Submission

This is a joint submission representing the shared perspectives of the following organisations:

Aboriginal and Torres Strait Islander Mathematical Alliance (ATSIMA)
Australian Association of Mathematics Teachers (AAMT)
Australian Mathematical Sciences Institute (AMSI)
Australian Mathematical Society's Women in Mathematics Special Interest Group (WIMSIG)
Australian Maths Trust (AMT)

The comments below are reflective of our combined thoughts on the vital importance of diversity in STEM to a vibrant, robust and creative mathematical and scientific community and workforce.

Definition

Diversity is a key attribute of any group of individuals. We agree with the definition of diversity as per the Victorian Government's Diversity and Inclusion Strategy 2019 – 2021:

> *"Diversity is about what makes each of us unique and includes our backgrounds, personality, life experiences and beliefs, all of the things that make us who we are. It is a combination of our differences that shape our view of the world, our perspective and our approach. Diversity is also about recognising, respecting and valuing differences based on ethnicity, gender, age, race, religion, disability and sexual orientation. It also includes an infinite range of individual unique characteristics and experiences, such as communication style, career path, life experience, educational background, geographic location, income level, marital status, parental status and other variables that influence personal perspectives."*

Diversity in Science

Scientific research and invention are collaborative human endeavours. Diversity's importance in activating the type of creative and analytical problem solving required of scientists and mathematicians is well documented:

> *"…in a problem-solving context, a person's value depends on her ability to improve the collective decision. A person's expected contribution is contextual, depending on the perspectives and heuristics of others who work on the problem. The diversity of an agent's problem-solving approach … relative to the other problem solvers is an important predictor of her value and may be more relevant than her ability to solve the problem on her own…diversity in perspective and heuristic space should be encouraged. We should do more than just exploit our existing diversity. We may want to encourage even greater functional diversity, given its advantages."*
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> *"Groups of diverse problem solvers can outperform groups of high-ability problem solvers", L Hong, S Page, Proceedings of the National Academy of Sciences, 2004*

A general note regarding maths engagement in Australia

Mathematical capability is fundamental to and underpins access to and achievement across all STEM subjects at secondary and tertiary levels. Mathematics has always been the language of science, but science and technology require mathematics as never before (Australian Academy of Science, 2016). Put simply, without mathematics, there can be no STEM.

Furthermore, Australia's innovation agenda relies on a strong supply of mathematically capable graduates for the growing data and analysis driven workforce. Our future wealth and prosperity will be influenced by research commercialisation of Australia's intellectual property, to drive advancement in the new technologies that will reshape our lives.

Despite this context, Australia continues to struggle to effectively engage young people in mathematics education, with TIMMS data (Thomson et al, 2021) showing that 50% of Year 8 students do not like learning mathematics and only 13% like mathematics very much.

Groups under-represented in STEM higher education courses and careers also consistently report worse outcomes against these metrics: whilst 17% of Year 8 males report that they very much like mathematics only 10% of females and 7% of students from a low socio-economic background agree with this statement. Similar trends are seen for student confidence in their mathematical abilities with 18% of male Year 8 students reportedly very confident, yet only 9% of females and 4% of students from a low socioeconomic background expressing the same level of confidence in their mathematical abilities.

This disparity is critical as young people's decisions regarding participation in post-compulsory mathematics education is driven by these beliefs, more than by their previous mathematics achievement levels (Gore et al, 2017). The proportion of students taking more advanced, calculus-based levels of mathematics as their "highest" maths subject has been in long-standing decline, comprising just below 30% of the cohort.

One factor impacting mathematics engagement and participation is maths anxiety, which acts to drive many young people away from the subject and hence further study:

> *'People with heightened levels of math anxiety often experience a lifelong tendency to avoid math, math-related situations, career paths that require math, and most notably, courses and degrees in Science, Technology, Engineering and Mathematics. In short, there is evidence that math anxiety negatively impacts math performance and can influence how one experiences and interacts with the world.'*
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> *"Disentangling the individual and contextual effects of math anxiety: A global perspective", N Lau, Z Hawes, P Tremblay, D Ansari, Proceedings of the National Academy of Sciences, 2021*

Maths anxiety affects between an estimated 6 and 17% of the population (Buckley, S., 2020, *Mathematics Teaching Toolkit*, State of Victoria (Department of Education and Training), including male and female students. Meta-analysis suggests that not only do boys consistently report more positive attitudes to mathematics, but that girls report greater maths anxiety (Else-Quest, N., Shibley Hyde, J. and Linn, M.C., 2010, *Cross-National Patterns of Gender Differences in Mathematics: A Meta-Analysis*, Psychological Bulletin 136(1)).

Not only students, but teachers, in particular at the primary level, can experience high levels of mathematics anxiety, reporting a lack of confidence in teaching the subject and in avoidance behaviours and may unintentionally transfer these negative dispositions to their students (Gresham, G. Preservice to Inservice: *Does Mathematics Anxiety change with teaching experience?,*2018, Journal of Teacher Education 69(1))

Specific diversity contexts in maths

There is also significant disparity in mathematical achievement levels, with under-represented groups comprising students from low socio-economic areas, of Indigenous background and from remote areas, ranking respectively three years, two years and one and a half years behind the equivalent group in mathematical literacy (Phillippa Smith, 2018).

Despite clear evidence, and significant investment by Government, industry and sector bodies in bolstering STEM diversity, particularly in mathematics, there are still significant challenges in this space. We have outlined two specific dimensions of these challenges below.

Diversity in maths - from the perspective of Indigenous people:

Although there have been improvements, the educational gap between Indigenous and non-Indigenous students in Australia persists in reading and numeracy (Close the Gap Report, 2020, https://ctgreport.niaa.gov.au/literacy-and-numeracy).

This gap persists because the educational system does not cater for the Aboriginal and Torres Strait Islander students who are situated in diverse Communities. For example,

- In many remote and rural Communities, there is a high turnover of teachers and principals which adds to lack of continuity in the students' education.
- In many Communities, students are mobile for a range of family and cultural reasons, which is often seen as a problem. There is a need to understand this mobility and work with the Community to ensure continuity of education.
- The education system does not cater for first language speaking Communities i.e., there is no direct support for bilingual education for Aboriginal and Torres Strait Islander Communities.
- Similarly, there is no direct support for Communities to create a bilingual program to revive language.
- The are limited resources on mathematics education for Indigenous students that connects their cultural, their language and Community life with the teaching and learning of mathematics.

- The teacher training through universities does not prepare teachers to work effectively in Indigenous Communities.

There has been limited investment in mathematics educational programs that cater for Indigenous students. For example, the last two major projects funded by the Federal Government on mathematical resources for teachers had no requirement for resources centred on Indigenous education in mathematics. These projects were reSolve: Mathematics by Inquiry (https://www.science.org.au/education/academy-school-education-programs/resolve-mathematics-inquiry) and the Educational Services Australia Mathematics Massive Open On-line Course (MOOC).

Recently, the National Curriculum has included Aboriginal and Torres Strait Islander Histories and Culture as a cross curriculum priority in the mathematics curriculum. ATISMA is hoping this will lead to more investment in Indigenous education for mathematics.

Diversity in maths - from the gender perspective

In primary schools: Despite demonstrating little difference in mathematics performance, there are significant differences in motivation between primary school aged boys and girls with girls reporting less self-efficacy, intrinsic motivation and higher mathematical anxiety than boys. [Gender Differences in Mathematics Motivation: Differential Effects on Performance in Primary Education, Frontiers in Psychology, 2020, S Rodriguez, B Reguero, I Pineiro, I Estevez, A Valle]

In high schools: There is a “persistent gender gap” between the percentage of male versus female high school students studying higher mathematics. In 2018, around 12% of male high school students were studying higher mathematics, compared to around 7% of female high school students. These percentages are almost unchanged over the preceding decade. [AMSI Report 2020, Fig 1.27]

Undergraduates in tertiary education: In 2018, women made up 38% of undergraduate students in the mathematical sciences (excluding honours), and 28% of honours students. The undergraduate percentage is a slight increase from 34% in 2012. [AMSI Report 2020, Fig 2.15 and Fig. 2.19.]

Honours and two-year coursework masters degrees: In 2019, women made up only 41 of the 204 completions of Honours and two-year coursework masters degrees from Australian universities (20%). This represents a large decrease compared with 2012, when women accounted for 71 of the 197 (36%) completions [Johnston (2013)].

Postgraduates: In 2019, of 145 PhD completions in mathematics in Australia, only 45 were by women, or 31%. Similarly there were 45 PhD completions by women in 2018. While the number of PhD completions is on an upward trend, the number of female completions seems to be static [Johnston (2020)]. For example, in 2015 there were 117 completions of PhDs in mathematics in Australia, of which 43 were by women, or approximately 37% [Johnston (2016)].

Academic staff: Across Australia, the proportion of academic staff in mathematical sciences roles who are women in 2018 was as follows, by level: 29% for casuals, 30% at Level A, 31% at Level B, 27% at Level C, 18% at Level D, 10% at Level E. [AMSI Survey 2018, data from 24 universities, quoted in AMSI Report 2020 Fig. 2.6]. There have been some gains: the percentage of Level D staff who are women has risen from 13.2% in 2013 (17.4% in 2015). However the percentage of Level E staff who are women has only increased slightly in that time and women remain significantly under-represented, in particular in more senior roles. Furthermore, research funding exacerbates these inequalities with analysis indicating that senior women researchers are less successful in accessing Discovery Project funding than their more junior male colleagues.

What we are doing to support diversity in Australian maths education

ATSIMA initiatives

ATSIMA's vision is for all Aboriginal and Torres Strait Islander students to be successful in mathematics. To meet this vision, ATSIMA programs are centred on the connection between mathematics and culture and ensuring that the teaching and learning of mathematics is connected to the local cultural of the students. ATSIMA has a membership base of around 1200 people.

ATSIMA has developed a paper that outlines its strategic direction and the four key initiatives it is delivering in mathematics education:

1. **Professional learning program:** This training provides professional development for in-service teachers on how they can teach mathematics from a cultural perspective in connection to their students and work with local Indigenous people to connect their knowledge to the teaching and learning of mathematics. ATSIMA is currently completing a project in partnership with NSW Education Department and Connected Community Schools across rural and remote NSW and will be work with the ACT and SA Education departments on a professional learning program. ATSIMA is also engaged by Schools directly.
2. **Resource Development:** There is a paucity of resources that connect the culture of the learner to the teaching and learning of mathematics. ATSIMA is currently developing these resources in connection to its professional learning program and another resource projects funded by GHD.
3. **ATSIMA Schools:** This program is still under development. The ATSIMA Schools program is for individual schools to make a commitment to Indigenous education in mathematics and to share success and facilitate training across a cluster of schools in the local area.
4. **STEM Camps:** ATSIMA, in partnership with the NSW Aboriginal Education Consultative Group (AECG) and the NSW Education Department, developed a series of STEM Camps for Indigenous students in NSW. These camps gave Indigenous students the opportunity to work with Elders, Indigenous professionals in STEM fields and Indigenous cultural knowledge holders on a series of STEM workshops over three days. These camps gave students hands-on experience of

STEM in connection to Indigenous culture. ATSIMA is currently work on developing this program on a national scale.

ATSIMA also runs a biennial conference to bring together people across the education system to share ideas and develop new ways forward. The next conference will be this year and held in Yirrkala, Arnhem Land, NT (9 to 11 October 2023).

AAMT initiatives

Nationally, AAMT advocates for all teachers and students for quality mathematics education and in particular, for those traditionally under-represented or disadvantaged in their mathematics learning.

AAMT specifically supports diversity by developing teachers' skills and knowledge teaching mathematics, through the provision of a range of professional learning activities across the country. Targeted presentations at state and national mathematics conferences focus on strategies and pedagogies to engage all students in authentic, motivating and challenging mathematics and in turn, to promote confidence and skill in mathematical activity.

The Focus on Maths program is an AAMT initiative targeted specifically at groups under-represented in mathematics and wider STEM learning. In this program, teachers and school communities apply for funding to support teacher professional learning to improve mathematics pedagogy, based on their locally identified and immediate needs. Applications are prioritised from schools in low socio-economic areas, rural, regional and remote schools and from schools with a high proportion of Aboriginal and Torres Strait Islander students, helping target areas of greatest need and potential impact.

AMSI initiatives

AMSI has had great success in delivering major projects, in conjunction with its partners, in order to help overcome gender imbalances in the mathematical sciences pipeline. Some examples are:

AMSI's Choose Maths program (2015-2020), funded by the BHP Foundation, involved school intervention in a limited number of geographic locations as well as national campaigns around career and gender awareness. This predominantly school-based program articulated into the tertiary sector through Choose Maths scholarships for women to attend AMSI events such as the Summer School, and through mentoring by female tertiary staff and students of schoolgirls.

AMSI's DESE funded *Securing Australia's Mathematical Workforce* (2016-21) program, supported 22 flagship events and attracted 2570 participants, to train Australia's expanding mathematical sciences workforce. AMSI delivered an extensive program of research training schools and scholarships, industry focused symposia, and advanced online subjects, to grow the nation's public and private sector workforce with advanced skills in the mathematical sciences and provides increased opportunities for female, First Nations and regional, rural and remote students.

AMSI's industry engagement arm, APR.Intern. successfully delivered the DESE funded National Research Internship Program (2017-2021). In delivering this program APR.Intern

successfully scaled to a national level, by delivering 650 internships to 340 different industry partners. The program also lifted the female STEM intern participation rate from 35% to 40% over the four-year period.

In 2023 AMSI was successful in winning a $1m grant, as part of the Federal Government's *Women in STEM and Entrepreneurship (WiSE)* grants program. The funding will see 113 women in STEM postgraduate research students placed into industry internships and receive entrepreneur training through APR.Intern. The funding will allow APR.Intern to expand its focus on gender diversity and increase the percentage of women in industry internships to 45%. Another aspect of the grant will be the Women in STEM Careers and Entrepreneurship Workshop which will increase research commercialisation skills, networks and knowledge among a wide group of female STEM postgraduate students.

WIMSIG initiatives

WIMSIG supports the following initiatives in support of women reaching their full potential as mathematicians:

Since 2014, WIMSIG has provided travel funding to more than 40 women mathematicians through the AustMS WIMSIG Cheryl E. Praeger Travel Awards, as well as supporting childcare costs related to conference attendance through the AustMS WIMSIG Anne Penfold Street Awards. In 2019, the AustMS WIMSIG Maryam Mirzakhani Award was established, to support international women students pursuing a postdoctorate degree in mathematics in Australia.

The WIMSIG Conference 2017, held at the University of South Australia, was the first mathematical conference in Australia in which all research talks were given by women. Attended by 190 participants from 10 countries, it was an inspiring and supportive event which received overwhelmingly positive feedback. The WIMSIG Conference 2021 was held at Monash University (postponed from 2020 due to the pandemic).

WIMSIG launched a mentoring scheme in 2020, with 25 mentor-mentee pairs in the pilot year.

AMT initiatives

The AMT (the Trust) has been delivering the Curious Minds program since 2015. Curious Minds is a Federally funded six-month academic and mentoring program for high performing young women in Y9 and Y10 from underrepresented cohorts, particularly from regional, remote, low socio-economic and Indigenous backgrounds. From 2015 - 2020, a total of 421 young women had participated in the program, with 49% of participants from low-SES schools, 4% of participants identifying as Indigenous and 14% of participants with English as their second language. This cohort reported a 30% increase in the enjoyment of mathematics after completing the course and 93% of the participants reported they were enrolled in or had already completed Y11/Y12 STEM subjects. From 2021, the program has increased its annual intake (from 60 to 120) with more than double the number of 22/23 program applicants for available spots.

In 2018, with support from the Government and corporate sponsors, the Trust began training and supporting an Australia team's participation at the European Girls' Mathematical Olympiad. Since this time, 16 young women have had the opportunity to compete at the premiere international pre-tertiary female-only mathematical competition, winning 15 medals, including a gold clean sweep in 2022. Australia's ranking in this competition from 2018 – 2022 is as follows: 20th, 14th, 12th, 12th and 3rd respectively.

Since this program has started, more than 100 young women have participated in the Trust's mathematical Olympiad programs and there has been a threefold increase in women teaching into the program. Numerous alumni have gone on to pursue maths and computer science degrees here in Australia and abroad. We are now making preparations to support an Australian team to participate in the European Girls' Olympiad in Informatics.

Recommended actions to address diversity in mathematics

1. For the support of underrepresented student populations in maths, provision for targeted training of pre-service teachers on how to identify and mitigate maths anxiety, encourage position dispositions towards mathematics in the classroom and build maths confidence as part of their university training, particularly for primary school teaching degrees.
2. For the support of underrepresented student populations in maths, provision for micro-credentials for practising teachers on addressing maths anxiety and building maths conference in the classroom.
3. Continued investment in dedicated mathematical education programs, training, mentoring activities and extracurricular opportunities that identify, support and celebrate under-represented populations' rich engagement with maths, especially in primary school and the early years of secondary school.
4. Universities and their accreditors must push for gender equity at all university levels, particularly in professorial roles. This will require care in hiring and promotion decisions, and attention to the climate for women in mathematics departments as they seek to attract, retain, and progress talent. This work must be done by Deans, Provosts, Heads of Schools, and other university leaders.
5. The Australian Government, and the Office of Women in STEM should consider inducements to grow the female proportion of PhD completions in the mathematical sciences.
6. Professional societies in mathematics and statistics must monitor the fraction of members, prize winners, committee members, and so on, by gender, and work to nominate women. Best practices for identifying and including women should be actively used to increase these fractions. Codes of conduct for meetings, activities, and membership should become the norm.
7. Work must be done in schools to make mathematics more attractive to girls – as well as to boys, as a strong foundation in mathematics is very important to making progress in STEM in the future.
8. The Australian government should consider further initiatives to grow the proportion of female mathematics graduates in the workforce.