VISION FOR A MATHS NATION

This is an exciting time in Australia for the mathematical sciences, and for science, technology and engineering. We have before us the Chief Scientist's proposal for a comprehensive plan for STEM — *Science, Technology, Engineering and Mathematics: Australia's Future* — and a government which is responding to it. The next 12 months will tell if we can shrug off a history of piecemeal policies and programs tied to the electoral cycle. Will we move forward in a strategic way that connects long term strategies for innovation and competitiveness, education and training, research and international engagement, all underpinned by a commitment to STEM, or fail where our competitors are succeeding?

PRIORITY A

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

PRIORITY B

Train the unqualified teachers of school mathematics and secure the supply of future maths teachers

PRIORITY C

Increase the number of girls studying maths and women employed in the quantitative professions

PRIORITY D

Boost the engagement of Australian business with mathematical sciences research

The mathematical sciences are of critical importance to our human and economic capital. Not only is mathematics ***the*** enabling discipline, it has a vital productive role planning and protecting our well- being. But we need the Chief Scientist's vision to be realised for the mathematical sciences to deliver. By many measures Australia has been running a mathematical deficit for years: low adult numeracy, falling numbers of trained teachers and worsening school performance, low participation by women, a critically low number of graduates, lack of access for regional and low SES areas and uneven uptake of mathematical and statistical capacity by business.

Demand for mathematical and statistical skills far outstrips falling supply, and maintaining Australia's international competitiveness, security, population health and climate stability requires a mathematically literate population.

This policy document identifies key priorities for intervention by Australian governments and for action by peak bodies — commercial, educational, scientific and technological. AMSI believes that these priorities must be addressed as the Commonwealth plans and implements its *Vision for a Science Nation*.

This document should be read in conjunction with AMSI's annual 2015 Discipline Profile of the Mathematical Sciences ***WWW.AMSI.ORG.AU/DISCIPLINE-PROFILE-2015***.

THE CASE FOR **ACTION**

PRIORITY A: *RESTORE PREREQUISITES*

The 20-year free fall in the enrolment share of the Year 12 calculus-based mathematics subjects, often referred to as intermediate or advanced, continues (see Section 2.3 of the 2015 Discipline Profile of the Mathematical Sciences). 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 become a Science Nation.

In response, the majority of Australia's universities have dropped these subjects as formal prerequisites for science and engineering degrees (see Table 2.10 of the 2015 Discipline Profile of the Mathematical Sciences) while continuing to assume the subject content is known. Only 14 per cent of science degrees have intermediate mathematics 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.

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. Phased re-introduction of prerequisites will take some time and has to be matched to improvement in the teacher cohort and changes in community attitudes. Prerequisites do send an unequivocal message to school communities that universities value these subjects.

Over 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 (see Section 3.3 of the 2015 Discipline Profile of the Mathematical Sciences), which is all the more apparent when seen in an international context (see Table 3.23 of the 2015 Discipline Profile of the Mathematical Sciences),
- Stagnating interest in engineering and science courses, and a concentration of university based research to a small number of institutions dangerously narrowing the support base for research training (see Section 4.2 of the 2015 Discipline Profile of the Mathematical Sciences),
- Reduced intake of mathematically qualified graduates into teacher training programs and 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. (see Section 2.3 of the 2015 Discipline Profile of the Mathematical Sciences),
- 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 graduates with sound mathematical and statistical skills and it 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.

OUR FUTURE AS A HIGH TECHNOLOGY, RESEARCH DRIVEN ECONOMY DEPENDS ON REVERSING THIS 20 YEAR TREND.

PRIORITY B: *FIX OUT-OF-FIELD TEACHING*

At least 30 per cent[1] of Year 7 to 10 maths classes don't have a qualified maths teacher, far in advance of any other subject (see Section 2.4 of the 2015 Discipline Profile of the Mathematical Sciences). The comparable international average is around 12 per cent. This statistic must be repaired as part of our STEM planning.

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 and our schools are fully staffed, 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.

1. This figure is probably closer to 40% but the data is volatile at the time of preparation (August 2015).

OUT-OF-FIELD TEACHING IS A NATIONAL ISSUE REQUIRING NATIONAL LEADERSHIP.

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.

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 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.

STATE AND FEDERAL GOVERNMENTS MUST ACT TOGETHER TO SOLVE THE TEACHER SUPPLY PROBLEM.

PRIORITY C: *LIFT FEMALE PARTICIPATION*

We have lived with low female participation rates in mathematics for too long. The fact that female adult numeracy is below that of males, around 30 per cent in some age groups, is the consequence. (See Section 2.5 of the 2015 Profile). 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. Low female enrolments in Year 11 and 12 advanced mathematics are a principal factor.

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.

DIRECT INTERVENTION IS THE ONLY WAY TO REVERSE THIS INDIVIDUAL AND COLLECTIVE DISADVANTAGE TO AUSTRALIA'S WOMEN.

PRIORITY D: *INCREASE BUSINESS ENGAGEMENT*

The 2015 report by the Australian Academy of Science — *The importance of advanced physical and mathematical sciences to the Australian economy* — indicated that, of those business sectors based on a single core science discipline, mathematics and statistics accounted for five of the top seven by $18 billion value and were placed first, second and third, with a total annual value to the Australian economy of $25 billion, across the seven sectors (Table 4.2 of the 2015 Discipline Profile of the Mathematical Sciences). Of those sectors based on multiple science disciplines, the mathematical sciences ranked in all of the top eight with a total value of $57 billion per annum (Table 4.3 of the 2015 Discipline Profile of the Mathematical Sciences).

Unfortunately, this stellar performance hides an alarming trend. At a time when our governments are trying to drive up the number of research trained STEM professionals in the commercial world, domestic PhD numbers in the mathematical sciences have stagnated and overall PhD commencements in 2014 were the lowest for at least four years (Table 3.21 of the 2015 Discipline Profile of the Mathematical Sciences). They are still among the very lowest in the OECD and at half the OECD average. Australian companies are increasingly sourcing skilled staff offshore or outsourcing their research capacity to offshore providers.

UNIVERSITIES AND BUSINESSES MUST IMPROVE ENGAGEMENT TO MAXIMISE THE ECONOMIC BENEFITS OF MATHEMATICS AND STATISTICS.

We must increase the penetration of our graduates into the business sector and build a vibrant private mathematical sciences research sector in areas such as data science, optimisation and computational mathematics. Currently, the discipline's interest in the ARC's Linkage Grant scheme indicates little appetite to engage with business (Table 4.7 of the 2015 Discipline Profile of the Mathematical Sciences). Engagement will require a significant change to the work readiness of our graduates and the willingness of the commercial world to invest in homegrown research and development in the mathematical sciences, the proven contributor to Australia's economy.

POLICY MEASURES TO DELIVER **A MATHS NATION**

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. The Australian Government to deliver a national STEM policy as envisioned by Australia's Chief Scientist, Professor Ian Chubb, with bipartisan support in the Australian and state parliaments.
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. Include professional development for both mathematics and careers teachers. It will also highlight government incentives to study mathematics and statistics. (Action: DoET, DoIS, ESA, state governments, research agencies, UA, teacher associations, AMSI, AIG, BCA, AustMS, SSAI, AAS, ATSE, STA)
3. Establish a mathematical sciences committee to advise the OCS's National Science and Mathematics Education and Industry Adviser on all the policy measures in this brief and more. (Action: OCS, Science Council, DoIS, DoET, AMSI)

PRIORITY A *MEASURES*

Immediate measures:

1. Set national three, five and 10-year targets for increased enrolments in Year 12 advanced mathematics subjects. (Action: Education Council, DoET, state governments)
2. Identify regions with low or no enrolments in 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 5 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 mathematics subjects at Year 12. The scholarships should be extendable into a postgraduate teaching qualification. (Action: DoET, state governments, UA)
6. HECS-free places in those first year university subjects designed to bridge mathematically under-prepared students into programs requiring mathematics and statistics. (Action: DoET, UA)

PRIORITY B *MEASURES*

Immediate measures to relieve the urgent shortages:

1. Upskill out-of-field teachers, starting in low SES and regional areas and with those teachers needing least discipline content (e.g. biology graduates with some maths/stats). Identify qualification/content providers from amongst the universities. Utilise Commonwealth-State agreements, make the upskill subjects HECS free and utilise NBN for online provision. Involve ESA. Set five-year targets. Provide a "Golden Hello" for teachers completing their upgrade qualification. (Action: Education Council, DoET, state governments, DoC)

2. Measures to increase the number of suitably prepared undergraduates who could proceed to teach school mathematics, including the 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 for early commitment by undergraduates to pre-placement training. HECS-free honours year for those subsequently completing teacher training. (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 **4.** below.

Structural measures for long term improvement:

1. "Golden Hello's" for new, qualified mathematics teachers working in "difficult to fill" positions. (Action: DoET, state governments)
2. Jurisdictions to return to offering salary increments/incentives for honours graduates and postgraduates to enter the teaching profession in the public school systems. (Action: state governments)
3. Every secondary school to have a maths/stats graduate as discipline leader within five years. Start with schools most in need and offer incentives to teachers (e.g. the UK's "Golden Hello" scheme) and schools. (Action: Education Council, DoET, state governments)
4. In order to teach Year 11 and 12 mathematics, graduates of pre-service programs must have a three year undergraduate sequence leading to a major in mathematics or statistics (50 per cent of total third year enrolment). Statistics must be represented in this sequence with a minimum of two subjects (each 1/8 of an annual load), at least one of which must be at second year level. Mathematics must be represented by a minimum of five subjects, at least one of which must be taken at third year level. 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 3+1 year degree plus graduate diploma-type combination. (Action: AITSL, deans of Education, state governments)
5. In order to teach secondary mathematics to Year 10, graduates of pre-service programs must have at least two subjects at first year and two subjects at second year in mathematics and statistics including at least one statistics subject 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)
6. Every primary school to have a 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)
7. Identify undergraduate degrees with mathematical sciences content and weight these studies in the calculation of GPAs for entry into postgraduate Diplomas of Primary Education. (Action: deans of education, AITSL, UA)
8. Improve and standardise relevant mathematics content in pre-placement training for primary teachers over the next 5 years. (Action: deans of education, AITSL, UA)

   a. Primary Bachelor of Education programs. Conventional entry from Year 12 must require a 70 per cent 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 subjects of mathematics content, identifiably tailored to the knowledge requirements of primary teachers, 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 subjects of mathematics pedagogical content knowledge. (Action: AITSL, Education Council, DoET, state governments, deans of education)

PRIORITY C MEASURES

1. Set three, five, and 10-year targets for the number of girls participating in advanced mathematics subjects in secondary school, and women participating in mathematics subjects at university. (Action: DoET, state governments, UA)

2. Review the Year 11 and 12 Australian Curriculum in mathematics and biology to better reflect the importance of mathematics in biological applications. (Action: ACARA)

3. Implement a nationwide awareness campaign to help female students, their parents, teachers and potential employers, as well as the general public, understand the value of mathematics in career choice and personal and national prosperity. The key messages are around equity of participation, innovation and prosperity for the nation (increased GDP) and accessing an untapped pool of graduates. (Action: AMSI-BHP Billiton, DoET, DoIS, ESA, state governments, research agencies, UA, teacher associations, AIG, BCA, AAS, ATSE, OCS, AustMS, SSAI)

4. Directly address the shortage of teachers in secondary schools by enticing the oversupply of biology graduates into the mathematics subjects at university that will 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)

5. Develop a national strategy aimed at retaining and promoting women in STEM academia and identify structural impediments preventing female career progression. Use the Athena SWAN model (UK) to set national standards and undertake a nationwide audit of STEM departments measured against key statistics. Expect university STEM departments to achieve minimum standards, setting one, three, five and 10-year targets. (Action: AAS, UA, STA, AustMS (WiM), AMSI, DoET, DoIS, SSAI)

6. Introduce targeted measures to increase the retention of female students from mathematical sciences 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, DoIS, AAS, AustMS (WiM), AMSI, SSAI)

PRIORITY D MEASURES

1. Commercialisation programs embedded in university research training along with research internships for the STEM disciplines. (Action: deans of science and engineering, UA, AMSI Intern)

2. Establishment of broad measures of impact of research which reward outcomes of commercial engagement while continuing to reward success for scholarship. (Action: ARC, UA, DoET, DoIS, Science Council, OCS, STA)

3. Establish sustained dialogue with private sector employers of mathematical sciences graduates with a view to improving work–readiness of graduates and establishing research collaborations. (Action: BCA, AIG, AMSI, deans of science, DoIS, OCS, DoET)

4. AMSI to work with its membership and the ARC to identify mechanisms to boost Linkage grant applications.

5. Provide a 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)

6. Targeted HECS-free places for honours and equivalent in mathematics and statistics to improve retention of domestic students into PhD programs. Only effective for those continuing to higher study. (Action: DoET, UA)

7. Provide a 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)

8. Re-weight the funding of PhDs in mathematics and statistics to match those in the physical sciences because of the heavy supervision burden. (Action: DoET, UA, deans of science)

LIST OF ABBREVIATIONS

AAS Australian Academy of Science

ACARA Australian Curriculum, Assessment and Reporting Authority

AITSL Australian Institute of Teaching and School Leadership

AMSI Australian Mathematical Sciences Institute

APA Australian Postgraduate Award

AIG Australian Industry Group

ATSE Academy of Technological Sciences and Engineering

AustMS Australian Mathematical Society

BCA Business Council of Australia

DoC Department of Communications

DoET Department of Education

DoIS Department of Industry

ESA Education Services Australia

GPA Grade Point Average

HECS Higher Education Contributions Scheme

OECD Organisation for Economic Co-operation and Development

OCS Office of the Chief Scientist

SES Socioeconomic status

SSAI Statistical Society of Australia Incorporated

STA Science and Technology Australia

STEM Science, Technology, Engineering and Mathematics

UA Universities Australia

WiM Women in Mathematics

Professor Geoff Prince FAustMs,
AMSI Director
August 2015

MISSION

AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

THE RADICAL IMPROVEMENT OF MATHEMATICAL SCIENCES CAPACITY AND CAPABILITY IN THE AUSTRALIAN COMMUNITY THROUGH:

The support of high quality mathematics education for all young Australians

Improving the supply of mathematically well-prepared students entering tertiary education by direct involvement with schools

The support of mathematical sciences research and its applications including cross-disciplinary areas and public and private sectors

The enhancement of the undergraduate and postgraduate experience of students in the mathematical sciences and related disciplines

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