IMPROVING AUSTRALIA'S **MATHS GRADES**

OUT OF FIELD TEACHING IS RIFE—far worse than our OECD partners, Year 12 enrolments are at an historic low and most of our universities have failed the schooling system by dropping maths prerequisites. NAPLAN results show the dire shortfall in maths amongst indigenous children and adult numeracy amongst women is way behind that of men. How can we have retreated so comprehensively from our position in the 1970s and '80s when prerequisites were effectively universal and our universities graduated maths teachers in abundance, many with honours degrees? Have mathematics and statistics become less important to our social and economic well-being? Of course not! DEMAND FOR MATHEMATICAL SCIENCES GRADUATES IS AT AN ALL-TIME HIGH HERE AND OVERSEAS.

On so many fronts Australia is failing at mathematics

The answers to these questions lie in the unintended consequences of Australia's broken system of teacher workforce planning and the competition amongst universities for student enrolments.

For example, despite a majority of our secondary schools experiencing a severe shortage of properly trained maths teachers for over two decades, most state teacher registration boards do not record the discipline qualifications of registered teachers. Nor does the Commonwealth record the discipline profiles of students as they graduate from pre-placement training at faculties of education in our universities. The result of this planning vacuum is a national increase in educational disadvantage, with many schools unable to teach the maths subjects that lead to STEM careers. Australia cannot solely rely on its well-resourced public and private schools alone to supply mathematics graduates, especially to the teaching profession. It is high time our governments moved on from talking about funding models to decisive action on teacher supply.

Our universities must speak with one voice to our schools, telling parents, teachers and students that intermediate Year 12 mathematics is necessary for university study in science, engineering and commerce. The reintroduction of clear maths prerequisites for university study will emphasise the national and personal importance of mathematics and give us some relief from the insidious ATAR gaming that trips up many students.

As data and its analysis becomes increasingly important in the economy so has the demand for mathematical sciences graduates by our private sector. And increasingly, large companies are looking overseas to fill these new positions while our local mathematical workforce rapidly ages. So, Australia's business community must do its part by providing a local employer perspective on the exciting career paths for mathematics and statistics graduates. Only a culture change will turn around our shortage of these graduates, especially women, one of the worst in the OECD.

This culture change must extend to the way we think about mathematical sciences research. The governments of our major trading partners and allies have made the resourcing of mathematical research a national priority. This is because they, along with their private sectors, understand the critical importance of frontier mathematical and statistical knowledge. For too long in Australia mathematics has been part of the kitchen equipment but not on the national menu.

A WHOLE OF SYSTEM APPROACH IS THE ONLY WAY TO TURN AROUND AUSTRALIA'S FAILING GRADES IN MATHS

This policy document identifies key priorities for intervention by Australian governments and for action by peak bodies—commercial, educational, scientific and technological. And, importantly Australia's mathematical sciences community must redouble its advocacy and its initiatives to revitalize our discipline and its workforce.

This document should be read in conjunction with AMSI's annual ***Discipline Profile of the Mathematical Sciences*** **amsi.org.au/discipline_profiles** and the Academy of Sciences' ***Decadal Plan for the Mathematical Sciences (2016–2025)*** **amsi.org.au/decadal-plan-2016-25.pdf**

KEY PRIORITIES FOR INTERVENTION

PRIORITY A

Our Teachers

Support the unqualified teachers of secondary school mathematics; deal with the widespread maths anxiety among primary school staff and secure the future supply of properly trained maths teachers

PRIORITY B

Culture change

Restore university maths prerequisites from their historic low and turn around declining school mathematics enrolments

PRIORITY C

An equitable future

Increase the rates of graduation in the mathematical sciences, especially amongst women and Aboriginal and Torres Strait Islanders, to grow and refresh the quantitative professions

PRIORITY D

World class

Build and support world quality infrastructure on a national scale in the mathematical sciences and increase our international research engagement

PRIORITY E

Innovation

Boost the engagement of Australian business with mathematical sciences research and better equip our graduates with the coding and data skills for business careers

THE CASE FOR ACTION

PRIORITY A Repair the Teacher Workforce

At least 26 per cent of Year 7 to 10 maths classes don't have a qualified maths teacher, far too high for a subject that is of central importance[1]. The comparable international average is around 12 per cent. This statistic must be repaired as part of our STEM planning.

Out-of-field teaching is a national issue requiring national leadership

The situation is made worse because regional and low SES communities bear the brunt of the problem. Many secondary schools don't have a single maths graduate on the staff. Even if we could magically fill the gap, our schools are fully staffed and displacing current teachers is out of the question. There is only one solution to the immediate problem and that is to provide professional development to the many conscientious and professional educators teaching maths without the requisite content knowledge.

Very few undergraduate students in the mathematical sciences aspire to be school teachers. This was not the case when undergraduate numbers in maths were higher.

State and Federal governments must act together to solve the teacher supply problem

So why aren't prospective teachers choosing to be maths teachers? Without an answer to this question we will not be able to secure the future supply of mathematically well-prepared teachers. It's not hard to join the dots: is it the quality of maths teaching in school that is the turn-off? There is no shortage of quality biology teachers and a steady supply of potential biology teachers exists for the foreseeable future. The socio-economic and gender demographics that supply prospective teachers are unlikely to be well served by school mathematics, with well-resourced schools being less likely to produce future school teachers. This downward spiral must be arrested.

Too many of our primary school teachers suffer anxiety about their own grasp of mathematics. While maths hurdle requirements for entry into primary teaching are welcome, we must assist our practicing teachers and ensure that our faculties of education are giving a higher priority to mathematical preparation in pre-placement training.

We must recognise the scale and impact of primary teacher anxiety about mathematics

The insidious impacts of teacher maths anxiety are known but inadequately acknowledged. For example, the influence of female teachers' attitudes on young girls is well documented[2]. In particular, female teachers' apparent or latent maths anxiety affects girls more strongly than boys and is a partial explanation for girls' disengagement with maths—noticeable in the NAPLAN and TIMMS results between Years 3–5 when the performance gap begins. Since well over 80 per cent of primary teachers are female and many of them are themselves not mathematically well-prepared, the problem is significant and urgent.

PRIORITY B Restore Prerequisites

"Most universities have sacrificed their prerequisites to make it easier to enrol students. It has nothing to do with the goals of education, and everything to do with the incentives built into the funding and school-leaver assessment systems. If we corrected that market failure, schools would respond by improving mathematics teaching into early primary years."
Dr Alan Finkel, Australian Chief Scientist

The 20-year free fall in the enrolment share of the Year 12 calculus-based mathematics subjects, often referred to as intermediate or advanced, seems to have plateaued[3]. However, the 2016 share of enrolments is 29 per cent less than it was in 1996. This is one of the greatest challenges to the health of the STEM disciplines and professions in Australia and will bedevil plans for Australia to an innovative, science-based economy.

In response to this decline in enrolment share the majority of Australia's universities have dropped these subjects as formal prerequisites for science and engineering degrees[4] while continuing to assume the subject content. Only 14 per cent of science degrees have

1 Pages 24–27 of the *2017 Discipline Profile of the Mathematical Sciences*
2 Beilock, S. L., Gunderson, E. A., Ramirez, G., and Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences (PNAS)* of the United States of America, 107(5), 1860–63
3 Page 21 of the *2017 Discipline Profile*
4 Table 1.31 on page 24 of the *2017 Discipline Profile*

intermediate maths as a prerequisite and then only in Victoria and Queensland. This reactive policy has sent a negative and misleading message to schools about the value of these subjects.

Universities must phase in restoration of maths prerequisites

It is gratifying that the University of Sydney has joined some major interstate universities by introducing mathematics prerequisites from 2019 and we urge the other NSW universities to follow suit. AMSI is particularly encouraged by the strong position taken on prerequisites in the recent report[5] of the House of Representatives Standing Committee on Employment, Education and Training.

Fixing this problem will repair some of the imbalance in maths, physics and chemistry enrolments at Year 12, limit ATAR gaming by both schools and students and give some measure of protection to the future supply of STEM graduates by ensuring adequate preparation of incoming students. Prerequisites send an unequivocal message to school communities that universities value these subjects. Their phased re-introduction will, however, take some time and has to be matched to schools' access to trained teachers and community culture change.

Our future as a high technology, research driven economy depends on reversing this 20-year trend

Over more than 20 years we have seen:

- Widespread removal of prerequisites and their replacement by dubious "assumed knowledge" advice
- Widespread university course realignments to cope with increasing numbers of less mathematically literate students
- Reduced graduation rates in the mathematical sciences[6], which are all the more apparent when viewed in an international context[7]
- Stagnating interest in engineering and science courses, with some notable exceptions
- A concentration of university based research to a small number of institutions dangerously narrowing the support base for research training[8]
- Reduced intake of mathematically qualified graduates into teacher training programs, reduced numbers of qualified secondary school teachers, especially in regional and low SES areas, leading to fewer students in calculus-based mathematics subjects at Year 12[9]
- The unavailability of these school subjects in many regional and low SES areas

This situation creates a structural impediment to meeting Australia's galloping demand for highly skilled mathematics and statistics graduates. This puts a brake on the national productivity growth enjoyed by other OECD countries where mathematics and statistics graduation levels are, on average, twice as high as those in Australia.

PRIORITY C More Maths, Less Disadvantage

Australia has one of the lowest rates of mathematical sciences graduations in the OECD, and a correspondingly small workforce. Bachelor degree completions in the mathematical sciences have been falling with the 2014 figure at a 14-year low and 40 per cent lower than in 2003[10]. Participation rates by women and by Aboriginal and Torres Strait Islander (ATSI) students in university mathematical sciences courses are unacceptably low.

The mathematical sciences, government and employers must partner to improve community awareness of the value of and demand for our graduates

Correlated with the 20-year decline in Year 12 intermediate and advanced maths is the increasing age of Australia's mathematical sciences workforce[11]. To make matters worse the mathematics workforce is not attracting younger females in anywhere near the same way as other STEM fields[12]. The twin culprits are the shrinking participation rates in Year 12 intermediate and advanced maths and the low participation rate by female students in advanced maths at Year 12 (less than 7 per cent of Year 12 girls versus more than 13 per cent boys)[13].

We have lived with low female participation rates in mathematics for too long. As a consequence female adult numeracy is below that of males, by around 30 per cent in some

5 *Innovation and creativity. Inquiry into innovation and creativity: workforce for the new economy* (May 2017). House of Representatives Standing Committee on Employment, Education and Training.
6 Pages 34–39 of the *2017 Discipline Profile*
7 Pages 40–41 of the *2017 Discipline Profile*
8 Pages 53–55 of the *2017 Discipline Profile*
9 Sections 1.3 and 1.4 of the *2017 Discipline Profile*
10 Figure 2.18, page 36 of the *2017 Discipline Profile*
11 Figures 3.7 and 3.8, page 47 of the *2017 Discipline Profile*
12 Figure 3.9, page 48 of the *2017 Discipline Profile*
13 Figure 1.28, page 22 of the *2017 Discipline Profile*

age groups[14]. While we often think of mathematics as an enabling discipline the flip side is more important: mathematical illiteracy is disabling. An egalitarian society like ours can't tolerate this endemic disadvantage to women.

In terms of the national economy, it is widely recognised that weak participation by women in many of the STEM professions is handicapping Australia's productivity and competitive advantage.

Direct intervention is the only way to reverse this individual and collective disadvantage to Australia's women

The low participation of women in senior roles in the mathematical sciences continues to be a serious concern for Australian universities. AMSI supports the Science in Australia Gender Equity (SAGE) initiative of The Australian Academy of Science and the Australian Academy for Technological Sciences and Engineering.

AMSI is proud to be working with the BHP Billiton Foundation to increase the participation of girls and women in study and career pathways that involve mathematics and statistics. We encourage the private and public sectors to double their efforts to include women in Australia's STEM future. Mathematical sciences educators in schools and universities must face the problem squarely.

Improving the provision of mathematics teaching to ATSI communities must be a shared responsibility

Aboriginal and Torres Strait Islander students face enormous hurdles in mathematics achievement. For example, at Year 9 only 64 per cent of indigenous students in remote Australia met the national minimum standard compared to 97 per cent of non-indigenous students in remote locations. In very remote locations the situation is even worse with more than half of ATSI students failing to meet the minimum standard[15]. In part this is due to the extreme difficulty in staffing maths classes in these areas. On the other hand it is known that indigenous teaching support staff in regional and remote are usually locals in long term employment at their schools. AMSI's experience in remote schools is that these staff are willing to improve their mathematical literacy when the resources are made available.

The disadvantage is also reflected in the numbers of ATSI staff and students in Australia's university mathematical sciences departments. In 2015 AMSI members reported just four staff who identified as ATSI and 151 students out of more than 10,000 studying mathematical sciences subjects.

At the same time a recent report from Queensland[16] indicates that indigenous school teachers are more heavily influenced in choosing teaching by factors relating to social contribution and equity than their non-indigenous peers. Other research shows the importance of contextualising mathematics for indigenous students. A concerted national effort to work with indigenous school support staff and to recruit indigenous maths teachers from Australia's mathematical sciences departments should therefore be a priority.

PRIORITY D Build National Research Infrastructure

AMSI believes Australia needs dedicated and sustainable national research infrastructure in the mathematical sciences in the form of a distributed national research platform. We also contend that the National Collaborative Research Infrastructure Strategy (NCRIS) must explicitly support the technical mathematical sciences requirements of the Australian innovation system.

National Research Platform

The Academy of Science's *Decadal Plan for the Mathematical Sciences (2016–2025)* recommends:

> *"Australian universities should collaborate with the discipline to source seed funding for a new national research centre in the mathematical sciences with the objective of enhancing connectivity with industry and strengthening the international collaboration and visibility of Australian research in mathematics and statistics."*

Mathematical sciences institutes and centres have become internationally recognised as an effective means of providing the infrastructure for both discipline-based and cross-disciplinary research essential for innovation and training across many areas. While AMSI itself delivers national research training programs in many locations and at international standard and scale, our national research program is not as extensive as those of our OECD comparators.

14 Figure 3.3, page 44 of the *2017 Discipline Profile*
15 Tables 1.9, page 15 and 1.14, page 17 of the *2017 Discipline Profile*
16 Wyatt-Smith, C., Du Plessis, A., Hand, K., Wang, J., Alexander, C., & Colbert, P. (2017). *Why choose teaching? A matter of choice: Evidence from the field.* A report prepared for the Queensland College of Teachers. Brisbane, Queensland: Learning Sciences Institute Australia.

Publicly available funding for Australian mathematical sciences research is limited in range and leaves significant strategically important gaps in the support of the discipline. AMSI aspires to be the national platform delivering a range of programs which will fill those gaps and deliver financial support to many more of Australia's mathematical scientists both inside and outside our universities and in the spirit identified in the Decadal Plan. We use the word "platform" rather than "centre" to avoid confusion about the nature of the facility.

The recent establishment of the MATRIX institute as an international research station by the University of Melbourne and Monash University is a significant and welcome step forward in the provision of research infrastructure as is the ARC Centre of Excellence for Mathematical and Statistical Frontiers. Sustainability remains an issue and AMSI believes that long term funding for initiatives such as MATRIX is vital.

From page 25 of the *Decadal Plan*

International research centres in the mathematical sciences

Many of Australia's competitors have realised that advancement in the mathematical sciences requires the creation of a new type of research centre that is not often seen in other disciplines. These centres are characterised by the following attributes:

- They are nationally coordinated to support the research capabilities of the nation as a whole rather than just a few institutions.
- They are broad in their discipline focus, offering opportunities in a wide-ranging spectrum of fields at the leading edge.
- They are agile and responsive to the needs of fast developing research and collaboration.
- They are a cost-effective way of supporting individuals and institutions.
- They facilitate linkages across the innovation system in the mathematical sciences — among universities, government agencies and industry.
- They are tailored to national geography and discipline demographics.

Australia currently has no funding mechanism to support a centre along these lines. (The ARC Centre of Excellence scheme and the Cooperative Research Centres scheme are both designed to concentrate capability in a restricted range of fields.)

NCRIS Capability

There is a wide and deep mathematical sciences capability gap in the NCRIS. It is the "at scale", flexible engagement of mathematical sciences researchers with our innovation system in the age of data and computation. Reliance on the mathematical and statistical capacity of end users in the NCRIS Science and Research Priority areas, government agencies and in Australian businesses is inadequate to the task of dealing with the major mathematical challenges of disruptive technologies and those that come with new and emerging areas of science.

In particular, this direct engagement with the mathematical sciences needs to be an explicit capability in NCRIS. AMSI recommends the future establishment of an NCRIS centre which will provide technical support for the collaborations of mathematical scientists with end users from government agencies, universities and private sector on topics such as climate change to advanced manufacturing and national security[17].

PRIORITY E Boost Business Engagement

Released in 2015, the Australian Academy of Science's report on the importance of advanced physical and mathematical sciences to the Australian economy illustrated the enormous and pervasive impact of mathematical sciences research on the Australian economy[18].

Unfortunately, this stellar performance hides an alarming trend. At a time when our governments are trying to drive up the number of commercially employed research trained STEM professionals, domestic PhD numbers in the mathematical sciences have stagnated. As a proportion of PhD degrees in all fields of education, PhDs in mathematical sciences

17 See AMSI's response amsi.org.au/2016-national-research-infrastructure-roadmap-capability-issues-paper-response/
18 Tables 4.2 and 4.3, page 52 of the *2017 Discipline Profile*

Universities and businesses must improve engagement to maximize the economic benefits of mathematics and statistics

are losing ground as they do not attract the same interest as other fields of education[19]. As a result, Australian companies are increasingly sourcing skilled staff offshore or outsourcing their research capacity to offshore providers.

We must increase the penetration of our graduates into the business sector. This is essential to build a vibrant private mathematical sciences research sector with capability across industry priority areas such as data science, optimisation and computational mathematics. While industry collaboration remains a notional priority, the discipline's interest in the ARC's Linkage Grant scheme indicates little appetite to engage with business[20]. In turn, the business sector only invests a minuscule fraction (0.2 per cent) of its R&D expenditure on the mathematical sciences[21]. Engagement will require a significant change to both the technical and generic skills of our graduates and the willingness of the commercial world to invest in homegrown research and development in the mathematical sciences, a proven contributor to Australia's economy.

The Australian government's decision to fund 1400 PhD research internships from 2017–2020 and delivered by AMSI Intern is a welcome call to action for universities, companies and government agencies. AMSI Intern, along with the ATN universities' Industrial Doctoral Training Centre in the Mathematical Sciences, are evidence of our discipline's willingness to engage with the national innovation agenda.

19 Pages 38–39 of the 2017 *Discipline Profile*
20 Figure 4.11 and 4.12, page 56 2016 *Discipline Profile*
21 Table 4.4, page 53 of the 2017 *Discipline Profile*

IMPROVING OUR MATHS PERFORMANCE
POLICY MEASURES

The policy and action measures outlined here need to be undertaken in concert by the various stakeholders: it is our strong view that isolated measures will not be successful.

OVERALL MEASURES

1. State and Federal governments to establish a mathematics pipeline taskforce charged with strategic planning to overcome the endemic problems of maths teaching in our schools and the severe and chronic shortage of mathematical sciences graduates. **Action:** *Education Council, Science Council, DoET, DoIIS, State governments, OCS, UA, AEU, AAMT, AMSI, AIG, BCA, AustMS, SSA, AAS, ATSE, STA*

2. A five-year national awareness campaign for mathematics and statistics targeted at both the school and higher education sectors. This campaign will highlight the importance of school mathematics studies for a wide variety of careers and trades and encourage the provision of effective advice on subject choice at secondary and post-secondary levels. It will include a strong gender equity component. Professional development for both maths and careers teachers should be included. It will also highlight government incentives to study mathematics and statistics. **Action:** *DoET, DoIIS, ESA, State governments, research agencies, UA, AEU, AAMT and state teacher associations, AMSI, AIG, BCA, AustMS, SSA, AAS, ATSE, STA*

PRIORITY A Repair the Teacher Workforce

Immediate measures to relieve the urgent shortages:

1. Upgrade out-of-field secondary teachers, starting in low SES and regional areas and with those teachers needing the least discipline content (e.g. biology graduates with some maths/stats).
   a. State teacher registration boards to audit practicing teachers to determine geographic distribution of out-of-field teaching.
   b. University mathematical sciences schools to work with faculties of education state by state

to increase the strategic provision of mixed delivery graduate diploma and graduate certificate courses to provide professional development.

c. Make these courses HECS free on condition that teachers remain at their schools.
d. Set five-year targets for reduction of out of field teaching.
e. Provide a three-year "Golden Hello" for teachers completing their upgrade qualification.

Action: *Education Council, DoET, State governments, education faculties, AMSI member departments, DoC*

2. Implement key strategies to increase the number of suitably prepared undergraduates proceeding to school mathematics teaching, including provision of effective advice on subject choice. For example, students undertaking a biology/biological sciences degree and intending to become secondary teachers could be encouraged through concrete Commonwealth incentives to complete sufficient tertiary mathematics and statistics subjects enabling them to teach secondary school mathematics as well as biology. Include incentives to encourage early undergraduate commitment to pre-placement training. HECS-free honours year for those subsequently completing teacher training.

Commonwealth Department of Education and Training to commission audit to determine the capacity of universities to train secondary maths teachers and model the trends in graduation rates over the next 10 years.

Action: *DoET, Deans of Science, Deans of Education, UA*

Note: *Year 11 and 12 mathematics subjects should in general be taught by those with a major in mathematics and/or statistics see measure 6 below.*

3. The jurisdictions to work with the mathematics teacher associations and school principals to provide professional development for primary teachers aimed improving competency and reducing mathematics anxiety. **Action:** *Jurisdictions, AAMT and state teacher associations, primary school principal organisations*

Structural measures for long term improvement:

4. Golden hellos for new, qualified maths teachers working in "difficult to fill" positions.
Action: *DoET, State governments*

5. Jurisdictions to return to offering salary increments/incentives to encourage honours graduates and postgraduates to enter teaching within the public school systems.
Action: *State governments*

6. Every secondary school to appoint a maths/stats graduate in the role of discipline leader within five years starting with the most in need schools. Introduction of teacher (e.g. the UK's "Golden Hello" scheme) and school incentive programs. **Action:** *Education Council, DoET, State governments*

7. To qualify as a Year 11 or 12 teacher, mathematics graduates of pre-service programs must have a three-year undergraduate sequence leading to a mathematics or statistics major (50 per cent of total third year enrolment). Both mathematics and statistics must be represented in this sequence. All of these subjects must be taught by the provider's mathematics and statistics discipline. In addition, graduates must take at least one subject of mathematical pedagogical content knowledge as part of a full year's study in education. This may be part of an integrated four-year program or as part of a three + one-year degree plus graduate diploma-type combination. **Action:** *AITSL, Deans of Education, State governments*

8. To qualify to teach secondary mathematics at Year 10 level, graduates of pre-service programs must have at least two first year and two second year mathematics and statistics subjects, including at least one statistics and at least one second year mathematics subject. The education year requirements are as for Year 11 and 12 already outlined above. **Action:** *AITSL, Deans of Education, State governments*

9. University mathematical sciences schools to share resources to offer third year subjects specifically targeted at prospective teachers. Such subjects would present senior school mathematics from an advanced viewpoint. They would also be available to out of field teachers seeking professional development **Action:** *AMSI member schools, Deans of Education*

10. Every primary school is to have an embedded mathematics specialist (an individual with appropriate tertiary content qualifications) within five years, by appointment or training with "Golden Hello" or incentives upon completion of training. Incentives to schools.
Action: *Education Council, DoET, State governments*

11. Undergraduate degrees identified as including mathematical sciences content to be weighted in the calculation of GPAs for entry into postgraduate Diplomas of Primary Education.
Action: *Deans of Education, AITSL, UA*

12. Primary teacher pre-placement training mathematics content improved and standardised within five years. **Action:** *Deans of Education, AITSL, UA*
    a. Primary Bachelor of Education programs. Conventional entry from Year 12 must require a 70th percentile score in any Year 12 mathematics subject in the Australian Curriculum: Mathematics, except Essential Mathematics or current equivalent. **Action:** *AITSL, DoET, Deans of Education, UA*
    b. The program itself must contain two mathematics subjects, identifiably tailored to primary teaching knowledge requirements, at least one of which must be taught in the first year. These subjects should be delivered in conjunction with the provider's mathematics and statistics discipline centre and are the subjects referred to in the paragraph above. In addition, the program should contain three mathematics subjects with pedagogical content knowledge. **Action:** *AITSL, Education Council, DoET, State governments, Deans of Education*

PRIORITY B Restore Prerequisites

Immediate measures:

1. Set national three, five and ten-year targets for increased enrolments in Year 12 advanced mathematics subjects. Follow Queensland's success in this regard using a bonus point system. Individual universities work with their feeder schools to encourage increased enrolments, especially amongst girls. **Action:** *Education Council, DoET, State governments, UA, universities*

2. Identify regions with low or no enrolments in intermediate and advanced mathematics subjects in Year 12 and coordinate and fund shared provision of these subjects. Use NBN.
Action: *Education Council, DoET, State governments, DoC*

3. Reinstate universal Year 12 mathematics prerequisites for science degrees commencing five years after the introduction of the senior Australian mathematics curriculum. DoET incentives to do so. **Action:** *Deans of Science, UA, DoET, OCS*

4. Reinstate Year 12 advanced mathematics prerequisites for engineering degrees where appropriate, commencing five years after the introduction of the senior Australian mathematics curriculum. DoET incentives to do so. **Action:** *Deans of Engineering, Engineers Australia, UA, DoET, OCS*

Structural measures for long term improvement:

5. Introduce an undergraduate scholarship scheme for students studying mathematics or statistics. This scheme should contain a component intended for students who wish to study the discipline but have been unable to access advanced Year 12 mathematics subjects. The scholarships should be extendable into a postgraduate teaching qualification.
Action: *DoET, State governments, UA*

PRIORITY C More Maths, Less Disadvantage

1. Set three, five, and ten-year targets to increase female participation in advanced secondary school mathematics subjects, and university mathematics subjects.
Action: *DoET, State governments, UA*

2. Review the Year 11, 12 Australian Curriculum in mathematics and biology to strengthen linkages highlighting the importance of mathematics in biological applications.
Action: *ACARA*

3. The discipline's learned societies should explore the impact of professional accreditation on graduation rates in other disciplines in Australia and in other countries with a view to its widespread introduction in Australia. **Action:** *Australian Mathematical Society, Statistical Society of Australia*

4. Implement a nationwide careers awareness campaign targeting female students, parents, teachers and industry and the general community promoting the value of mathematics as a personal career choice or as multiplying career options, and as a pathway to national prosperity. The key messaging should focus on participation equity, innovation, national prosperity (increased GDP) and accessing an untapped pool of graduates. **Action:** *AMSI-BHP Billiton, DoET, DoIIS, ESA, State governments, research agencies, UA, AAMT and state teacher associations, AIG, BCA, AAS, ATSE, OCS, AustMS, SSA*

5. Take direct action to reverse secondary school teacher shortage by enticing the oversupply of biology graduates into university mathematics subjects to equip them with the mathematics required to teach. Since these graduates are predominantly women, some understanding of strategies for increasing participation of women will be necessary at university/lecturer level. A second strategy is to entice existing biology teachers to up their skills with a mathematics qualification. **Action:** *DoET, Deans of Science, Deans of Education, UA*

6. Develop a national strategy to increase the mathematics school teaching capacity in regional and remote Australia, particularly targeting areas with high ATSI enrolments. AMSI's member departments, ATSIMA, Faculties of Education and State and Federal governments to work together to increase ATSI maths teacher graduation rates. **Action:** *ATSIMA, AMSI member departments, State governments, DoET, PM&C, Deans of Education*

7. In regional and remote areas with high ATSI enrolments and high teacher turnover make mathematics professional development available to teaching support staff, in particular ATSI staff. **Action:** *ATSIMA, State governments, DoET, PM&C*

8. Develop a national strategy on the retention and promotion of women in STEM academia through the SAGE initiative and WiM. This will include the identification of specific structural barriers to female career progression. Undertake a national audit of AMSI departments measured against key statistics. Use the best performers as exemplars. Expect university STEM departments to achieve minimum standards, setting one, three, five and ten-year targets. **Action:** *SAGE, UA, STA, WiM, AMSI, SSA, ARC*

9. Introduce targeted measures aimed at increasing retention of female mathematical sciences students and supporting their progression from undergraduate study to honours, masters and PhD. Build national networks through established events and the Women in Mathematics Group. Introduce initiatives to specifically engage and support female students in the mathematical sciences—PhD scholarships, travel scholarships, access to childcare. **Action:** *DoET, DoIIS, AAS, AustMS (WiM), AMSI, SSA*

PRIORITY D Build National Research Infrastructure

1. AMSI and its membership should work with universities, governments and research agencies to resource AMSI as a distributed national research platform and to provide a sustainable basis for the operation of single site research centres such as MATRIX. **Action:** *AMSI, universities, ARC, DoET, DoIIS, State governments, AAS, ATSE*

2. NCRIS should explicitly include mathematics and statistics as a "capability" and resource it through the establishment of a collaborative facility to provide technical support for the engagement of expert mathematical scientists with end users in the government agencies and private sector in key areas of data science, optimisation and computational science. **Action:** *NCRIS, OCS, AMSI, government agencies*

PRIORITY E Boost Business Engagement

1. Embed commercialisation programs into existing university research training along with STEM research internships. **Action:** *Deans of Science & Engineering, UA, AMSI Intern*

2. Establish broad measures of impact of research that reward outcomes of commercial engagement while continuing to reward success in scholarship. **Action:** *ARC, UA, DoET, DoIIS, Science Council, OCS, STA*

3. Engage in sustained dialogue with private sector mathematical sciences graduate employers to improve technical and generic skills of graduates and establish research collaboration pathways. In particular, mathematical sciences departments should have direct lines of communication with employers and ensure that all our graduates have effective computing and data skills. With a view to the strategic growth of graduations, AMSI member departments should seek industry and agency collaborations in computationally driven developments like big data, large scale and long term simulations, industrial optimisation and design.
Action: *AMSI and its member departments, BCA, AIG, Deans of Science, DoIIS, OCS, DoET*

4. AMSI, its membership and the ARC to identify mechanisms to boost Linkage grant applications, especially in computationally driven areas like data science, large scale and long term simulations, industrial optimisation and design. **Action:** *AMSI Member departments, ARC, major employers*

5. Implement the recommendations of the AiGroup's June 2017 report[22] on School-Industry STEM skills partnerships, including professional development for teachers of mathematics and a national forum on STEM Education. **Action:** *OCS, AiGroup, Education Council, Deans of Education*

6. Provide dedicated allocation of Australian Postgraduate Awards (APAs) in mathematics and statistics to the universities to improve retention of domestic students from honours and masters programs. Incentives for universities which provide such a dedicated allocation from their own award program. Especially important in smaller and regional universities.
Action: *DoET, UA, Deans of Science, AMSI*

7. Provision of targeted HECS-free places for mathematics and statistics honours degrees or equivalent to improve retention of domestic students, especially women into PhD programs. Only effective for those continuing to higher study. **Action:** *DoET, UA*

8. Provision of stipend top-up on APAs to improve retention from honours and masters programs. This is particularly important in statistics where employment demand is severely reducing retention. **Action:** *DoET, UA*

9. Re-weighting of PhD funding in mathematics and statistics to match that in the physical sciences because of the heavy supervision burden. **Action:** *DoET, UA, Deans of Science*

Professor Geoff Prince
AMSI DIRECTOR
October 2017

22 *Strengthening School-Industry STEM Skills Partnerships (June 2017)*. Final report of a project commissioned by the OCS and delivered by the AiGroup

Abbreviations

AAMT	Australian Association of Mathematics Teachers
AAS	Australian Academy of Science
ACARA	Australian Curriculum, Assessment and Reporting Authority
AEU	Australian Education Union
ATN	Australian Technology Network
AITSL	Australian Institute of Teaching and School Leadership
AMSI	Australian Mathematical Sciences Institute
APA	Australian Postgraduate Award
AIG	Australian Industry Group - AiGroup
ATSE	Academy of Technological Sciences and Engineering
ATSI	Aboriginal and Torres Strait Islander
ATSIMA	Aboriginal & Torres Strait Islander Mathematics Alliance
AustMS	Australian Mathematical Society
BCA	Business Council of Australia
DoCA	Dept. of Communications & the Arts
DoET	Dept. of Education & Training
DoIIS	Dept. of Industry, Innovation & Science
ESA	Education Services Australia
GPA	Grade Point Average
HECS	Higher Education Contributions Scheme
IDTC	Industrial Doctoral Training Centre (ATN)
NCRIS	National Collaborative Research Infrastructure Strategy
OECD	Organisation for Economic Co-operation and Development
OCS	Office of the Chief Scientist
PM&C	Dept. of Prime Minister & Cabinet
SAGE	Science in Australia Gender Equity (AAS & ATSE)
SES	Socioeconomic status
SSA	Statistical Society of Australia
STA	Science & Technology Australia
STEM	Science, Technology, Engineering and Mathematics
UA	Universities Australia
WiM	Women in Mathematics

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