2019

the UPDATE

9th ed.

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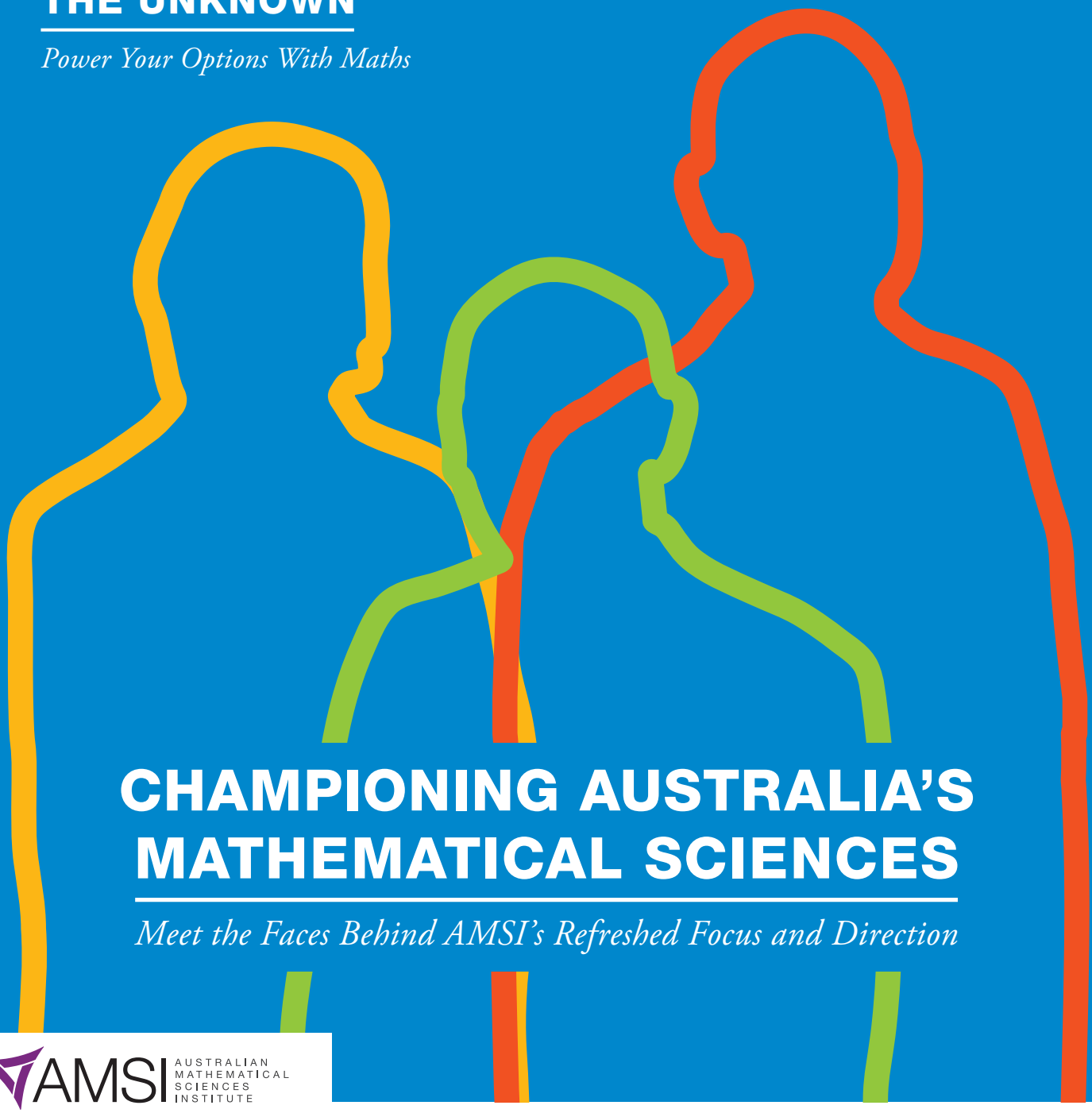
PLANNING FOR THE UNKNOWN

Power Your Options With Maths



CHAMPIONING AUSTRALIA'S MATHEMATICAL SCIENCES

Meet the Faces Behind AMSI's Refreshed Focus and Direction

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

2019 SCIENTIFIC EVENTS

2 - 6 SEP	CHALLENGES IN **HPC**	ANU
9 - 13 SEP	**MATHEMATICS OF PHYSIOLOGICAL RHYTHMS**	DEAKIN
30 SEP - 4 OCT	ANALYSIS ON **MANIFOLDS**	ADELAIDE UNI
7 - 11 OCT	APPLIED MULTIVARIATE **STATISTICS METHODS WORKSHOP**	UON
11 NOV	OPTIMISATION METHODS IN WILDFIRE EMERGENCY MANAGEMENT	RMIT
20 NOV	STOCHASTIC & ALGEBRAIC MODELS FOR GENOME EVOLUTION	UTAS
25 – 29 NOV	**SENSITIVITY ANALYSIS & UNCERTAINTY QUANTIFICATION WORKSHOP**	ANU
2 - 6 DEC	AMSI**BIOINFOSUMMER**19 A SYMPOSIUM IN BIOINFORMATICS	USYD
8 - 12 DEC	DATA SCIENCE **DOWN UNDER**	UON
16 - 17 DEC	**FINITE GEOMETRY:** A WORKSHOP IN HONOUR OF **TIM PENTTILA**	ADELAIDE UNI

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Australian Government Department of Education

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COVER ILLUSTRATION: MICHAEL SHAW

PHOTOGRAPHY: MICHAEL SHAW

Welcome to the ninth issue of the Update. It has been a busy time, with a hectic schedule in AMSI Choose Maths as well as our Research and Higher Education and APR.Intern programs.

There have also been significant publications including the launch of our second Occasional paper on out-of-field teaching and the release of joint research with CSIRO Data 61's Ribit.net, *Advancing Australia's Knowledge Economy*. Both these reports resulted in significant and important national conversations about key challenges facing the mathematical pipeline. You can catch up on these significant reports on pages 7 and 20.

In this issue, I am joined by Deputy Director, Professor Mat Simpson and AMSI Board Chair, Dr Adelle Howse for a special feature on the Institute's new strategic direction and vision. The refreshed strategic plan comes at a pivotal time for AMSI, as we seek to diversify our funding and support our programs in the long-term.

We champion mathematics and statistics from education and research training to research and industry innovation. This reflects the importance and impact of mathematics in our lives and communities, something beautifully illustrated by the latest AMSI Choose Maths Careers campaign. If you want to save the environment, protect health, advance technologies or even help your favourite sporting team win, choose maths.

WE CHAMPION MATHEMATICS AND STATISTICS FROM EDUCATION AND RESEARCH TRAINING TO RESEARCH AND INDUSTRY INNOVATION

You'll also find special coverage of the AMSI Vacation Research Scholarship Program, interviews with superstar maths teacher, Eddie Woo and the University of Sydney's Head of Mathematics and Statistics, Professor Jacqui Ramagge, and a research feature on Statistical Astronomy.

Happy Reading.

Professor Tim Brown

TEACHER, AUTHOR & TV PRESENTER

Catching Up With Eddie Woo

Wootube founder, Choose Maths Award winner and face of *Maths Adds 2019*, Eddie Woo has reinvented himself as Australia's best loved celebrity maths teacher. The author and Logie nominated TV star reveals how life has changed and his advice for Aussie students.

YOU ARE ONE OF AUSTRALIA'S BUSIEST MATHS TEACHERS. WHAT ARE YOU DOING NOW?

As a classroom teacher, I continue to teach mathematics at Cherrybrook Technology High School. As the Leader of Mathematics Growth for the NSW Department of Education, I travel all around the state (and the country!) to run professional learning for teachers and engage the general public with mathematics. I'm also the Education Ambassador for the University of Sydney, which enables me to highlight the role of educators and showcase the quality of the Australian education system as a whole.

YOU ARE ALSO AN AUTHOR AND STAR OF ABC'S TEENAGE BOSS...

I never thought I'd be a published author or TV host, but this just goes to show how much mathematics enables you to reach opportunities you might never have predicted! It's wonderful to have a platform beyond the classroom to show people that mathematics is practical, relevant and beautiful.

CONGRATULATIONS ON YOUR RECOGNITION AS 2018 AUSTRALIAN LOCAL HERO

It's an enormous privilege to be honoured in the Australian of Year Awards, and I'm so thankful for the opportunity I've had to speak across the country about the importance of schools and the wonder of mathematics. I hope it serves as an emblem and reminder of the value of teachers in society – education is an investment in our future!

IT IS AMAZING WHAT YOU HAVE MANAGED TO ACHIEVE, WHAT'S NEXT?

There's lots more work to be done to support mathematics teachers and shift our culture's attitude toward mathematics and education – I'm looking forward to continuing that work in and outside of schools around NSW and beyond.

WHAT WOULD YOUR ADVICE BE TO YOUNG AUSTRALIANS CONSIDERING THEIR FUTURE?

Mathematics opens doors, and it does so in every career path imaginable. Firstly, you may not yet realise that you want to go into a field that contains substantial mathematics – fields like finance or engineering. But secondly, even in jobs that are not explicitly focused on mathematical work, the thinking processes and decision making you will make are always supported by mathematical foundations. The longer you stick with maths, the more these options will be available to you.

Eddie Woo was awarded a Choose Maths Teacher Excellence Award in 2016. His YouTube Videos and other material can be accessed from his website misterwootube.com

IT'S WONDERFUL TO HAVE A PLATFORM BEYOND THE CLASSROOM TO SHOW PEOPLE THAT MATHEMATICS IS PRACTICAL, RELEVANT AND BEAUTIFUL

IMAGE COURTESY OF THE AUSTRALIAN OF THE YEAR AWARDS

PLANNING FOR THE UNKNOWN

Power Your Options With Maths

By Laura Watson

With students expected to have multiple careers, AMSI's 2019 careers campaign is helping inspire futures across Australia.

You'd be hard pressed to find a 16-year-old who can talk with any certainty about what their life will be like in five years, let alone at 32. Yet, generations of teenagers have found themselves trying to answer variations of the same question. What do you want to be? What are you going to do after you leave school?

With young Australians predicted to have multiple career changes, possibly up to 17 in their lifetime, this is no longer a simple conversation starter. In the past, students were encouraged to plan towards their choice of job. Some always knew their destiny and others found it in the musty pages of a thick careers guide. Then after completing the requisite study, the expectation was you'd get busy following the yellow brick road to success. A ladder often climbed within one company.

It is difficult to pick a future from a book when we don't know what jobs will exist in 10, 15 or 20 years. What skills will be needed and where? Automation, advancing technology and big data are among many emerging disruptors set to shake up the job market. While this presents exciting opportunities—data science and robotics for example—how can you plan for the unknown?

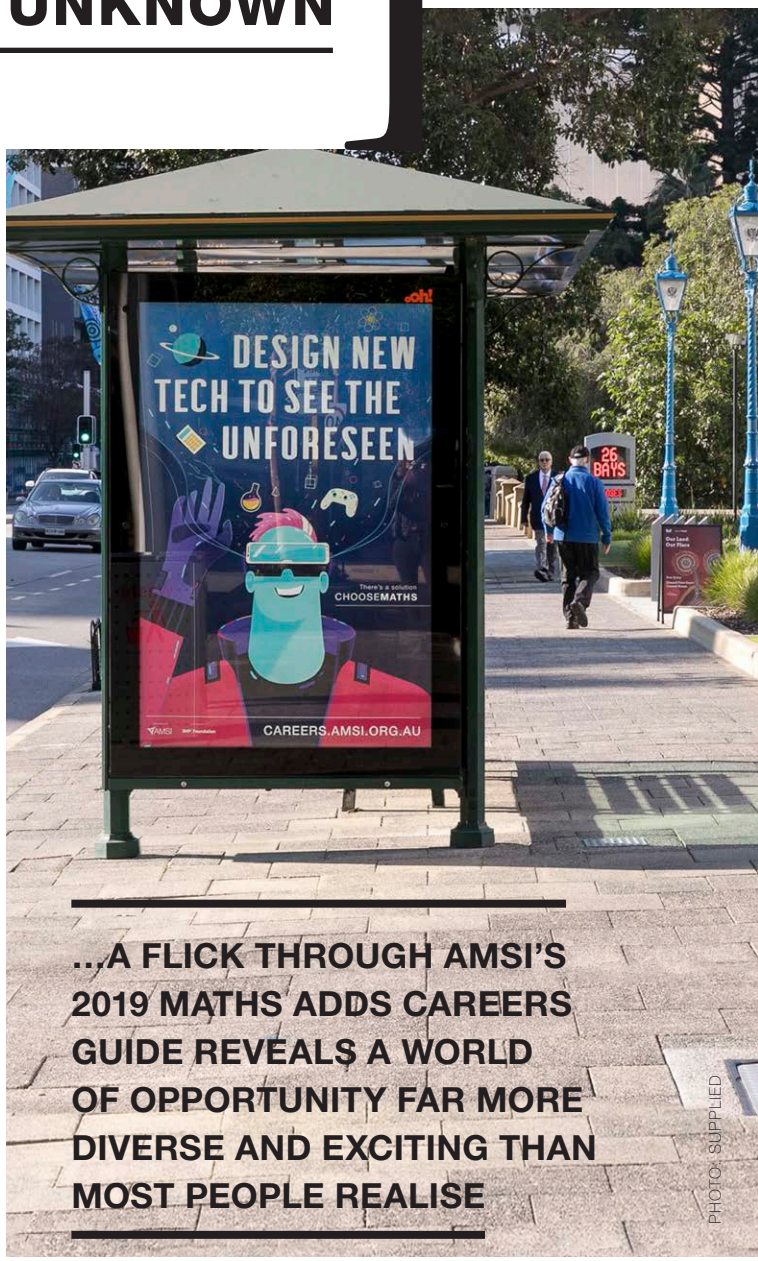
If, as predicted, success for future generations is not in the destination but the journey, how do we support career planning? Importantly, how do young Australians ensure they are future proof?

The best advice for Aussie students is to keep their options open with transferrable skills that provide the agility, knowledge and flexibility for reinvention in response to new opportunities. A message that lies at the heart of the biggest ever AMSI Choose Maths Careers Campaign.

Now rolling out across radio, billboards, social media platforms and in classrooms nationally, the BHP Foundation-funded campaign highlights the demand for maths and statistics in nearly every sector. From sport, science, health, protecting the environment and even getting to space, high-level quantitative and analytical skills are in demand. Truly, these skills can make your career soar.

A quick search on careers.amsi.org.au or a flick through AMSI's 2019 *Maths Adds Careers Guide* reveals a world of opportunity far more diverse and exciting than most people realise.

Perhaps one of the biggest reasons for misconceptions about maths is its absence from most job titles despite being a critical skill. Thanks to the Choose Maths project and resources such as Maths Adds, AMSI is changing how Australia views and values maths and statistics. This is shifting perception of these skills among parents, teachers, students, careers advisors and community leaders.



...A FLICK THROUGH AMSI'S 2019 MATHS ADDS CAREERS GUIDE REVEALS A WORLD OF OPPORTUNITY FAR MORE DIVERSE AND EXCITING THAN MOST PEOPLE REALISE

PHOTO: SUPPLIED

Importantly it is rewriting the script for career planning. The aim of this bold new approach is less about fitting a prescribed mould and more about capacity to thrive in uncertainty and embrace the unexpected. It is about expecting more and being ready for anything.

Our advice for young Australians asked about future career plans is stand like a superhero and answer "I'm going to help shape tomorrow with maths." □

Now in its third year, the AMSI Choose Maths Careers Campaign is funded by the BHP Foundation as part of the Choose Maths project. Discover more about the campaign and download resources at careers.amsi.org.au

PROTECT US FROM GLOBAL WARMING

There's a solution

CHOOSE**MATHS**

DELIVERED BY AMSI

SUPPORTED BY BHP | Foundation

CAREERS.AMSI.ORG.AU

OUT-OF-FIELD TEACHING CRUNCH

Shortfall in Mathematically Trained Teachers Widens

By Melissa Trudinger and Laura Watson

After decades of inaction, out-of-field teaching is a deepening issue across Australian high schools. AMSI has issued a call to action to address the problem.

Australian secondary student numbers are soaring, with over 650,000 extra secondary students expected in schools by 2026. At the same time, universities are struggling to attract mathematics graduates to teaching and little data on mathematics preparation in teaching qualifications is available. The shortage is entrenched and severe—graduate recruitment alone will not be enough to reverse it—so training for the existing teacher workforce is critical.

Released in May, *Australian Secondary Mathematics Teacher Shortfalls: A Deepening Crisis*, warns isolated solutions such as initiatives to boost the flow of maths graduates into education will fall short of tackling an issue that has been worsening over three decades. AMSI Director, Professor Tim Brown has called for urgent action to set rigorous subject knowledge benchmarks in teacher qualifications, transparency of the status of Australia's mathematically prepared teacher workforce and retraining for those already in the classroom.

"The AMSI study is an important reminder to all Australians of the critical importance of addressing this long-standing unsolved problem. When I was President, the Council of Deans of Science released an important study on this issue by Kerrie-Lee Harris and Felicity Jensz in 2006. Despite strong public reaction there was no successful follow-up," he says.

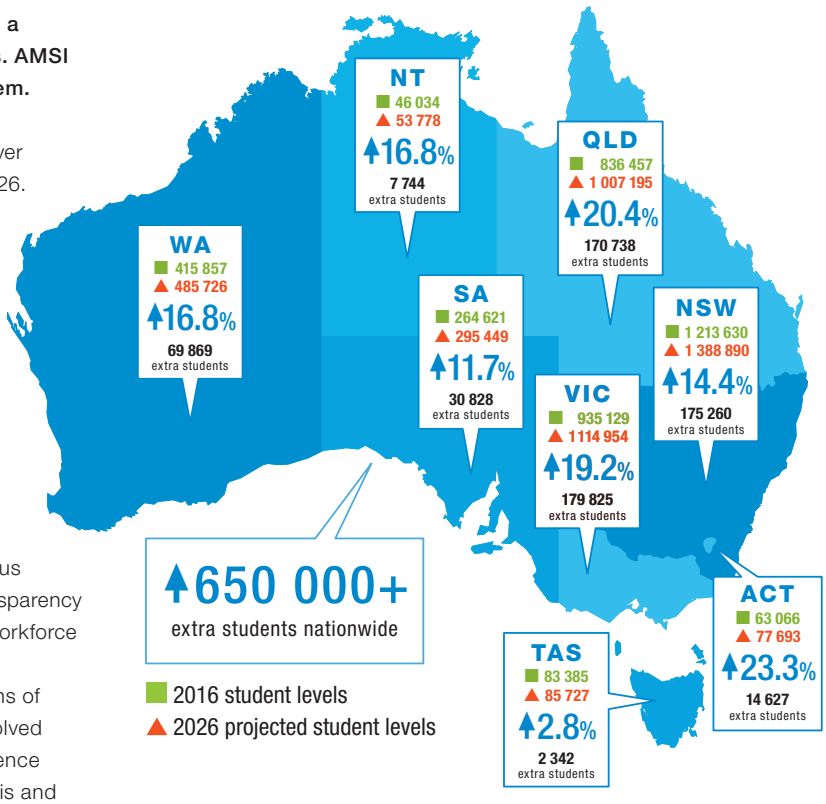
IT IS CRITICAL ANY SOLUTION TAKES A LONG-TERM APPROACH WITH FOCUS ON STRENGTHENING BOTH NEW AND EXISTING TEACHERS' MATHEMATICAL KNOWLEDGE AND CONFIDENCE

MICHAEL O'CONNOR, AMSI SCHOOLS OUTREACH MANAGER

AMSI Schools Outreach Manager and one of the paper's authors Michael O'Connor warns recruitment of new teachers would have little effect without measures to strengthen the current workforce.

"AMSI released modelling last year that shows quick fixes to out-of-field maths teaching will not be enough to address this issue," he says.

Projected Increases in School Student Population by State (All Sectors)



GRAPH: PETER GOSS, GRATTAN INSTITUTE

Co-author and AMSI Honorary Senior Fellow, Jan Thomas OAM, said the worsening crisis is a result of over three decades of inaction by Australian governments, both federal and state.

"This paper demonstrates the historical failures that have contributed to the current crisis in our classrooms. The number of mathematically prepared teachers in Australian has been in decline since the 1980s. The mathematical community including AMSI has been calling for action for decades," says Thomas.

Out-of-field maths teaching has long been a policy priority for the Institute, as the discipline struggles to maintain a supply of fresh talent to replace an aging workforce. Despite science, technology, engineering and mathematics (STEM) being a must for Australian growth employment sectors, we are continuing to see falling rates of engagement with high level mathematics. □

Australian Secondary Mathematics Teacher Shortfalls: A Deepening Crisis, was published in May 2019 by AMSI Honorary Senior Fellow Jan Thomas OAM and AMSI Schools Outreach Manager Michael O'Connor. It can be downloaded from amsi.org.au/occasional-paper-2

INSPIRING A NEW GENERATION

Transforming Maths in and Beyond the Classroom

By Melissa Trudinger and Laura Watson

The University of Sydney's Prof. Jacqui Ramagge talks about growing up Spanglish, education challenges and the image problem facing the mathematical sciences.

CAN YOU TELL ME A LITTLE ABOUT YOUR BACKGROUND AND MATHEMATICAL INFLUENCES?

I was born in London to Spanish immigrants. Culturally, I consider myself a combination of Spanish and English; Spanglish perhaps! Neither of my parents had undertaken any higher education. My mother left school at 14 and my father had been skipping school to work in the fields from the age of eight. We spoke Spanish at home. When I started school at the age of five my English was quite hesitant, but I always remember being able to do the maths exercises. From a cultural perspective I was lucky because people are expected to do maths in Spain; it is not seen as something that only the talented do. In fact, maths is so much in the mainstream of the culture that there is a mathematical insult: "you are more useless than a zero on the left." My family valued education highly and encouraged me at every step of the way.

WHO WERE YOUR ROLE MODELS AND MENTORS AS A WOMAN ENTERING THE MATHEMATICAL SCIENCES? HOW IMPORTANT WAS THIS SUPPORT?

With exception of Cheryl Praeger, most of my mentors were men, and they were all very supportive. Both of my physics teachers in senior high school were women and they were very unsupportive. I don't think someone is a good mentor just because they are a woman. There is of course the question of visibility. At high school, there were only three of us studying Further Maths (the highest level of maths available) and two of us were girls. So at that time I was in the majority! It was only much later that I realised this was unusual. Frankly, I had never really thought about it. However, I am painfully aware that I am a survivor of the system, and that those for whom a role model is important have likely not survived. I try to be visible and make the invisible visible. For example, when I give talks in schools, I start by saying "Hi! My name is Jacqui and I am a Professor of Mathematics at the University of Sydney. There are two things about me that are not obvious. It is not obvious that English is my second language, and it is not obvious that I was the first person in my family to go to university." I usually close by saying something along the lines of "If I can do it, so can you."

WHAT ARE THE BIGGEST ISSUES FACING MATHEMATICS EDUCATION RIGHT NOW, AND WHAT SHOULD WE BE DOING ABOUT THEM?

The biggest issue facing mathematics education, which you highlighted in the recent AMSI Occasional Paper, is the number of secondary school teachers who are teaching mathematics out-of-field, by which I mean without having significant university-level mathematics. It is estimated that up to one third of maths teachers in high school are teaching out-of-field. Even if we could suddenly find the thousands of teachers that would be required to replace them, there is the issue in that those teachers who are currently teaching out-of-field cannot simply be removed from the system (and I am not for a minute suggesting they should be).

One of the reasons that we are so short of maths teachers is that the proportion of students majoring in mathematical sciences has not increased over the last 20 years, but the demand from industry has increased enormously. This has decreased the numbers of students going into teaching significantly, and it becomes a vicious cycle.

…EMPLOYERS OFTEN DON'T SPECIFICALLY GO OUT LOOKING FOR MATHEMATICIANS, BUT THEY VALUE THEM GREATLY WHEN THEY DO EMPLOY THEM…

Part of the solution lies with the very employers who are so keen to employ our graduates. If we encourage students to study the mathematical sciences, the message is clouded by a perceived conflict of interest – clearly it is in our best interests to have more students studying mathematical sciences. However, if employers get the message out, and particularly if they put their money where their mouths are by providing scholarships, then the message is much more powerful for both prospective students and their parents.

Part of the problem is that employers often don't specifically go out looking for mathematicians, but they value them greatly when they do employ them. This is connected to that terrible statistic of proportion of graduates whose employment is related to their undergraduate studies. Mathematicians often fare badly on this measure because they are not explicitly employed as mathematicians, even though they use their mathematical training every day of their working lives because of their critical thinking and analytical skills. Statisticians, often in the guise of data analysts, tend to do a little better on this measure. It is possible that the rise of Data Science as a concept will help turn this around further.

The mathematical sciences have an image problem, and employers need to be part of the solution in fixing it. ⇨

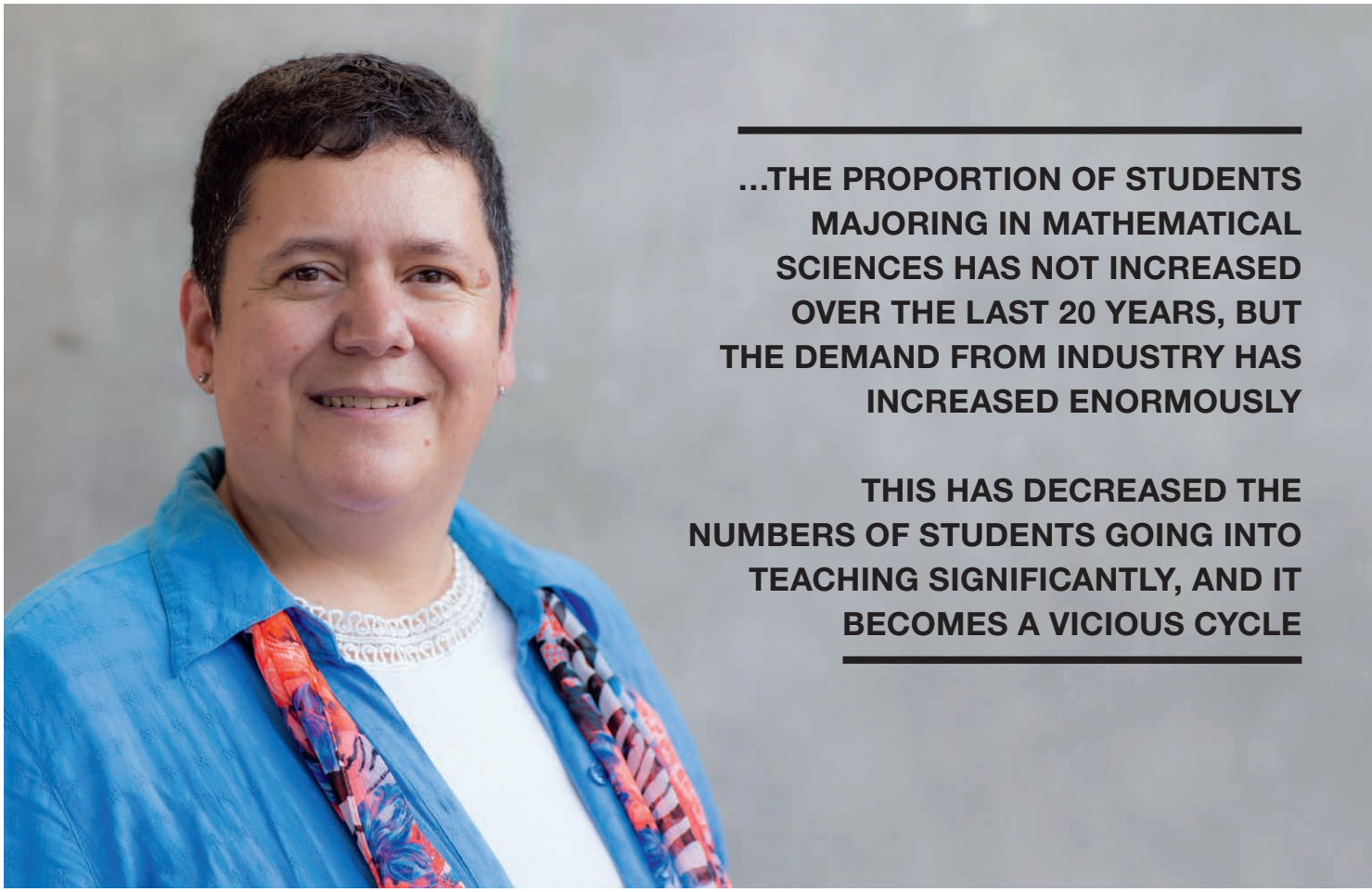


PHOTO: THE UNIVERSITY OF SYDNEY

...THE PROPORTION OF STUDENTS MAJORING IN MATHEMATICAL SCIENCES HAS NOT INCREASED OVER THE LAST 20 YEARS, BUT THE DEMAND FROM INDUSTRY HAS INCREASED ENORMOUSLY

THIS HAS DECREASED THE NUMBERS OF STUDENTS GOING INTO TEACHING SIGNIFICANTLY, AND IT BECOMES A VICIOUS CYCLE

WHAT ADVICE WOULD YOU GIVE STUDENTS CONSIDERING THEIR SUBJECT OPTIONS FOR YEARS 11 AND 12? WHY SHOULD THEY STICK WITH MATHS?

My advice to students is always to take the highest level of mathematics and English that they can. They are the fundamental enablers and enhance performance in all areas. There is overwhelming evidence that taking lower levels of mathematics at high school negatively impacts university performance in other disciplines. Rather than be tempted to mortgage their futures for little benefit, students should invest in their long-term performance by studying as much mathematics and English as they can.

AS THE AUSTMS PRESIDENT 2019–2020, WHAT ARE YOUR KEY PRIORITIES FOR THE SOCIETY, ITS IMPACTS ON AUSTRALIAN MATHEMATICS AND PARTNERSHIP WITH AMSI?

Key priorities for the AustMS include equity and financial sustainability. I'll deal with the boring but pragmatic priority first. The Society has flourished for many years due to its publishing activities, which have helped to subsidise activities of great benefit to its members. With the move towards open access publication, we need to ensure that we can live within our means with sufficient cash flow for all the activities and programs we want to run.

The more exciting priority is that of equity, diversity, and inclusion. As well as gender equity, I think we need to work on broader diversity and inclusion, particularly on Indigenous mathematics and culturally-appropriate programs for Indigenous communities. I think we have a role to play in narrowing the gap between Indigenous and non-Indigenous Australians, which is currently unacceptably large. I would also like to establish an AustMS ALLY network with appropriate training.

The main difference between AustMS and AMSI is that we have individuals as members whereas the AMSI members are institutions. We therefore have slightly different roles to play, but it is vital we cooperate and work well together. The combination of AMSI with its various member institutions, including AustMS and SSA, and institutes with nationwide impact such as MATRIX and SMRI can be very powerful. By working together, we can deliver great services and outcomes for the discipline and the nation. □

From January 2020 Prof. Jacqui Ramagge will be Durham University's Executive Dean of Science. Currently the Head of the School of Mathematics and Statistics at the University of Sydney and President of AustMS 2019–2020, Jacqui has been a member of AMSI's Education Advisory Committee since 2009. Other roles include being on the advisory panel for the senior secondary mathematics curriculum for ACARA.

SUMMER OF RESEARCH

Undergraduate Students Get a Taste of Research Life

By Melissa Trudinger

In a bumper year for AMSI's Vacation Research Scholarship (VRS) Program, Scott Carnie-Bronca and Theresa O'Brien swapped sand and sun for a summer of research.

Ice-cream and long days at the beach would top most people's list for a summer cool-down. Teen scientist Scott Carnie-Bronca, however, spent his summer using statistical modelling to simulate the effects of energy transfer in and out of a battery.

"Scott's work used mathematics and real-life data to estimate the required amount of battery storage — much, much more than what we have right now — to achieve the ultimate goal of an all-renewable energy grid," says Scott's supervisor Dr Giang Nguyen.

During initial project stages, Scott compiled datasets for both renewable energy generation and usage for 2018. This data was then used to create a model for energy transfer into and out of a battery using various real-world effects such as battery capacity and degradations of charge to provide accurate simulations of a battery's charge throughout the year.

"From the simulations, I determined that the optimal combination is approximately 4.2GW of solar generation, or about 80 medium-sized solar farms, connected to 5,200,000MWh of energy storage — a battery 40,000 times larger in capacity than the current largest battery in Australia. These amounts could be reduced by including alternative generation methods to the model, such as wind or geothermal which are steadier over time," explains Scott.

For the University of Wollongong's Theresa O'Brien, the VRS experience provided a fantastic space to combine her broad interdisciplinary background in social sciences with maths and stats.

Using a mixture of mathematical equations and stochastic processes to create a computer simulation reflecting the somewhat random and intensely social experience of stand-up comedy, Theresa's project investigated how laughter spreads through a comedy audience. The simulation was then compared to real-world data collected from recordings of comedy performances.

"I have gained a lot of insight into how hard it is to model social behaviour with maths, because humans don't lend themselves to this kind of research very well. We have to be really careful to not overstate our results and to verify our models because it's much easier to program something completely unrealistic and disconnected from reality than something that reflects what people actually do," says Theresa.

Scott and Theresa were 2 of 69 undergraduate students selected for $3000 scholarships in a bumper 16th year for the program. For

THERE IS A LOT OF FUTURE RESEARCH POTENTIAL IN THIS PROJECT. MY HOPE IS TO PUBLISH A PAPER OUT OF WHAT WE HAVE SO FAR

THERESA O'BRIEN, AMSI VACATION RESEARCH SCHOLAR

PHOTO: ACARA PHOTOGRAPHY

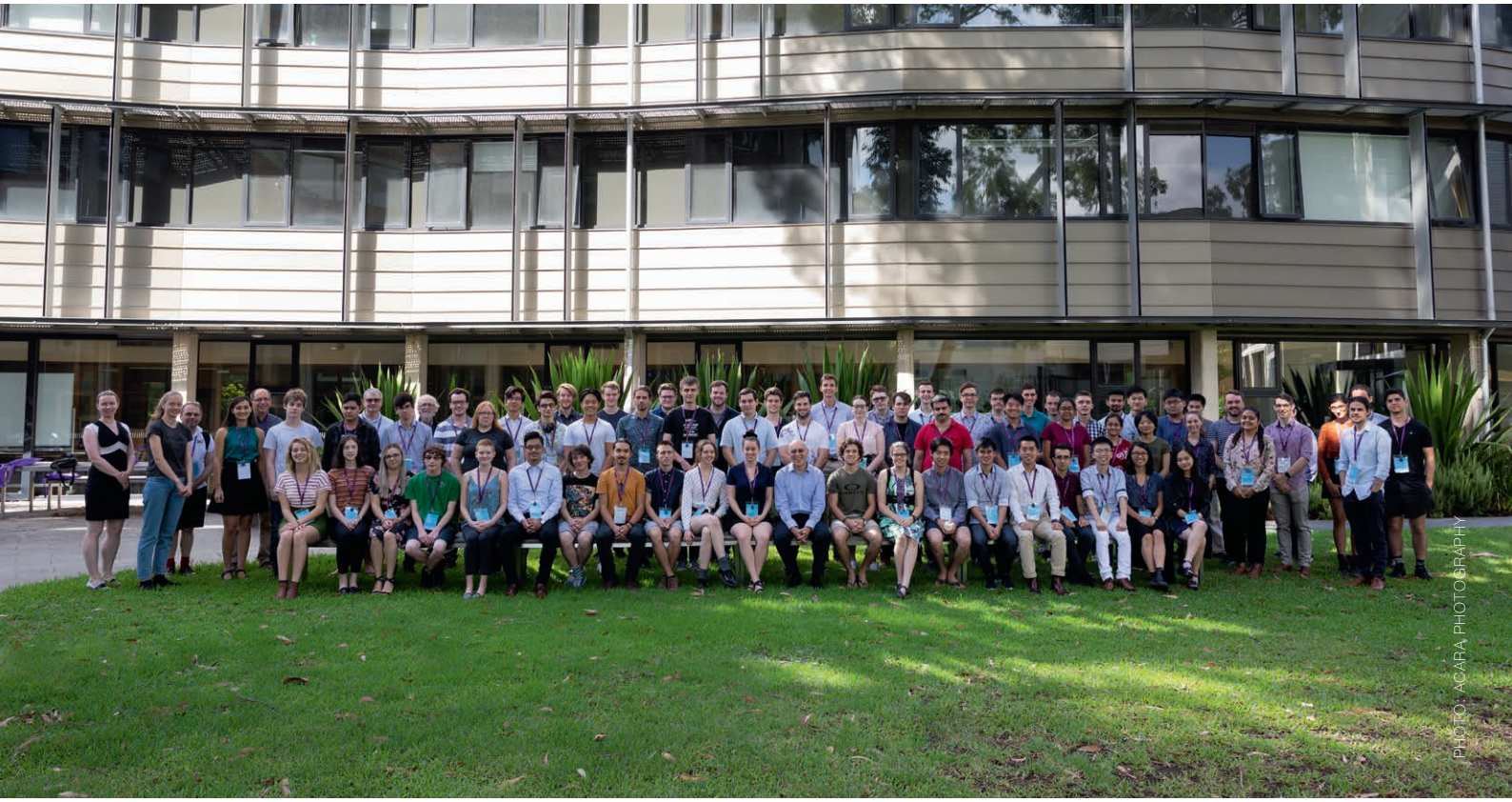


PHOTO: ACARA PHOTOGRAPHY

many, the highlight was a chance to attend AMSIConnect in Melbourne. The annual conference marks the end of six weeks of research with networking and information sessions to support career planning. It is also a chance for each student to speak on their project with prizes on offer for top presentations. Theresa received third prize for her talk, with first prize awarded to Alexander Lai De Oliveira from the University of Adelaide and second prize to Kyria Wawryk from Monash University.

AMSI Director Professor Tim Brown said increased interest in the scholarships reflected a growing awareness of the opportunities across the spectrum of fundamental to applied research, as well as the need to complement specialist knowledge with soft skills.

"The program is fast becoming a must for students to build skills and knowledge through practical research application in a real-life setting," said Professor Brown.

For Scott, the project provided practical experience and valuable insight into applying research to real-world problems.

"Working on a project through VRS allowed me to experience mathematical research with other students interested in mathematics.

THE PROGRAM IS FAST BECOMING A MUST FOR STUDENTS TO BUILD SKILLS AND KNOWLEDGE THROUGH PRACTICAL RESEARCH APPLICATION IN A REAL-LIFE SETTING

PROF. TIM BROWN, AMSI DIRECTOR

The project also helped me decide to continue in research after university. I plan on continuing to work in the field of stochastic modelling, however probably not in the field of energy," said Scott.

Similarly, Theresa has also found that the project has offered clarity and direction to her future studies.

"There is a lot of future research potential in this project. My hope is to publish a paper out of what we have so far. I plan to do more work in this field, namely mathematical modelling in social science, even if it isn't related to this specific project," she said.

Scott Carnie-Bronca and Theresa O'Brien were recipients of AMSI Vacation Research Scholarships in 2018-2019. Scott's project report and blog post can be found at vrs.amsi.org.au/student-profile-scott-carnie-bronca/ and Theresa's can be found at vrs.amsi.org.au/student-profile-theresa-obrien/.

The scholarships are jointly funded by AMSI and the Australian Government through AMSI's Securing Australia's Mathematical Workforce project.

For information on applying for 2019-2020 scholarships, visit vrs.amsi.org.au

CHAMPIONING AUSTRALIA'S MATHEMATICAL SCIENCES

Meet the Faces Behind AMSI's Refreshed Focus and Direction

This year has brought a wave of change to AMSI's leadership with the appointment of Professor Tim Brown as Director, as well as Deputy Director Mat Simpson and Board Chair Adelle Howse. They spoke to Update's Editorial Team about maths and the future of AMSI.

It has been a big first six months for AMSI Director, Professor Tim Brown and Deputy Director, Mat Simpson. Since joining the Institute in January, AMSI's strategic plan has undergone a refresh and the Board has welcomed a new Chair, Dr Adelle Howse, and five new members.

Dr Howse's appointment follows a long history with the Institute as a member of the Board since 2012—most recently as Deputy Chair—and as a member of the Industry Advisory Committee.

The expansion of the Board with five independent members has injected a wide diversity of backgrounds and skills, transforming governance at a pivotal time for the Institute.

Always a strong feature of AMSI, according to Professor Brown, the continuing involvement of roughly 50 per cent working academics and 50 per cent external members will play a critical role in the Institute's ongoing internal and external engagement. Importantly, this diversity of backgrounds and connections with the mathematical sciences enriches the Board and AMSI, its vision and strategic direction as the national mouthpiece for the discipline.

As a key promoter of the importance of encouraging female participation in mathematical sciences at all levels, the latest appointments are also in line with the recently published goals of the Australian Academy of Science's *Decadal Plan for Women in STEM*.

AMSI'S VISION GETS AN UPDATE

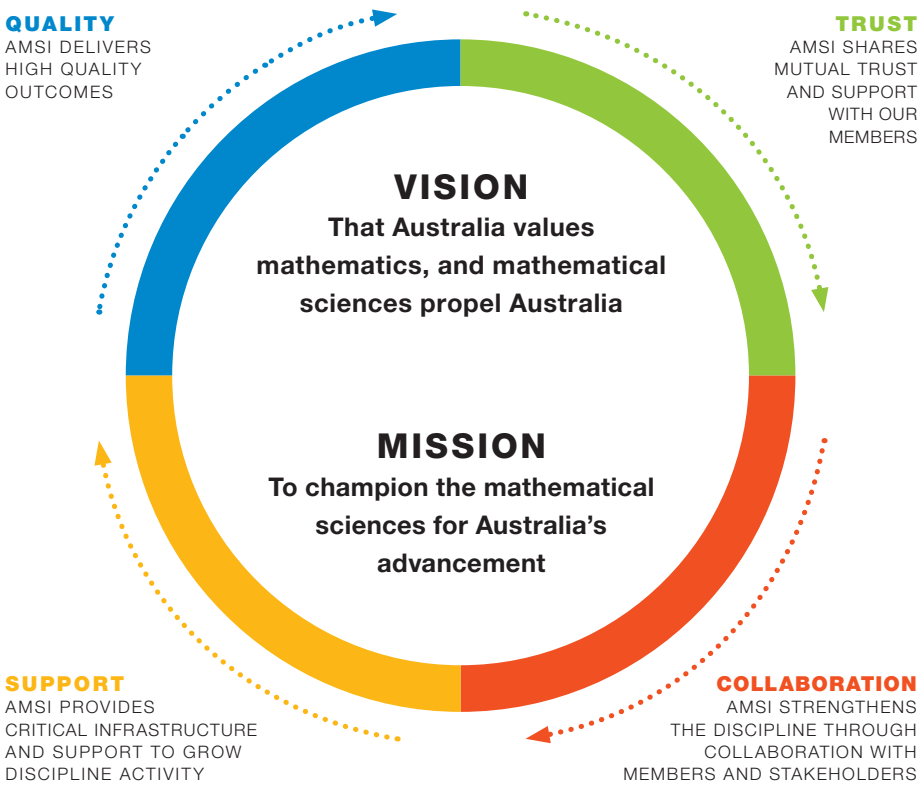
AMSI has refined both its mission and the goals in a new strategy statement that sets an ambitious and exciting agenda moving forward.

Significantly, this new strategic direction is responsive to the recent evolution of Australia's mathematical sciences, clarifying how AMSI can best contribute and champion mathematics and statistics for the benefit of Australia.

At its heart, AMSI's most influential work to date—programs impacting schools, research, higher education and industry innovation—has succeeded through its capacity to galvanise the mathematical sciences community, allowing achievement and impact that would have been impossible separately. Behind the scenes, AMSI has been particularly effective in its liaison with government, philanthropy, industry and education stakeholders, opening opportunities for Australian students that may not have otherwise been within their reach.

Building on this success, the newly focused strategy will assist AMSI in developing its business plan and funding strategy. Ensuring vital programs are supported by a sustainable and diverse funding portfolio is a key priority to allow the Institute to continue its work and deepen its impact across the mathematical sciences pipeline.

AMSI Update spoke to Professor Brown, Dr Howse and Professor Simpson about what comes next for AMSI and the Australian mathematical sciences.



EVERY AUSTRALIAN SHOULD HAVE THE OPPORTUNITY TO GET A FIRST CLASS MATHEMATICS AND STATISTICS EDUCATION BOTH AT SCHOOL AND AT UNIVERSITY

PROFESSOR TIM BROWN

PHOTOGRAPHY: MICHAEL SHAW

AMSI's new director Tim Brown has hit the ground running to navigate a hectic first six-months.

WHAT ATTRACTED YOU TO AMSI AND THE OPPORTUNITY TO CONTRIBUTE TO ITS IMPACT AS DIRECTOR?

There's a story that I shared with the selection committee, that I was telephoned about the opportunity, and laughed, because I thought that my time for contributing in that kind of way to the mathematical sciences in Australia was in the past. But when I looked at the range of activities that AMSI is doing, I realised that I really wanted that opportunity. And once I'd made that decision, I was really keen to participate in this wonderful array of activities that AMSI has been pioneering for Australia.

HOW HAS YOUR BACKGROUND PREPARED YOU FOR STEPPING INTO THE AMSI DIRECTOR ROLE?

I think many of the roles that I've done over the years have been important in preparing for this really challenging and exciting role. Clearly, being professor of statistics now for over 30 years, has given me a deep appreciation of the beauty and power of the mathematical sciences, and being Head of the School of Mathematics and Statistics was very important to understand the way in which academic aspirations meet university processes and desired outcomes.

During that period, I was very engaged with selecting students into university, not just from within the university but more broadly as part of the assessment committee of the Victorian Curriculum and Assessment Authority, and the scaling committee of the Victorian Tertiary Admissions Centre. This gave me exposure to the challenges of mathematics education in schools, something that I'd also enjoyed interacting with when I was at UWA and Monash.

My roles as Dean and DVCR gave me a lot more external focus more broadly in STEM and research across the nation, and this has given me an appreciation of the way that government interacts with universities, both the challenges and the opportunities.

CAN YOU TALK ABOUT THE ROLE OF MATHEMATICS TEACHERS AND WHY IT IS SO VITAL FOR AMSI TO KEEP PUSHING FOR ACTION ON ISSUES SUCH AS OUT-OF-FIELD TEACHING AND THE NEED FOR PROGRAMS SUCH AS CHOOSE MATHS?

Educational research shows very clearly that really deeply informed mathematics teachers make a big difference in classrooms. Sticking closely to a textbook is possible without an advanced understanding of mathematics, but we will continue to have lower levels of participation overall in advanced maths, particularly for girls, unless we transform the educational experience.

If we don't, we will continue to have a STEM workforce that is under-prepared and Australia will increasingly lag behind advanced countries in the world in productivity, and general well-being, because mathematics and statistics affect daily life—can positively affect daily life—in every area. So, the schools are the place where that chain of reactions that can produce either nuclear power, or the opposite, are really crucial.

The balance between understanding mathematical concepts and applying them will always be challenging. It's really important that teachers are encouraged to do both. At its simplest, it comes down to how will I use this maths in my everyday life?

So keeping Choose Maths and the initiatives there going is really high priority. ⇨

DO YOU THINK YOU'D HAVE HAD THE CAREER YOU HAVE WITHOUT THE INFLUENCE OF YOUR MATHS TEACHER, KEN EVANS?

I certainly wouldn't have studied mathematics at university, without Ken's influence. He is a person who deeply cares about the beauty of the underlying mathematics. The fact that mathematics is not just about numbers, it's about patterns and structure, was something he communicated wonderfully in Year 11 and 12. It opened a door to many, many new worlds.

At the same time, his teaching of applied mathematics, probability and so on, always was very precise in framing problems, and then drawing out what mathematical tools were relevant for those problems. I remember how careful he was and how insistent he was that we do this very carefully.

There is a lot of teaching out there that is not nearly as careful as it should be about doing that. And I think when you are careful—particularly in applied maths—then a lot of the mistakes don't happen. And conversely, when you are not careful, beware.

HOW CAN WE IMPROVE COMMUNITY PERCEPTIONS OF MATHEMATICS AND ITS VALUE TO THE COMMUNITY AND THE AUSTRALIAN ECONOMY?

I think the mathematical sciences does have an image problem, arising from the view that mathematics is mechanical, rather than imaginative and creative. And it's hard, because there are abstract ways of thinking that are necessary to really understand mathematics at the level where creativity and imagination comes into play. So that's a very big challenge for teachers at any level, there's always a balance between the techniques and having the capacity to see that broader picture.

Making the effort to relate mathematics to practical application is one of the key parts. And really, that can be done with any mathematics from preparatory grade in school through to PhD. Of course, it becomes easier at the higher levels because there's more of an assumed background of skills that can be drawn on. But it really needs to start early.

Our APR.Intern program is making a lot of connections with industry but this is a slow process. Big changes in public attitudes, such as wearing seatbelts or decreasing smoking, took really big campaigns over a long time, so this will be a long term challenge for AMSI and for the government and for society, generally.

AS A STATISTICIAN AND APPLIED MATHEMATICIAN HOW IMPORTANT HAS INDUSTRY ENGAGEMENT BEEN IN YOUR CAREER?

I've always been a pure mathematician—a probabilist—but from the beginning I've also been interested in applications and statistics. Throughout my career, I've had consulting on the go at the same time as research and teaching. The delight of consulting and engagement is that it's not just one person solving a problem. It's the interaction that generates both the problem in statistical terms, and the interpretation of the results. Often, the methods aren't deep. But finding the right way to think about the problem to acknowledge the practical constraints, as well as the theoretical desirable properties of a solution – that balance requires a lot of two way communication.

WHAT ARE THE TOP THREE KEY POLICY AREAS YOU'D LIKE TO SEE PRIORITISED BY THE NEWLY ELECTED FEDERAL GOVERNMENT?

First, focus on harnessing Australia's mathematicians and statisticians to improve productivity. Economies can grow and people can have jobs without exploiting more mineral or agricultural resources, if we're being really smart. Mathematics has a lot to offer in that area.

Second, make sure every Australian has the opportunity to get a first class mathematics and statistics education both at school and at university.

Third, act to increase opportunities for every section of the Australian community to participate in and enjoy mathematics. In particular, I'm thinking of girls, but there are other sections of the community that don't have the same opportunities to study – kids in remote areas for example, and kids in underprivileged areas in cities, not just traditionally low socioeconomic areas, but the outer suburbs where schools may be very challenged with population growth.

IF YOU COULD ADDRESS FUTURE GENERATIONS ON BEHALF OF THE MATHEMATICAL SCIENCES, WHAT WOULD YOU WANT THEM TO KNOW?

It's not routine. Despite what you might have had to do so far. It's just like music. It has the capacity to transform your soul as well as open up many doorways that would otherwise be closed. It's worth making the effort, because, like many things, it's not easy to go below the surface, but if you do, you'll find that its mysteries become less mysterious. And when they do, there'll be lots of unexpected ways to apply your knowledge.

Prof. Tim Brown has had a long academic career across the University of Bath, Monash University, University of Melbourne, University of Western Australia, Australian National University and La Trobe University. He has been a Professor of Probability, Statistics and Data Science in totality for over 32 years and has held leadership positions such as Head of Department of Statistics; Head of Department, Mathematics and Statistics; Dean of Science; and Deputy Vice Chancellor (Research). He joined AMSI as Director in January 2019.

PHOTOGRAPHY: MICHAEL SHAW

DR ADELLE HOWSE

AMSI's Board Chair, Dr Adelle Howse, talks about loving maths, her career and why the discipline needs a national voice.

A C-SUITE EXECUTIVE AND COMPANY DIRECTOR, YOU HAVE A PhD IN MATHEMATICS. HOW HAS MATHS PLAYED A ROLE IN YOUR CAREER?

As an undergraduate, I studied maths and went on to complete a PhD. However, the "real world" was calling and I took a graduate management trainee program at Unilever. From there I explored roles as an analyst in venture capital, and in energy forecasting/modelling, jobs that very much utilised my maths skills. At the same time I continued to add to my portfolio with a diploma in Applied Finance, and later, an Executive MBA.

Over more than 20 years, I have worked predominantly in energy, construction, resources, infrastructure and property, progressing from forecasting and analytic roles to general management and then senior executive and board positions. I found myself attracted to jobs where my maths background and knowledge offered me a competitive advantage, and I enjoyed the complexity of these roles. These days I am involved in strategic consulting and execution for corporations on market position, mergers, acquisitions and divestments, business transformation and operational performance improvement.

While I don't explicitly apply my PhD work in the business world, there are many common elements—complexity, unstructured problems, chaos—and mathematics provides a powerful tool kit.

FOR ME, MATHS IS THE LANGUAGE OF THE UNIVERSE THAT WE LIVE IN – IT IS POWERFUL, BEAUTIFUL, INFINITE WITH NEVER ENDING CHALLENGES

WHY DID YOU JOIN THE AMSI BOARD? HOW HAS IT CHANGED THIS YEAR?

I joined the AMSI Board because I believe strongly in the Institute's mission to support and grow Australia's mathematical sciences capacity and capability which generates economic value for us as a nation. If we all attain a minimum numeric skill set and have the ability to use logic and a capability to solve problems (even if we don't go on to study tertiary mathematics), a strong numeric workforce will result in less errors, better quality, increased productivity and innovation. This needs to start with schools.

At the other end of the mathematics spectrum, the contribution that mathematical sciences research makes to our society is astounding, and I never cease to be impressed and amazed by the accomplishments and the applications of mathematical sciences to the world around us. This is truly value creating.

The Institute has attracted five new highly credentialed board members, I am delighted to welcome such a diversity of backgrounds, experience and skills. The new appointees include Director of PhillipsKPA, Anne Baly, former Bureau of Meteorology Chief Scientist and Corporate Executive, Science and Innovation, Dr Sue Barrell, Deputy Vice-Chancellor (Research) at University of Western Australia, Professor Robyn Owens, Biarri Co-Founder Joe Forbes and Director of the Australian Synchrotron, Professor Andrew Peele. ⇨

The addition of these five outstanding field leaders provides significant strategic strength to support AMSI to achieve its mission. This equips AMSI with deep capability and knowledge in areas including: STEM leadership, mentoring and advocacy, public and education sector experience, policy reforms, change management, research training, industry experience, strategy and commercial innovation.

HOW HAS AMSI CHANGED SINCE YOU BECAME INVOLVED? HOW WILL THE BOARD CONTRIBUTE TO DELIVERY OF THE REFRESHED STRATEGIC PLAN AND BUSINESS STRATEGY?

I see AMSI as a collaboration entity for mathematical sciences in Australia with the force to bridge schools with academia and academia with industry, and in turn interact with Government on important policy matters. AMSI's ongoing focus is to ensure students have a bright future in a robust and growing Australian economy, and corporate and non-profit entities will have the workforce they need to deliver outcomes.

The Institute has grown significantly in the years since I joined the Board in 2012, it now has 41 members including many of Australia's leading academic institutions and organisations and delivers substantial initiatives of scale and significance to Australia as well as continuing to direct programs specifically for the mathematical sciences community.

The Institute's many strong and powerful programs and initiatives, such as the Choose Maths project and APR. Intern, contribute significantly to the Australian economy. Playing a part to help deliver on these initiatives, and to continue the transformation of AMSI to achieve an independent sustainable platform requires us to identify new opportunities for the Institute to impact the mathematical pipeline and this is part of the attraction for me. I'd like to continue building commitment from industry, government and the education sectors—working collaboratively to achieve the institute's mission and demonstrating true value-add along the way. My vision for AMSI includes developing a deeper awareness amongst parents, students, teachers and the community of the benefit of and demand for mathematical skills in the Australian workforce, and promoting a broader engagement between industry and the mathematical sciences.

It is an exciting time for AMSI and the Board is working with AMSI Director, Professor Tim Brown to refresh the business strategy and set a new sustainable direction for the Institute. Tim's leadership capability, academic background and enthusiasm are all important ingredients to the future success of the Institute.

HOW DO WE CHANGE COMMUNITY PERCEPTION OF MATHEMATICS AND ITS VALUE IN THE REAL WORLD?

The world is now completely fascinated with big data, machine learning, artificial intelligence, blockchain, automation and robotics and this fascination is helping to create a stronger appreciation of mathematics, which is an integral component of these technologies. This creates a stronger demand for mathematically skilled employees and supply should also respond as these applications have broader and more attractive image appeal. We also have numerous examples of mathematically trained business founders who have successfully created multi-billion dollar businesses and CEOs leading corporations who have a background in mathematical sciences, and this is helping to elevate the profile and image of the field.

GROWING UP, WERE YOU ALWAYS INTERESTED IN MATHEMATICS?

I have always loved maths, from the very first memory of my mother asking me at a very early age to solve 1+1.

For me, maths is the language of the universe that we live in – it is powerful, beautiful, infinite with never ending challenges. Much like the real world, it requires logic, knowledge and creativity to find solutions for complex problems.

WHAT CAREER ADVICE WOULD YOU GIVE YOUNG PEOPLE? HOW WOULD YOU INSPIRE THEM TO STICK WITH MATHS?

First of all, I always say to people that if they truly have identified a topic that they are passionate about that they should pursue it. My second point is that whatever your passion is, having mathematical skills will allow you to be more successful in any chosen career. Finally I strongly recommend studying as high a level of mathematics as possible because it gives you the ability to solve problems, to design solutions from scratch and this is a highly valuable skill.

Recently appointed as AMSI's Board Chair, Dr Adelle Howse is a well-credentialed professional with a track record in the delivery of strategic business transformation, operational performance improvement, business planning and analysis, structured M&A and corporate finance solutions. Adelle has been a member of AMSI's Board since 2012, serving on the Industry Advisory Committee and as Deputy Chair.

PHOTO: SUPPLIED BY QUEENSLAND UNIVERSITY OF TECHNOLOGY

ONE OF THE KEY PRIORITIES FOR AMSI IS TO MAINTAIN THEIR EXCELLENT WORK IN THE PROMOTION OF THE IMPORTANCE OF MATHEMATICS TRAINING

PROFESSOR MAT SIMPSON

AMSI Deputy Director Mat Simpson talks to us about his career as a mathematical biologist and the importance of AMSI in promoting maths at all levels.

CAN YOU TELL US ABOUT YOUR BACKGROUND AND THE INFLUENCES THAT HELPED SHAPE YOUR CAREER AND LOVE OF MATHS?

I studied environmental engineering at the University of Newcastle (Australia), and I made this choice because when I finished high school I knew that I was very interested in mathematics and computer programming, and I was really intrigued to learn how to use these skills to solve problems. One of the memorable events of undergraduate training in engineering is to use a combination of simple mathematical models and experiments to make and test predictions. The first-year experience of designing a model bridge was very exciting since it forced students to use mathematics to design a bridge and then to use experiments to test it. Drawing free body diagrams and calculating forces in components of the model bridge seemed rather abstract, but then to design and assemble the bridge, take it to the laboratory and test whether it could support some particular weight really forced us to understand the value of mathematical modelling. As I progressed through my postgraduate degree in environmental engineering, at the University of Western Australia, I was continually drawn more to the more theoretical aspects of engineering and this resulted in me commencing a postdoctoral fellowship at the University of Melbourne in mathematical biology at the conclusion of my PhD. I have worked as an applied mathematician ever since.

DO YOU THINK YOU WERE ALWAYS DESTINED TO BE A MATHEMATICIAN?

Yes. During both high school and university I was always far more interested in mathematics and mathematically-oriented subjects than anything else I was studying. I value the training I received as an engineer because of the emphasis placed upon using mathematical models to develop and test ideas. This awareness of treating mathematical modelling as a complementary tool has been pivotal to my research in mathematical biology.

WHAT ARE SOME OF THE APPLICATIONS AND CHALLENGES OF YOUR RESEARCH?

Most of my research involves applying mathematical models to provide insight into biological processes, ⇨

such as biological experiments aimed at studying collective cell migration and collective cell behaviour. Some of my group's recent work involves developing new mathematical models of cell proliferation to describe new experimental technologies that reveal the details of the cell cycle within individual cells. Understanding the cell cycle is very important since many drugs developed to treat disease, such as cancer, aim to regulate or interfere with the cell cycle in some way. One way of improving our understanding of drug design is to develop mathematical models and simulation tools for these experiments. By comparing experimental observations with modelling predictions, we begin to learn whether we have incorporated the essential features of the experiments into our model so that the model can make useful predictions. One of the challenges of working in this area is the ongoing need to become familiar with new experimental technologies. Fortunately, one of the best ways of doing this is to work with scientists from other disciplines who can provide insight into these new techniques.

WHAT DEVELOPMENTS ARE YOU PREDICTING IN YOUR FIELD WITHIN THE NEXT FIVE TO TEN YEARS?

Ongoing developments in computing and computing power mean that our ability to apply mathematical models to probe increasingly complex biological observations and experiments is always advancing. This is very exciting because our ability to use large-scale computation to identify parameters in mathematical models, to use experimental data to make objective choices about the best kind of model, and our ability to use computation to automate these choices is really exciting. One of the distinguishing features about applying mathematical modelling ideas to biological processes is that there can be very little consensus in the literature about the kind of model that ought to be used. In contrast, in fields such as engineering and physics, for example, we have well established models to describe many problems in solid mechanics and fluid mechanics. The situation in biology is very different, and the question of model selection is very important, so I am very excited to see the developments in this field over the next decade, with the eventual aim of automatic model selection and model parameterisation.

DO YOU THINK THERE IS STILL A LACK OF UNDERSTANDING OF THE VALUE OF MATHEMATICS? HOW CAN AMSI CONTRIBUTE TO CHANGING HOW AUSTRALIA SEES MATHS AND ITS IMPACT ON THE AUSTRALIAN ECONOMY?

In my work, the most obvious example of the lack of understanding of the value of mathematics and training in mathematical sciences is clear when I attend university open day and the Tertiary Schools Expo in Brisbane each year. Our school of mathematical Sciences at QUT is part of our Science and Engineering Faculty, so high school students who enjoy mathematics (along with their parents) routinely ask about degree programs in engineering and computer science. Almost always the conversation involves a discussion of whether a degree in mathematical sciences is of interest, with an avalanche of inevitable questions about what kind of employment options exist for mathematics graduates. AMSI makes many fantastic contributions to the promotion of mathematical sciences, but over many years I have found that the publication of the AMSI Careers Guide (Maths Adds) is perfect for showing people clear evidence of the value of mathematical science training in the workforce. I have often wondered whether I would have opted for a mathematics degree instead of an engineering degree had such information been available to me.

WHY IS AMSI SO IMPORTANT AS A VOICE FOR AUSTRALIA'S MATHEMATICAL SCIENCES? WHAT DO YOU SEE AS THE PRIORITIES AS THE INSTITUTE MOVES FORWARD WITH ITS NEW STRATEGY?

I believe that AMSI's success as a voice for Australia's Mathematical Science community lies in the fact that AMSI is involved with school-level education and training, university-level education and training together with engagement with industry and government. Having a national body that provides a cohesive connection across these potentially disparate activities is vitally important so that the broad role of mathematical sciences is promoted at all levels. My personal view is that one of the key priorities for AMSI is to maintain their excellent work in the promotion of the importance of mathematics training. The AMSI Choose Maths project, with the aim of improving public perception of mathematics and the development of a pipeline of mathematically trained graduates, is essential to ensure the prosperity of Australia.

Mat Simpson is Professor of Mathematics at Queensland University of Technology. He was appointed Deputy Director of AMSI and Chair of the Research and Higher Education Advisory Committee in late 2018.

OPEN UP YOUR WORLD

Open up talent, skills and theory to industry and they'll open up new worlds of innovation and opportunity. Share untapped PhD knowledge to influence, evolve and shape our world in so many ways. Apply PhD theory in the real world with APR.Intern.

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aprintern.org.au

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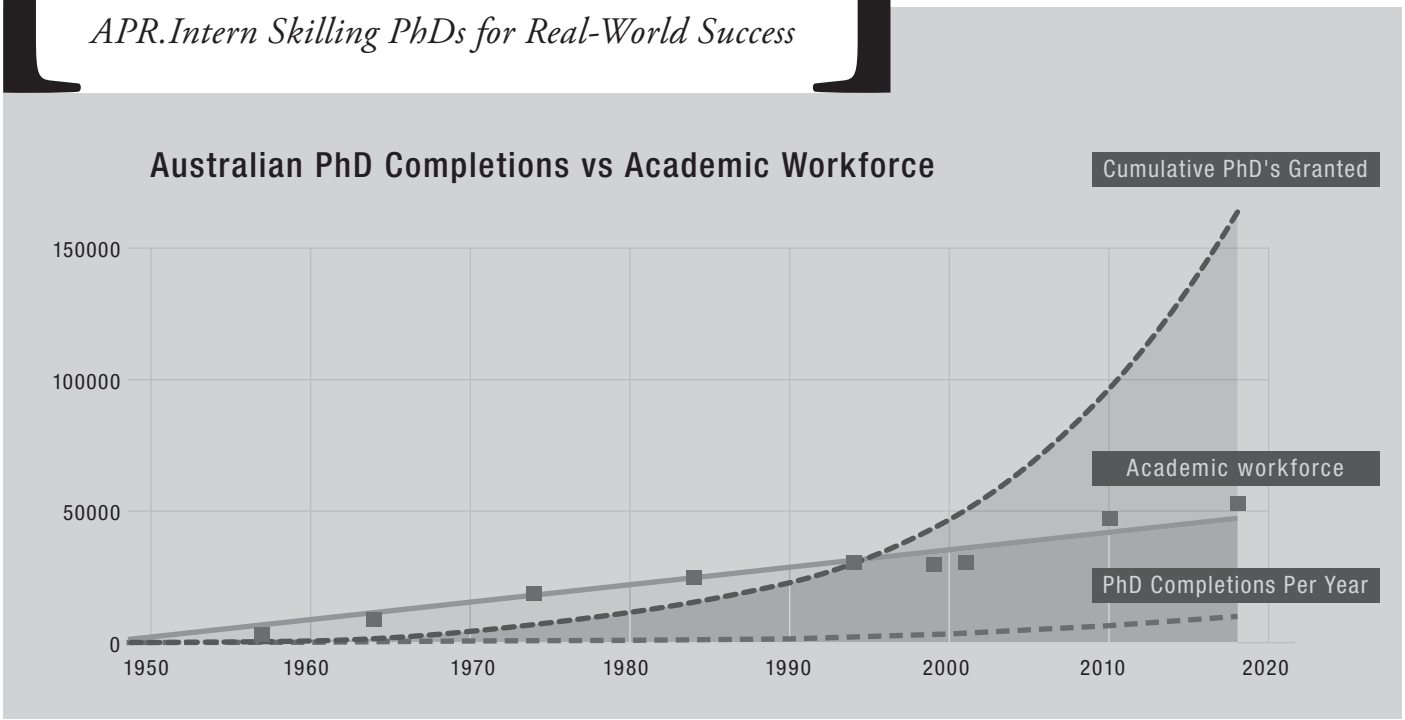
APR.Intern Skilling PhDs for Real-World Success



GRAPH: AMSI/CSIRO DATA61

By Laura Watson and Melissa Trudinger

As AMSI's national internship PhD program deepens its impact across key innovation sectors, new data reveals demand for specialist expertise.

Complementing specialist expertise with workplace skills is a key priority for Australian PhD students, as a recent report from AMSI and CSIRO Data61's student-employer matching platform, Ribit.net shows over half plan to leave academia following their studies.

Released in May, *Advancing Australia's Knowledge Economy* reveals PhD completions have soared from 4000 to 10,000 annually since 2001. With not enough jobs in academia to absorb all these PhD graduates, growth in industry demand for this workforce is good news.

"While there are not enough jobs in academia, a growing focus on innovation is fuelling a need for research and analysis capability across nearly every industry sector," says report co-author and AMSI Policy Officer, Dr Maaike Wienk.

Medical technologies and pharmaceuticals, advanced manufacturing, mining technologies, environmental goods and services and technology all make the list, as high-growth innovators seek an edge through PhD recruitment. In the public sector, health care, government and defence are significant employers of PhD graduates. All these industry growth areas are key sectors for APR.Intern.

"Aligned to industry growth sectors, this report reflects our industry engagement strategy particularly our focus on SMEs, large organisations, defence, health and manufacturing," says APR.Intern Director and Melbourne Enterprise Professor, Gary Hogan.

WHILE THERE ARE NOT ENOUGH JOBS IN ACADEMIA, A GROWING FOCUS ON INNOVATION IS FUELLING A NEED FOR RESEARCH AND ANALYSIS CAPABILITY ACROSS NEARLY EVERY INDUSTRY SECTOR

With big industry and SMEs keen to harness quantitative, analytical and research expertise, AMSI Director, Tim Brown, says packaging expertise with workplace skills is critical. "PhDs are no longer solely a ticket to academia, this report confirms pathways to prepare PhDs for industry and link them to potential employers are critical," he says.

For many of the students who have taken up this wisdom, combining specialist expertise with soft skills such as communication and stakeholder management has been akin to developing superpowers.

"APR.Intern is one of the best ways to start fresh in the market and develop the skills and networks needed to pursue industry. I learnt how machine learning is used in industry, new techniques, and developed essential soft skills," says Nazanin Borhan, a former PhD Intern at Atlassian.

BUILDING PARTNERSHIPS TO STRENGTHEN INNOVATION

For many students, AMSI's APR.Intern program has proven a powerful gateway as they make the transition to industry. Open to all universities, small-to-medium and large enterprises, and government bodies, the Program matches companies with PhD students and supervising academics to undertake three to five month, tightly-focused research projects. Recent partnerships have further opened opportunities at the frontline for defence, health and medical research and manufacturing.

In May, APR.Intern announced a $230,000 partnership to subsidize 23 PhD internships through the WA Government's new Defence Science Centre (DSC). Deepening ties with Western Australian universities, these opportunities open an important avenue to prepare PhDs with industry skills while helping drive real-world defence innovation.

"The placements under the APR.Intern program will allow SMEs to cost-effectively tap into specialist research talent with unique skillsets to advance Western Australian defence innovation," says Professor Hogan.

It's a win for the WA government too, as the partnership will contribute to their support for small business-led defence innovation and ongoing efforts to secure the state's STEM future.

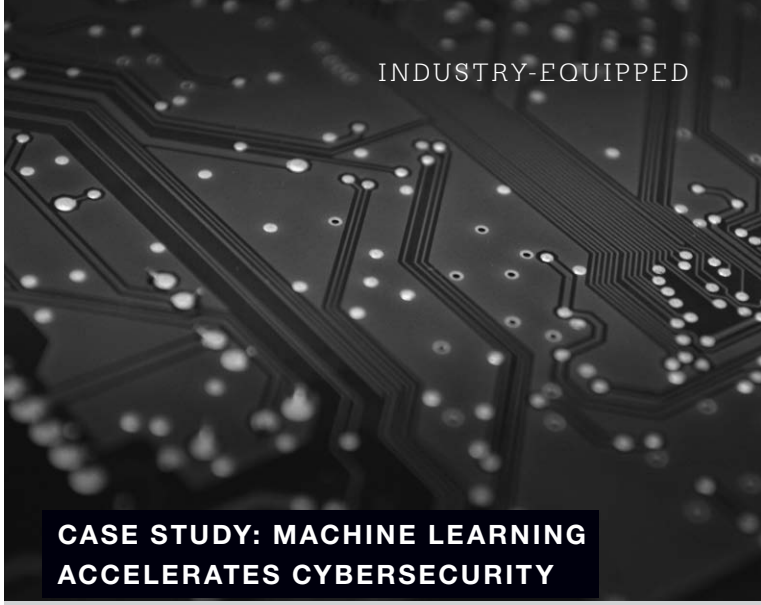
"This partnership will foster essential research-industry collaboration, accelerating WA defence innovation and building STEM capability position the state as a global innovation leader," said WA Defence Issues Minister Paul Papalia. This is the latest in a line of recent defence sector MOUs, with opportunities available through partnerships with Victoria's Defence Science Institute and NSW's Defence Innovation Network, as well as 100 internships nationally through the Defence Science and Technology Group.

Interns are also benefiting from opportunities opened up by partnerships with the Australian Bureau of Statistics, the Victorian Comprehensive Cancer Centre, the ARC Centre for Personalised Therapeutics Technologies, and the Innovative Manufacturing CRC.

PHOTO: SUPPLIED BY DSC

Photo: *WA Minister for Defence Issues, Paul Papalia, Minister for Defence Industry, Melissa Price, and Chief Defence Scientist, Tanya Monro, at the DSC launch.*

The 2019 AMSI/Data 61 report "PhD Employers, Advancing Australia's Knowledge Economy", is online at amsi.org.au/advancing-australias-knowledge-economy/



CASE STUDY: MACHINE LEARNING ACCELERATES CYBERSECURITY

As society moves more services and data online, the attack surface for cyber criminals increases – presenting a major risk to organisations.

When cybersecurity start-up, Cydarm Technologies, identified alert triage as the key to efficient incident response, the team collaborated with APR.Intern to enlist the skills of Federation University Australia IT PhD candidate, Paul Black.

With over 30 years of technical experience in industry, mature-age student Paul was able to bring both new and well-seasoned programming approaches to the internship. The result was an innovative machine learning system, automating the severity assessment of security alerts.

THE PROJECT REALLY HELPED TO IDENTIFY THE TRANSFERABILITY OF MY NEW SKILLS AND MODERNISE MY THINKING

"Machine learning has become a critical aspect of cyber security research and the opportunity to put new theory to practice improved my techniques."

For Cydarm CEO and Founder, Vaughan Shanks, welcoming an APR.Intern allowed his business to rapidly develop a new end-to-end system, increasing efficiency via automated alert triage.

"Initial testing demonstrated accurate predictions and fine-tuning will cement validation for external use. The system's delivery within a short time frame was a great success," says Vaughan Shanks.

Cydarm Technologies saw value in Paul's skills and extended the project from four to five months to see completion.

Following his time at Cydarm Technologies, Paul was offered a security researcher position at the Internet Commerce Security Lab (ICSL) in Federation University Australia where he will draw from his experience solving industry problems with computing expertise.

This internship was supported by both the Australian Government and the Defence Science Institute, through its partnership with APR.Intern.

STATISTICAL CHALLENGES IN ASTRONOMY

New Statistical Approaches to Make Sense of Complex Data

PHOTO: PIXABAY

By Dr Sarah Martell and Dr Yanan Fan, UNSW

Astrostatistics is a growing field of research, driven by an increasing complexity in astronomical data sets and the development of new mathematical methods for data analysis and model fitting.

There are particular types of astronomy research that are well suited to an astrostatistics approach. These include fitting complex models (e.g. parameter estimation and uncertainty quantification for the spatial distribution and velocities of stars in the Milky Way), time series analysis (e.g. searching for the periodic Doppler-shift signal of a planet in irregularly-spaced radial velocity measurements of its host star), and morphological classification (e.g. classifying star clusters in images as symmetric, asymmetric, or not really clusters).

Astrostatistics focuses on the topics in astronomy that benefit most from statistical analysis, and astronomers tend to be enthusiastic about new statistical techniques and tools. Bayesian and Monte Carlo methods are commonly used for model fitting, Principal Component Analysis is standard for dimensionality reduction, and a number of methods including k-means, DBSCAN and Gaussian mixture modelling are popular for clustering analysis. More recent additions to the astronomical repertoire include t-distributed Stochastic Neighbour Embedding for dimensionality reduction, and phylogenetic classification, convolutional neural networks, and random forest algorithms for classification.

Large survey science is increasingly important in astronomy, and there are a number of ongoing and upcoming projects that will collect high-dimensional data for millions of stars and galaxies. Statisticians who specialise in topics such as dimensionality reduction, clustering algorithms and high-dimensional visualisation have a lot to offer, particularly to astronomers looking to find physically meaningful structure and unexpected outliers in extremely large data sets. The challenge is to develop new statistical tools that can scale well to the size and dimension of the data.

The workshop, *Statistical Challenges in Astronomy*, brought together both statisticians and astronomers to discuss and identify how the two disciplines could work together on the challenges in interpreting large and complex astronomical data sets.

One useful method that is not widely used in astronomy was the focus of the keynote presentation by Dr Daniel Foreman-Mackey, from the Flatiron Institute. He described the concept of Gaussian process regression, and how to use it to improve model fitting for astronomical data with correlated errors.

Using a Gaussian process, a data set is approximated with a combination of a mean model and a noise model, with a likelihood function that is a multivariate Gaussian. The covariance matrix for the data is populated according to a "kernel" with a shape that is set by the parameters of the noise model.

The likelihood function can be written as:

$$log\, p(\{y_n\}|\theta, a) = -\frac{1}{2} r_\theta^T K_a^{-1} r_\theta - \frac{1}{2} log\, det K_a - \frac{N}{2} log(2\pi)$$

where y_n are the data, θ are the parameters of the mean model, a are the parameters of the noise model, and r_θ are the residuals

between data and model.

$K_a = \sigma_n^2 \delta_{nm} + k_a(x_n, x_m)$ is the covariance matrix, where k_a is the kernel function.

This likelihood function can then be input into an optimisation algorithm to find the values for θ and a that best reproduce the data set. Scalability to large datasets with this method was also discussed.

A second method with the potential for wide application to astronomical data is the use of unsupervised learning methods such as SOPHE (Second Order Polynomial Histogram Estimator). Keynote speaker Professor Inge Koch described this method of constructing high-dimensional histograms, which efficiently handle problems with high dimensions and large sample sizes and can be used to detect clustering of the underlying data.

Although SOPHE was illustrated with examples from flow cytometry data, it is clear that such generic methods can be equally useful in astronomy, for example, when interest is in finding groups of stars with similar chemical properties.

The research talks at the workshop all featured open-source software written in either R or Python. Over the past ten years, sharing data and software has come to be widely accepted as good practice in the astronomical community, and the *Astrophysics Source Code Library* has steadily added ~200 new freely available codes per year, contributed by researchers. Community-supported libraries like *Astropy* have flourished, and the journals Astronomy and Computing and *The Journal of Open Source Software* were created to encourage the publication and citation of useful software written by the research community.

In the next ten years this trend toward sharing and transparency is expected to continue, with large survey projects producing freely available libraries of custom analysis tools for their publicly available data, as is already done by the NASA Kepler mission. □

This is a modified version of the feature that appeared in AMSI's 2017-2018 Research Report, which can be downloaded from amsi.org.au/research-report-2018

CASE STUDY: USING STATISTICS TO SPEED UP SPECTROSCOPIC DATA ANALYSIS

Large spectroscopic surveys are adding rich detail to our understanding of the stars in the Milky Way. In spectroscopy, the light from a star is dispersed by wavelength using diffraction gratings before being captured by a detector. The spectra of stars carry a lot of information about their physical conditions (surface temperature, surface gravity and elemental composition), and classically astronomers carry out a physical analysis of the spectrum: the strengths of individual absorption lines are used to determine the physical conditions based on a model of the structure of the stellar atmosphere. However, this process is time-consuming, and it is not practical for analysing the tens of thousands to millions of spectra acquired by current and future spectroscopic surveys. Astronomers are turning to mathematical methods to provide a non-physical analysis of the spectra that produces the same results as physical analysis much more quickly, without losing accuracy. tSNE is a dimensionality-reduction technique, and astronomers use it to group stars with similar spectra. The tSNE maps in Figure a show large groups, representing major phases of stellar evolution, and also small sets of outliers, which have spectra that are distinct from the large groups because of unusual elemental abundances or unusual physical conditions.

The tSNE method works by finding a low-dimensional (2D or 3D) coordinate system that retains as much of the information as possible from the original high-dimensional data by minimising the Kullback-Leibler divergence

$$C = \Sigma_i \Sigma_j p_{ij} \log \frac{p_{ij}}{q_{ij}} = \Sigma_i \Sigma_j p_{ij} \log p_{ij} - p_{ij} \log q_{ij}$$

between the joint probabilities p_{ij} in the high-dimensional space and q_{ij} in the low-dimensional space. For further explanation of the method, coding and example data sets see lvdmaaten.github.io/tsne/.

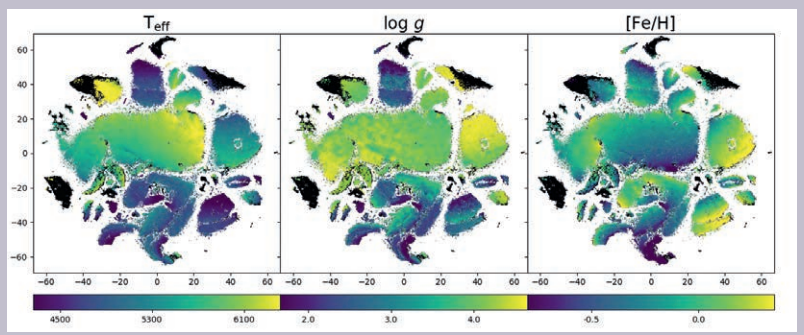


Fig a. A tSNE (t-distributed Stochastic Neighbour Embedding) map built using spectra (brightness as a function of wavelength) for 342,682 stars. The algorithm compares the spectra of the stars, and places one dot in this map for each star based on its spectral similarity to other stars. In this figure, the dots are colour-coded by surface temperature (left panel), surface gravity (centre) and heavy element abundance (right). While many stars are arranged in smooth distributions on this map, there are several smaller "islands" containing stars with spectra that are distinct in some way from the majority of stars. Figure from S. Buder et al. 2018, *Monthly Notices of the Royal Astronomical Society*, 478, p 4513 (arxiv.org/pdf/1804.06041.pdf), with data from the GALAH Survey (galah-survey.org).

KEY PRESENTERS

DR DANIEL FOREMAN-MACKEY

Daniel Foreman-Mackey is an Associate Research Scientist at the Flatiron Institute's Center for Computational Astrophysics (CCA) in New York (USA). His research focuses on developing novel data analysis methods and applying them to astronomical survey datasets.

PROFESSOR INGE KOCH

Professor Inge Koch has recently joined the University of Western Australia as Professor of Statistics and Data Science. Previously she held a part-time research appointment at the University of Adelaide and was the Executive Director of AMSI's Choose Maths initiative. Her research focus is on the statistical analysis of multivariate and high-dimensional data.

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