector have a big role to play in keeping up the momentum for change.

"For engineering, achieving greater diversity in all its forms is important not just because it is the right thing to do, but also because it will lead to greater innovation and to better solutions to the complex problems that the world faces."

Professor Raper was Deputy Vice-Chancellor (Research) at the University of Wollongong 2008-2018, and prior to that, had a storied career in education and management at the universities of Newcastle, Sydney and UNSW, as well as the Missouri University of Science and Technology.

She is now in London as Founding Lead, PLuS Engineering at The PLuS Alliance.

The Ada Lovelace Medal is a national award given annually by the University of NSW's Faculty of Engineering. It is named for Augusta Ada Byron, later Countess Ada Lovelace, an English mathematician who worked on Charles Babbage's revolutionary mechanical general-purpose computer, the Analytical Engine.

*Photo: Jacqui Manning, UNSW.*

## Tanya Monro is Australia's first female Chief Defence Scientist

**Academy Fellow Professor Tanya Monro has been appointed Chief Defence Scientist, the first woman to hold the role.**

Professor Monro is currently Deputy Vice-Chancellor Research and Innovation and an ARC Georgina Sweet Laureate Fellow at the University of South Australia.

She will take up her new position in March from Academy Fellow Dr Alex Zelinsky.

Minister for Defence Christopher Pyne said Professor Monro's research has had significant impact in areas spanning manufacturing, telecommunications, defence and health.

"Professor Monro will bring extensive experience working at senior levels in both industry and educational institutions to this integral and nationally significant role," Minister Pyne said.

"In a complex and changing environment she will lead and develop the defence science organisation, while collaborating with research agencies, industry and international partners."

She was the inaugural Director of the Institute for Photonics and Advanced Sensing from 2008 to 2014, and was also the inaugural Director for the ARC Centre of Excellence for Nanoscale BioPhotonics at the University of Adelaide.

Her research is in the field of photonics, with a focus on sensing, lasers and new classes of optical fibres.

## Gordon Wallace leads new 3D bioprinting initiative

**Australia's newest 3D printing initiative, TRICEP, launched last November with Dr Gordon Wallace at the helm as Director.**

TRICEP – Translational Research Initiative for Cellular Engineering and Printing – offers SMEs, research institutions and industry the opportunity to partner with leading researchers to develop and commercialise 3D bioprinting technologies for use in the medical industry to combat significant clinical challenges.

Director, Professor Gordon Wallace, said TRICEP is positioned to unlock breakthroughs in the treatment of significant medical conditions.

"The TRICEP team has a strong track record of identifying and customising materials and fabrication protocols to deliver 3D bioprinting solutions for real world clinical problems.

"This includes the development of the Biopen for cartilage regeneration, the iFix Pen to treat corneal ulcerations, and 3D Alek to create printed ears," Professor Wallace said.

"Our in-house ability to develop both customised hardware and bio-inks, as well as our expansive clinical network, makes us uniquely placed to help companies create a complete end product that is tailor-made to combat a specific medical challenge.

"TRICEP can help Australian SMEs to capitalise on these commercial opportunities to gain an advantage in this growing field with accelerated knowledge, product development and skills base."

TRICEP is an initiative of the University of Wollongong, and draws on expertise and facilities available within the ARC Centre of Excellence for Electromaterials Science and the Australian National Fabrication Facility Materials Node.

# Doug Macfarlane wins almost $1m in funding and prizes

Photo: Monash University

A large amount of funding announced by the Australian Government's energy agency has been awarded to Professor Doug MacFarlane from the Monash School of Chemistry.

The Government's funding is aimed at driving innovation in exporting renewable hydrogen to international partners.

Professor MacFarlane received more than $915,000, which will support a project on ammonia production from renewables. The ammonia is produced at ambient temperature and pressure using just water and nitrogen sourced from the air we breathe.

"Ammonia is emerging as an ideal renewable energy storage vehicle that is suitable for large scale export," said Professor MacFarlane.

"The funding support will allow us to assemble a world-class team to bring this important technology to the next stage of commercial readiness.

"Australia has a pre-eminent position in the world in regard to the potential for large-scale generation of renewables and this technology will provide a ready means of transportation of this hydrogen energy to important markets in Asia."

Hydrogen – or hydrogen carriers like ammonia – are potentially ways for Australia to export renewable energy. Electrical energy can easily be converted into hydrogen via electrolysis.

Professor Macfarlane was also recently awarded the $50,000 Victoria Prize for Physical Sciences for his ground-breaking work in renewable energy conversion that uses a new class of materials known as "ionic fluids".

His discoveries are poised to have a significant impact on renewable energy opportunities for Australia, both in the local energy market and for export.

Minister for Innovation and the Digital Economy, Philip Dalidakis, said the Victoria Fellowships and Victoria Prize were key as they provided our leading scientists and innovators with the support they needed to develop life-changing treatments here in Victoria.



# Global views
# Local solutions
# Planetary impact

**Climate change, dwindling resources, complex infrastructure and humanity's impacts on the environment pose challenges unlike any we've witnessed before. These challenges are motivating government, industry and research institutions to collaboratively develop information streams for detecting and measuring environmental changes on local and global scales.**

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CREATE CHANGE

An example of this collaboration at The University of Queensland is the Remote Sensing Research Centre (RSRC). The RSRC uses remotely sensed data, field-work and spatial models to measure, map and monitor biophysical properties in terrestrial, atmospheric and aquatic environments, to better understand and manage the earth's environment and resources.

Whether responding to the crisis facing coral reefs, or assisting government agencies to develop analytics on key environmental indicators, we understand that the power of research is multiplied by working together. Work with us to develop solutions that meet your needs. You ask the questions. We conduct the research and together, develop lasting solutions.

Work with us. Study with us. Collaborate with us.

Visit **www.rsrc.org.au/work-with-us**

# Ten Fellows honoured on Australia Day

Ten Academy Fellows are among 1127 outstanding and inspirational Australia to have been named in the Australia Day honours.

Overall, women received 37.4 per cent of awards – the highest percentage ever. Female recipients in the Education sector received three honours for every two to men.

Academy President, Professor Hugh Bradlow, said: "These awards reflect tremendous careers, dedicated to excellence in various fields of science, technology and engineering.

"I know the entire Fellowship will join me in congratulating the 10 Fellows who have been honoured."

***Read the citations at applied.org.au/honours.***

### Companion (AC) in Order of Australia

- Dr Elizabeth Dennis AC FTSE (ACT)
- Professor Peter Hoj AC FTSE (QLD)
- Emeritus Professor Richard Larkins AC FTSE (VIC)

### Officer (AO) in Order of Australia

- Professor Barney Glover AO FTSE (NSW)
- Professor Ross Large AO FTSE (TAS)

### Member (AM) in Order of Australia

- Dr James Harvey AM FTSE (NSW)
- Dr Carrie Hillyard AM FTSE (QLD)
- Dr Chris Pigram AM FTSE (ACT)
- Professor Judy Raper AM FTSE (NSW)
- Professor Zhiguo Yuan AM FTSE (QLD)

# John Church wins Frontier Knowledge Award in Climate Change

**The world's top sea level expert Professor John Church is the first Australian awarded the BBVA Foundation Frontiers Knowledge Award in Climate Change.**

Professor Church, from the Climate Change Research Centre at UNSW, was recognised for linking satellite observations with in-situ measurements and numerical modelling. He identified the human impact on sea level changes and discovered that the rate of increase is accelerating over time.

Forecasts developed from their research warn that without drastic greenhouse gas reductions, sea levels could rise more than one metre by the end of this century, threatening homes of 100 million people living on the coast.

Professor Church said this award is a recognition of the importance of the science.

"It also acknowledges the progress that has been made over recent decades and the role that the three of us have made in contributing to the science," he said.

Professor Church shares the prize and €400,000 prize money with French space geodesist Anny Cazenave and British climate scientist Professor Johnathan Gregory.

Since the early 1990s, sea levels have been climbing at a rate of three millimetres each year, giving a mean increase of eight centimetres over the past 25 years. The researchers' work identifies that warmer oceans and melting ice sheets in Greenland and Antarctica, caused by human footprint, is causing the pace of sea-level increases to accelerate.

*John Church on a research voyage to Antarctica.*

"Without significant, urgent and sustained greenhouse gas mitigation we will cross the threshold leading to many metres of sea level rise over coming centuries. In my opinion, we are uncomfortably close to these thresholds," Professor Church said.

"The mitigation needs to be substantially more than Australia's, and the worlds, current commitments. We need to recognise the need to act, develop short and long-term goals and plans to achieve these mitigation goals.

"We have the technology and knowledge – what we lack is the will to make it happen," he said.

Now in its 11th year, the international award recognises significant contributions in the areas of scientific research and cultural creation. Professor Church's award will be presented at a ceremony in Madrid in June. Prize recipients are selected from a large global cohort of applicants from leading institutions.

Australian Government
Department of Industry, Innovation and Science

# Business

## Cooperative Research Centres Projects (CRC-P) grant applications open in the first half of 2019.

*Up to $3 million in matched funding is available for investing in R&D for new technologies, products and services. If you are working with at least one small or medium-sized enterprise and one research organisation, you could be eligible.*

For more information visit **business.gov.au/CRC-P** or call **13 28 46**.

This assistance is offered as a part of the
Australian Government's Cooperative Research Centres Program.

# International award for distinguished optics pioneer

**Distinguished Professor Min Gu has been awarded a top international prize named in honour of the Nobel-winning inventor of holography, Dennis Gabor.**

The International Society for Optics and Photonics (SPIE) has announced Distinguished Professor Gu as the 2019 recipient of the Dennis Gabor Award in Diffractive Optics.

Professor Gu, who is the Associate Deputy Vice-Chancellor for Research Innovation and Entrepreneurship and director of the Laboratory of Artificial-Intelligence Nanophotonics at RMIT University, said he was honoured to receive the Dennis Gabor Award.

## At the frontier of research

"Optics is a tremendously exciting field and nanophonotics is at the frontier of research in so many ways," he said.

"Our work is driven by a desire to deliver real solutions to the real issues faced by industry and the community in conjunction with artificial intelligence.

"We seek industry input from the very start, to deeply understand the challenges and develop tailored technological solutions that can have a genuine impact, so it's wonderful to receive this international recognition for our research."

*Distinguished Professor Min Gu. Photo: RMIT University*

He gained a PhD degree in optics from the Chinese Academy of Sciences, before moving to Australia in 1988.

Internationally renowned for his expertise in 3D optical imaging theory, Professor Gu's discoveries are helping drive the development of solutions to some of the biggest challenges in renewable energy, information technology and big data storage.

## Major advancements

His research has led to major advances in how data is stored, displayed and transmitted. This work has also radically decreased the amount of energy needed when it comes to using data, potentially unlocking major environmental benefits.

The Dennis Gabor Award is presented annually by SPIE, in recognition of outstanding accomplishments in diffractive wave front technologies, especially those that further the development of holography and metrology applications.

The award will be presented to Professor Gu at a ceremony in August this year in San Diego, California.

# Marlene Kanga's sight set on global change

**Dr Marlene Kanga spoke at the opening of the World Science Literacy Forum in Beijing in September 2018, the only woman to speak on the first day, in her role as President of the World Federation of Engineering Organisations (WFEO).**

The theme for the Conference was Science Literacy for a Shared and Better Future.

"Science is at the heart of all new technologies that have transformed our world. It is important for the community to understand basic scientific ideas and the impact that science has on our lives," Dr Kanga said.

"Engineers are particularly important in encouraging science literacy. We are the problem solvers and implement solutions based on science."

The Conference also discussed the important role of an international effort in public science literacy in achieving the UN Sustainable Development Goals.

Implementing the UN Sustainable Development Goals is a key objective of the WFEO, she said.

*Dr Marlene Kanga at the opening of the Global Engineering Congress 2018, London.*

"Every one of these goals requires the application of scientific principles and engineering solutions.

"These goals require engineers to take an integrated approach for future development, combining progress in economic prosperity, social inclusion and environmental sustainability."

In October 2018, Dr Kanga gave the keynote at the Global Engineering Congress in London, celebrating WFEO's 50th anniversary.

The sold-out event ran the slogan "do engineering differently", encouraging engineers to realise that they have the capacity and skills to make changes the world urgently needs for a better sustainable world.

It was the first time engineers came together to discuss sustainable development, and was congratulated by UN Secretary General, Antonio Gutterres, who is an electrical engineer.

"The messaging of the power of engineering needs to be part of the community's understanding of science and the impact it has on their lives," Dr Kanga said.

"Such an understanding may also influence policy in Australia for sustainable development to address critical issues: extreme heat and drought and other impacts of climate change, water, energy and resource management."

# From an Indian village to a global authority on nanotech

# ACADEMY PEOPLE

> If it weren't for the support from my parents and two influential high school teachers, I would be ploughing the fields in India. I feel fortunate that I have had so many opportunities in my life, with so many people supporting me.

Professor Chennupati Jagadish forged his career from a small Indian village, studying by the dim light of a kerosene lamp. The global authority on nanotechnology said that without the enduring support from his parents and teachers, he would today be ploughing fields in India, rather than pioneering next-generation optical devices in Australia.

In his gratitude, and to "give something back to the next generation", Professor Jagadish and his wife Vidya created the Endowment Fund, which facilitates four 10-week intensive internships at the Australian National University for students from the developing world.

Professor Jagadish is the Head of the Semiconductor Optoelectronics and Nanotechnology Group of the Australian National University and the Convenor of the Australian Nanotechnology Network.

Here he discusses his upbringing, the future of nanotechnology and the Endowment Fund.

## How do you see developments in optical devices being used in, let's say, 20 years?

Nanoscience and nanotechnology is an exciting area to work in, both from a fundamental science point of view, as well as in applications. Opportunities and applications are limitless, allowing us to discover new phenomena. And we're already seeing impact in electronics, computers, sensors and more.

At the nanoscale, the properties of materials change due to their large surface area to volume ratio, and quantum effects. This creates opportunities for developing new classes of devices like sensors, lasers, solar cells, photodetectors and new applications in neural engineering.

In the next 20 years we'll see nanophotonic devices with applications in virtual reality, augmented reality, autonomous vehicles, green internet, IoT, Li-Fi (technology that uses light to transmit data), quantum and secure communication systems.

## How did your upbringing inspire you to create the Endowment Fund?

I come from a farming family in India and started my life in a small village, studying by the light of a kerosene lamp until I finished Year 7. In Year 8 I moved in with my high school Maths teacher until I started living on my own in Year 11.

If it weren't for the support from my parents and two influential high school teachers, I would be ploughing the fields in India. I feel fortunate that I have had so many opportunities in my life, with so many people supporting me.

In my gratitude to all those who have helped, I thought it was time for me to giving something back to the next generation and to create opportunities for them.

Our endowment began by providing four internships to students from the developing world to spend three months at the ANU Research School of Physics and Engineering. Based on the success of this program, ANU Colleges of Science and Research Schools have decided to offer additional 35 scholarships from India to carry out their internships at any Research School within the Colleges of Sciences.

My wife Vidya and I are delighted that the Endowment has opened the doors for so many young people. Our intention was to open doors for students from the developing world (though to date only students from India have applied for the scholarships), while ANU Colleges of Science Future Research Talents Program specifically targets students from India.

## Do you have a particular stand-out story about one of the recipients you can share?

The Endowment offered a fellowship to a young scientist from a small university in India and local media covered his visit to ANU. His institution made his job permanent and increased his salary by 50 per cent. Based on his work at ANU, he has published a research paper. It is satisfying to see that a three month visit to ANU supported by the Endowment enabled the career of a young scientist.

## What has been the proudest moment of your career?

My pride and joy are my students, post-docs and young academics who have worked in my group at ANU. Seeing them achieve their dreams and goals is the most enjoyable part of my life.

I am humbled and grateful that I was honoured with the appointment as an AC, Companion of Australia, by the Governor General during 2016 Australia Day honours. Winning the UNESCO medal is another international honour for which I am most grateful.

Both were completely unexpected, making them extra special. I am grateful to India for providing me the education and nurturing me from childhood to adulthood, and I'm grateful to Australia for giving me the opportunities to flourish and prove myself as a scientist and an academic.

*Photo: Stuart Hay via ANU*

# Kadambot Siddique recognised in Africa and India

**Professor Kadambot Siddique, director of the University of Western Australia's Institute of Agriculture, can add two new accolades to his CV.**

He became the first Australian to be elected fellow of the African Academy of Sciences (AAS), and recently received an Excellence Award for Community Service from the World Malayalee Council.

The Excellence Award reflected the role he played in the Kerala Government initiative, "Rebuild Kerala" – in particular in the agriculture sector, following recent flooding in the southern Indian state. It also honoured his broader achievements in science.

It was presented by the Chief Minister of Kerala, Pinarayi Vijayan.

The AAS is the only continental academy in Africa and provides advisory and think-tank functions for shaping Africa's science, technology and innovation strategies and policies.

Professor Siddique who is a member of the Australia-Africa University Network steering group said he is humbled and honoured to be recognised by such a prestigious Academy.

"I look forward to joining senior leaders in the Academy and contributing to the African community through science and technology," Professor Siddique said.

Professor Felix Dakora, president of AAS, said his research on the adaptation, physiology, genetics and agronomy of crops has boosted cereal and grain legume production in dryland environments.

"Professor Siddique's major contribution to dryland agriculture has seen crop yield improvements in wheat and grain legumes, and the release of several new grain legume cultivars," Dr Dakora said.

In 2016, the United Nations Food and Agricultural Organization appointed Professor Siddique the Special Ambassador for the International Year of Pulses. He received the 2014 Western Australian of the Year Award, Member of the Order of Australia and Urrbrae Memorial Award. He is also recipient of the prestigious Dunhuang Award from China.

# NEXT GOVERNOR-GENERAL IS A STELR SUPPORTER

**The next Governor-General to Australia, General David Hurley, was elected an Honorary Fellow of the Academy in 2016.**

He has been an enthusiastic supporter of the Academy's STELR program, presenting a set of renewable energy equipment to the 600th STELR School last year with his wife Linda Hurley.

"It is the highest honour to be asked to be the Governor-General and I am humbled by the offer of this appointment," General Hurley said.

"Linda and I look forward to continuing to serve the people of New South Wales over the first half of next year, with my role as Governor-General due to begin in late June 2019."

*General David Hurley at Wadalba Community School celebrating the 600th STELR School milestone.*

From his weekly boxing workouts with Indigenous children as part of the Tribal Warriors program to his frequent regional trips, Governor Hurley is known for being generous and approachable to old and young alike.

Prior to his appointment as Governor of New South Wales, General Hurley served in the Australian Army for 42 years, including as the Chief of the Defence Force from 2011 to 2014.

He was appointed a Companion of the Order of Australia in 2010 for eminent service to the Australian Defence Force and was awarded the Distinguished Service Cross for his leadership during Operation SOLACE in Somalia in 1993.

General Hurley will be sworn in on 28 June 2019, to allow for the fulfilment of his duties as Governor of New South Wales.

*Photo: University of NSW.*

# Vale Sir Rupert Myers KBE AO FTSE FAA

**The Academy lost a committed and passionate supporter with the death of former President, Sir Rupert Myers KBE AO FTSE FAA, on 21 February, his 98th birthday.**

Sir Rupert was elected a Fellow in 1979 and served as President from 1989 to 1994, having earlier been honorary editor of Focus magazine and Vice-President (1985-88).

Academy President, Professor Hugh Bradlow FTSE, expressed his condolences to Sir Rupert's wife, Nancy, and their family.

"I first met Sir Rupert in the late 1980s. I found him to be most personable, very thorough and totally objective. When I became a Fellow of the Academy in 1991, I found his leadership progressive and inspirational," Professor Bradlow said.

In their final interaction, Sir Rupert had expressed warm support for Professor Bradlow's initiatives to strengthen the Academy's impact.

The Academy's sixth President, Dr John Zillman AO FTSE, said: "Sir Rupert was a marvellous champion of the Academy and one of the most meticulous, careful and thoughtful people I ever worked with.

"I had the privilege of serving as Honorary Secretary of the Academy when he was President and our almost daily early morning (ie before 7am) exchange of faxes of draft letters and documents became an integral part of ATSE modus operandi in those years.

"He never settled for anything less than the best possible but always made sure it was achieved with calm consideration, kindness and sensitivity."

Former President and now Chief Scientist of Australia, Dr Alan Finkel AO FTSE, expressed his sadness, noting that Sir Rupert had reached out several times to him and provided much appreciated encouragement and support for the STELR schools education program in its early years.

Sir Rupert had a storied career, including being appointed the Foundation Professor of Metallurgy at the University of New South Wales in 1952, where he subsequently served as Pro Vice-Chancellor (1961-69) and was appointed its second Vice-Chancellor (1969-81).

During his tenure as Vice-Chancellor, the university saw massive growth to become Australia's largest in 1976 with more than 18,000 students. His challenge included leading the university through a time of student unrest and political activism.

Among his honours, Sir Rupert was appointed a Knight Commander of the Order of the British Empire (KBE) in 1981. He was also appointed an Officer of the Order of Australia in the 1995 Australia Day Honours for his efforts in promoting innovation and commerce in the fields of science, technology and engineering.

His career had, however, modest beginnings. Sir Rupert began his education at Lloyd Street Public School in the Melbourne suburb of East Malvern, before attending Melbourne High.

At the University of Melbourne, he studied metallurgy, graduating with a BSc in 1942, an MSc in 1943 and a PhD in 1948 – the first PhD in science to be awarded in Australia. Previously, doctorates were gained at British universities.

He held a large number of public appointments, including Chair of the Australia School of Nuclear Science and Technology, Chair of the NSW Coastal Council, Council Member of the Standards Association of Australia and Member of the Sydney Opera House Trust.

Sir Rupert remained active within the Academy's NSW Division until very recently, when health took its toll, but his intellect and fun-loving character stayed with him to the last – even while undergoing dialysis.

He held great affection for his role with the Academy, writing in 2005: "Looking back on my time as President I recall several matters of some significance.

"One was the official opening of our newly refurbished headquarters, Ian McLennan House, by Mr Bill Hayden. It was his first official function as the new Governor-General and mine as President.

"Another was the considerable task of implementing the wide-ranging recommendations of Sir Frank Espie's committee which charted a new course for the Academy. I believe that these changes dramatically enhanced the organisation and operations of the Academy.

"Perhaps the most far-reaching and yet not widely known event was the discussions which went on quietly but intensively between the Academy and the Institution of Engineers Australia about their respective roles. One outcome was the addition of 'Engineering' to the Academy's name."

Sir Rupert concluded his retrospective with: "As the Academy celebrates its thirtieth anniversary it is timely to recall the initiative and foresight the Founding Fellows demonstrated and to thank them for setting it on a successful course.

"For my part I express my immense admiration of the many very busy Fellows who freely give so much time to advancing its work."

The Academy would now, in turn, like to pay tribute to Sir Rupert for his tireless efforts and dedication.

***Sir Rupert is survived by his second wife, Nancy. His first wife, Io, died in 2001. They had three daughters and a son.***

# IN MEMORIAM

## A leader in power and water

**Mr Murray Jackson FTSE was an outstanding leader in the Australian power and water industries and a highly respected and much valued contributor to the Academy.**

His contributions in the fields of innovative engineering and management of government business enterprises and the interface between technology and society were significant.

As Commissioner of the Snowy Mountains Hydro-electric Authority, he is credited with the restructure of the Authority from a government corporation to a commercial corporation supplying hydro power to the very competitive National Electricity Market, and water to irrigators in the Murray-Darling Basin.

He was also associated with the promotion of the strong link between the Snowy Mountain Scheme and the Australian people.

Mr Jackson began his career as a professional engineer with the SEC in Victoria before moving to the Electricity Commission of NSW.

He became Manager of the Bayswater power station in NSW in 1983, before stepping up to become the Director of Power Production with Pacific Power in Sydney.

In 1993 he became Commissioner of the Snowy Mountains Hydro-electric Authority. While in that role he also completed an MBA with the University of New England.

He served as Chief Executive Officer of Genesis Energy (also known as Genesis Power) from April 1999 to August 2008.

Under his stewardship, Genesis became the largest energy retailer and third largest energy generator in the NZ market. He led the company through a transition from a single coal fire power station to becoming a diverse gas and electricity energy provider with six hydro power stations, a thermal power station, a wind farm and two co-generation plants.

Throughout this time he continued to invest in people and provide new opportunities by launching the Genesis Energy National Apprentice Scheme, now in its fifth year.

He moved on to become Managing Director of Westernport Region Water Corporation, a role he held until 2015.

Mr Jackson was involved in the development of key industry managers through the Mt Eliza Business School and was its Guarantor Member.

He was elected a Fellow of the Academy in 1998 and was a member of the Energy and Water forum.

Mr Jackson died on 9 September 2018, aged 75.

## Oceanographer rose to global prominence

**Dr Angus McEwan FTSE was Chief of the CSIRO Division of Oceanography from 1981 to 1995 and served as the sixth President of the Australian Meteorological and Oceanographic Society (AMOS) from 1998-99.**

He was elected a Fellow of the Australian Academy of Science in 1982 and an Honorary Fellow of the Australian Academy of Technology and Engineering in 1994.

Born in Scotland, he immigrated to Melbourne with his mother and brothers in 1947, gaining a diploma in engineering at Caulfield Technical School. After his National Service, he got a job at the Aeronautical Research Laboratories in Melbourne.

A cadetship enabled him to extend his studies at the University of Melbourne where he graduated with a BEMech (Hons) (1960). He was then awarded a Vacuum Oil Scholarship to complete his masters, MEngSc (1962). He again went to work for the Aeronautical Research Laboratories on heat transfer problems.

Thanks to a CSIRO Fellowship and later a Public Service Board Scholarship, he attended Cambridge, graduating with a PhD in 1966 for his work on the distortion changes in turbulence as flow goes over a step.

Dr McEwan then returned to Australia and the Aeronautical Research Laboratories to work on hypersonic re-entry problems (1966-69). He then joined the CSIRO Division of Meteorological Physics (later Atmospheric Research) supported by a Queen Elizabeth II Fellowship (1969-71).

In 1971, Dr McEwan was appointed a senior research scientist with the task of creating a geophysical fluid dynamics laboratory within this Division. During this period, in 1975, he was invited as a Rossby Fellow to the Woods Hole Oceanographic Institution, USA.

In 1981 Dr McEwan was appointed chief of the new CSIRO Division of Oceanography in Hobart. He then served as senior science advisor to the Commonwealth Bureau of Meteorology. It was during this time that Dr McEwan served as President of AMOS.

In addition to his research, and several roles in the advancement of Australian marine science, Dr McEwan was active in the UNESCO Intergovernmental Oceanographic Commission, culminating in becoming chair of the Oceanographic Data Exchange Policy group (2001-02).

Dr McEwan died in Hobart on 5 September 2018, aged 81.

*With thanks to the Australian Meteorological and Oceanographic Society.*

# An outstanding advocate for science

**John Hooke CBE FTSE, businessman, philanthropist and an outstanding advocate for science and nanotechnology has died aged 85. He screened the first television broadcast in Australia and supported physics research at the University of Sydney.**

Mr Hooke graduated from the University of Sydney with a Bachelor of Science majoring in Physics, and then a Bachelor of Engineering (Electrical) with first class honours and the University Medal. His gift to the University in 2011 helped establish the University of Sydney Nano Institute.

He was elected a Fellow of the Academy in 1983.

He recognised the revolutionary potential of nanoscience. Sydney Nano's work includes a project to ease drought by capturing water from the atmosphere, while another involves creating tiny robots that could enter the human body to diagnose and treat disease.

As a young man working for Amalgamated Wireless (Australasia), also known as AWA, Mr Hooke screened from the back of an old Arnott's van the first experimental television broadcast in Australia in 1954.

He joined AWA after university and was involved in the production of the first transistors. He rose through the company to become chairman and chief executive in 1974, succeeding his father, Sir Lionel Hooke. He was on the board of companies including BHP, AMP, National Australia Bank and Channel Ten. He was chairman of Tubemakers of Australia.

Mr Hooke was involved in manufacturing policy issues and was chairman of the Defence Industry Committee. In 1979 he was made CBE for his service to industry.

He believed strongly in the need for the commercialisation of innovative technology and was always ready to encourage and support new Australian technology businesses. He worked with the founders of Appen – now one of Australia's major technology enterprises – and was a foundation investor when the company listed on the ASX in 2015.

In his later years he served as council member and deputy president of the Science Foundation for Physics, as foundation board member of the Brain and Mind Centre, and as board member of the University of Sydney's philanthropic campaign, Inspired.

John Hooke died on 28 October 2018 aged 85.

*With thanks to The Sydney Morning Herald.*

### Earlier tributes

You can read obituaries for many of our deceased Fellows online.

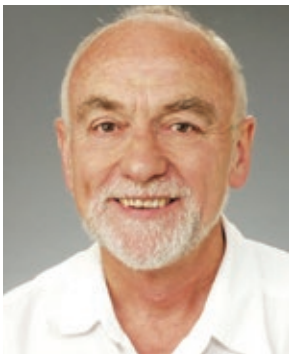
Visit **applied.org.au/obituaries.**

# MOVERS AND SHAKERS

*Kiran Mazumdar-Shaw*

*Peter Høj*

*Lyn Beazley*



*David Rand*

*Tony Barry*

*Marlene Kanga*

*Alan Finkel*

## Kiran Mazumdar-Shaw

The chair and managing director of Biocon Limited, Bangalore, India, Kiran Mazumdar-Shaw, has been elected a Foreign Fellow of the National Academy of Engineering in the USA.

## Peter Høj

University of Queensland Vice-Chancellor Professor Peter Høj AC has been elected to the Fellowship of the National Academy of Inventors in the United States.

## Lyn Beazley

Professor Lyn Beazley has been awarded an Honorary Degree from the Australian National University "for her efforts to encourage every Australian child to learn and love science".

## Andrew Peele

Director of the Australian Synchrotron Professor Andrew Peele is one of two Australians appointed to assist with the development of a $500 million synchrotron facility in Mexico, the first and largest of its kind.

## Michelle Simmons

UNSW Sydney quantum physicist and 2018 Australian of the Year Professor Michelle Simmons has been appointed Honorary Patron of Mateship by the Australian Embassy in the United States

## Marlene Kanga

President of the World Federation of Engineering Organisations, Professor Marlene Kanga, was named the 2018 Professional Engineer of the Year by Engineers Australia.

## Alan Finkel

Chief Scientist of Australia and former Academy President, Dr Alan Finkel, has been awarded the 2018 Peter Nicol Russel Memorial Medal, the most distinguished award granted by Engineers Australia.

## Robert Vertessy

The Murray Darling Basin Authority has appointed Professor Robert Vertessy as Chair of the Advisory Committee on Social, Economic and Environmental Sciences.

## Tony Barry

Aurecon senior consultant Tony Barry has been appointed Vice-President of the International Federation of Consulting Engineers (FIDIC).

## Ian Poiner

Dr Ian Poiner has been appointed Chair of the Great Barrier Reef Marine Park Authority. Dr Poiner has previously chaired the Integrated Marine Observing System, and he was the CEO of the Australian Institute of Marine Science.

## Chennupati Jagadish

Australian National University physicist Professor Chennupati Jagadish has been elected as a Foreign Fellow of the Indian National Academy of Engineering (INAE).

## David Rand

The third edition of the book Fuel Cell Systems Explained was recently published, co-authored by Academy Fellow and former CSIRO Chief Research Scientist Dr David Rand.

*Branka Vucetic*

*Tony Wong*

*Denise Goldsworthy*

*Tony Weiss*

*Thomas Maschmeyer*

*Kathryn Fagg*

*Alan Joyce*

## Tony Wong

Professor Tony Wong received the International Water Association's prestigious Global Water Award, recognising his influential work and research in water sensitive urban design.

## Honorary Bragg Members

The Royal Institution of Australia has inducted three Fellows as Honorary Bragg Members: **Dr Megan Clark, Professor Maree Smith** and **Alan Joyce**.

## Denise Goldsworthy

Managing Director of Alternate Futures, Denise Goldsworthy, has been appointed to one of two vacancies on the Cooperative Research Centres Advisory Committee.

## Kathryn Fagg

Engineer and President of Chief Executive Women, Kathryn Fagg, has been appointed to the CSIRO Board for a five-year term.

## Nigel Lovell

Professor Nigel Lovell is part of a University of NSW team that recently won a US Naval Research grant of almost $500,000 to continue their research into neural interfacing.

## Peter Newman

John Curtin Distinguished Professor Peter Newman, an urban design and transport sustainability expert, has been was named Scientist of the Year at the 2018 Western Australian Premier's Science Awards.

## Hugh Bradlow

The National Academy of Engineering of Korea has announced the appointment of Professor Hugh Bradlow as a Foreign Member.

## NSW Premier's Prizes

**Professor Tony Weiss** and **Professor Branka Vucetic**, both from the University of Sydney, were awarded the NSW Premier's Prizes for Science and Engineering.

## Robin Stanton

Australian National University computer scientist Professor Robin Stanton was inducted into the Pearcey Hall of Fame.

## Chloe Munro

Monash Professorial Fellow and Australian energy expert Chloe Munro was featured on the list of the Australian Financial Review's 100 Women of Influence 2018.

## Eric Wolanski

Coastal oceanographer and ecohydrologist Dr Eric Wolanski recently co-authored an Elsevier book Coasts and Estuaries: The Future.

## Eureka Prizes

**Professor Thomas Maschmeyer** won the Eureka Prize for Leadership in Innovation and Science; **Professor Tony Weiss** won the Eureka Prize for Innovation in Medical Research; and **Professor Andrew Blakers** won the Eureka Prize for Environmental Research. Read more at applied.org.au

## Prime Minister's Prize

**Dr Simon Poole** and **Dr Steven Frisken** were awarded the $250,000 Prime Minister's Prize for Innovation for creating and commercialising optics technology underpinning the global internet.

# WHAT'S ON


*Notes to future women in tech, from the Grace Hopper Celebration 2018, USA.*

## CREATE INNOVATION 2019 ASIA PACIFIC

**1-3 April, Melbourne**

Creative Innovation 2019 Asia Pacific will bring together hundreds of innovators, futurists and leaders from business, government, academia, community, not-for-profits, media and the arts.

With international speakers and master classes, the conference will explain what drives change, the implications for the future and the strategies that must be adopted for success in a rapidly changing future.

## AUSTRALIA NEW ZEALAND MARINE BIOTECHNOLOGY SOCIETY CONFERENCE

**20-22 May, Sydney**

As one of the strongest voices of advocacy for marine biotechnology, the Australia New Zealand Marine Biotechnology Society connects scientists, technologists, investors, government industry and the community.

Its marine biotechnology conference will present the latest updates in the sector and cover commercialisation of marine bioproducts, environmental remediation and influencing public policy.

## HOPPER DOWN UNDER

**29-31 July, Brisbane**

Modelled on the Grace Hopper Celebration, the world's largest gathering of women technologists, Hopper Down Under will celebrate diversity in technology in the Asia-Pacific.

Created by women technologists, for women technologists, this inaugural conference is produced by AnitaB.org and brings together women technologists at all levels, from undergraduate to CEO, to build relationships, learn, and advance their careers.

Hopper Down Under offers technical and career development sessions, including poster sessions, a Career Fair, a Tech Expo, mentoring circles, and more.

## 22ND INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS (ICCM22)

**11-16 August, Melbourne**

ICCM22 provides a forum for the presentation, exchange and discussion of the latest research into composite materials and their applications around the theme "Advanced Composites: Research and Impact".

The conference aims to explore the future of composite materials, covering aerospace, construction, wind energy, automotive, electronics and more. ICCM22 will include plenary talks, keynote lectures, oral and poster presentations and site visits.

# What we're reading

**BIANCA LE AND DR EMILY FINCH**

**Dr Emily Finch** is a policy analyst at the Academy with a PhD in geology and a love of literature. She coordinates the Academy's Minerals, Infrastructure and Health forums, and is working on a decadal plan to boost the participation of women in STEM.

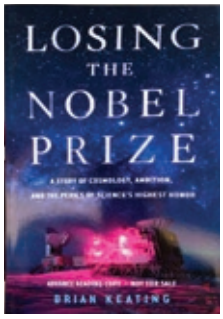
**Bianca Le** is a PhD candidate at Monash University investigating the effects of premature birth on heart development. She was a former policy intern at the Academy and was involved in developing the decadal plan for women in STEM. Read her interview with Professor Lisa Harvey-Smith on page 52.


## *The Best Australian Science Writing 2018*

*The Best Australian Science Writing 2018* showcases insights from some of Australia's brightest minds. The collection of articles, poems and essays describes some of 2018's biggest scientific puzzles and the people working on them: from quantum physics, to solving Australia's cane toad problem – and even how Australian researchers saved the former Chief Scientist's life.

Each contribution in this book is engaging and explains the science in a way anyone can comprehend. And thanks to science writer Michael Lucy, I might even understand the basics of quantum entanglement now!

I particularly enjoyed learning more about Academy Fellow and 2018 Australian of the Year, Michelle Simmons, who wrote the insightful forward. This collection is a must-read for any science enthusiast, regardless of their background. - EF

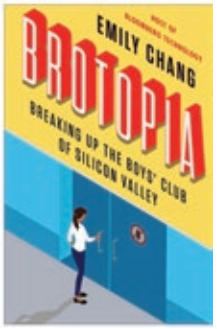



## *Losing the Nobel Prize* by Brian Keating

In 2014, nearly 10 million people around the world tuned in to a media conference broadcast live from Harvard University. A team of astrophysicists announced they had discovered strong evidence of the spark that ignited the Big Bang, which immediately led to rumours of an imminent Nobel Prize. However, the pressure to publish results in time for the prize nominations caused researchers to jump to the wrong conclusions, causing the loss of a once-in-a-lifetime honour and, more importantly, the loss of scientific credibility.

Cosmology Professor Brian Keating gives readers an insider's glimpse into the mechanics of the world's most prestigious accolade, one that was created to advance and reward scientific progress, but instead may actually impede it.

Keating provocatively argues that the flawed meritocracy of the Nobel Prize reflects the toxic and competitive culture of science research itself. Part memoir, part cosmology guide, part cautionary tale, Losing the Nobel Prize reads like fiction and will challenge you to consider how we regard one of the most famous awards in history and its winners. - BL




## *Brotopia: Breaking up the boys' club of Silicon Valley* by Emily Chang

While it is well known the tech world is dominated by men and riddled with systemic gender discrimination, few outsiders are aware of how deep the rabbit hole goes. Journalist Emily Chang unravels the toxic work culture that thrives on rampant sex parties, hot tub client meetings and drug-fuelled networking events that occur inside Silicon Valley.

Brotopia exposes the aggressive, misogynistic, work-at-all-costs environment that has shut women out of the greatest wealth creation in the history of the world. The broader repercussions of this bro culture reach further than the employees themselves. A biased workplace will inevitably lead to the creation of biased technologies that women will interact with daily.

Chang reveals just how hard it is to crack the Silicon ceiling and provides a platform for the many women in Silicon Valley who are now trying to speak up and fight back. This book is well-researched, well-considered and very relevant in our increasingly digitised and socially-conscious society.

Brotopia should be a mandatory read for anyone working in tech; however, many of the themes are also relevant to other male-dominated fields such as advertising and finance. - BL

> *"Brotopia exposes the aggressive, misogynistic, work-at-all-costs environment that has shut women out of the greatest wealth creation in the history of the world."*

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# Qiaoliang Bao

Monash University

Monash University's Materials Science and Engineering Associate Professor Qiaoliang Bao has been recognised as a 2018 Highly Cited researcher for his influence across multiple fields, consistently ranking in the top 1 per cent of citations over a decade.

An ARC Future Fellow, Associate Professor Bao's work explores everything from low-energy electronics and nanomaterials to light detection and bio-chemical sensing. His research has been published in more than 180 peer-reviewed publications, including prestigious journals such as Nature, Nature Photonics, Nature Chemistry, Nature Communications and Advanced Materials.

His most recent paper, published in Nature's October 2018 edition, explores the development of new materials for use in nanophotonics, a rapidly expanding field of optics and materials.

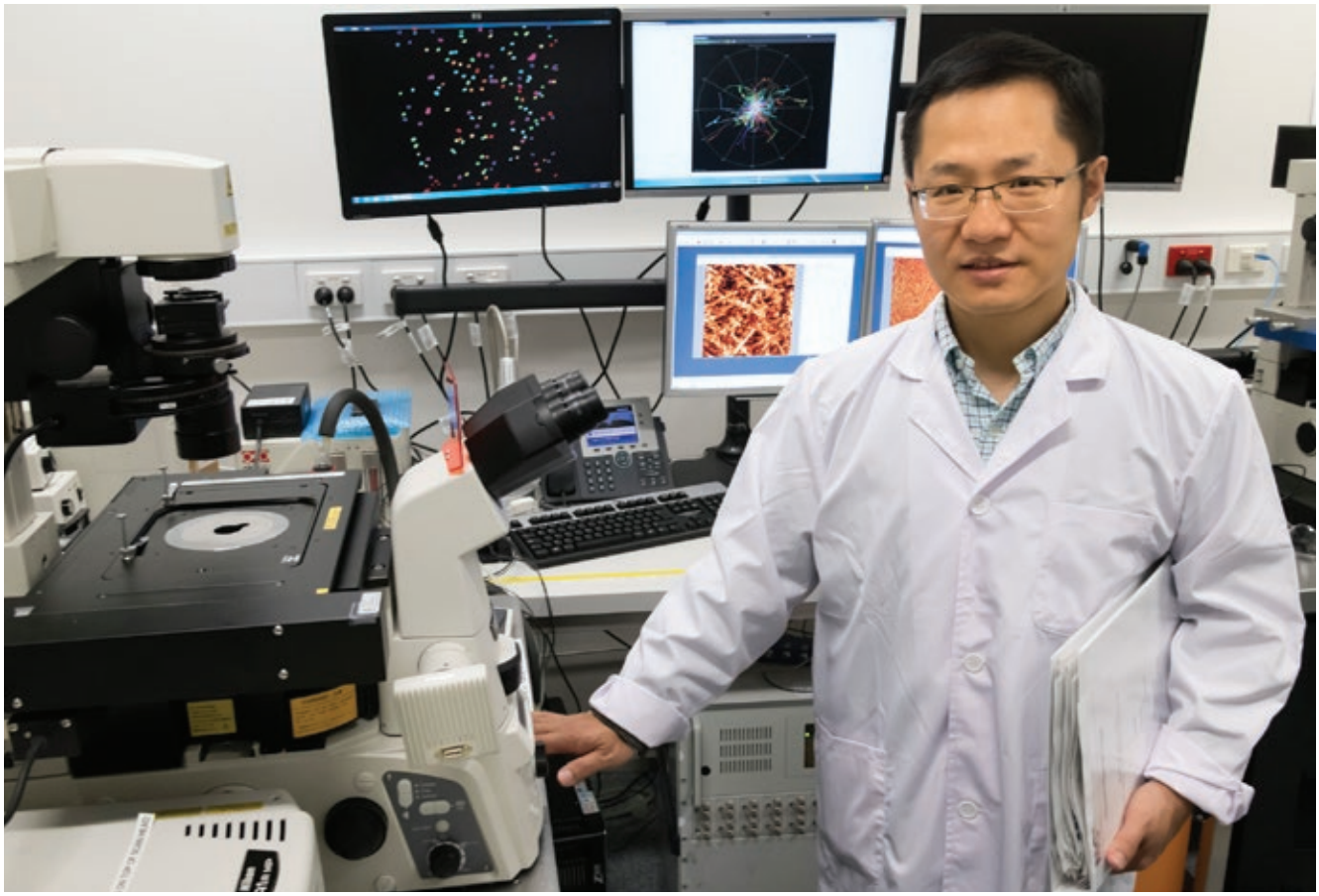
Unlike conventional optics such as lenses and microscopes, where the focus or direction of light is limited to the wavelength, nanophotonics can guide and work with light at the nanoscale.

This means optical devices like lasers and transistors can be miniaturised. This has significant implications for a range of technologies, from speedy, energy-efficient data transmission to ultra-thin solar cells, which not only work better when light is transformed close to the surface, but also cost less to produce.

Associate Professor Bao's Nature paper investigates the usefulness of a naturally occurring nanomaterial called van der Waals crystal to develop new forms of polaritons, a type of quasiparticle, for use in nanophotonics.

"The polaritons open the door to unprecedented nanophotonic device functionalities, such as directional strong light-matter interactions, integrated flat optics and nanoscale directional energy transfer, for applications ranging from bio-sensing to quantum nanophotonics," said Associate Professor Bao.

"The study of polaritons in natural layered materials is a vibrant area of research at the vanguard of physics, materials science and engineering. We believe this work will encourage other researchers to continue to unfold novel effects in other classes of quantum materials."

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