AMSI CHOOSE**MATHS** RESEARCH

[*No. 5 - 2019*]

Gender Report 2019
Mathematics and Gender: Are Attitudes and Anxieties Changing towards Mathematics?

Inge Koch, Editor

AMSI AUSTRALIAN MATHEMATICAL SCIENCES INSTITUTE

Executive Summary

The under-representation of girls and women in high level mathematics courses in secondary school, in university mathematics degree programs, and in mathematics-related careers in many western countries is of concern for economic and gender equity reasons.

The partnership between the Australian Mathematical Sciences Institute (AMSI) and the BHP Foundation is working to build mathematical capability and increase participation of girls and young women across the mathematical sciences pipeline from classroom to industry through the Choose Maths project. To meet industry demand for highly capable graduates with increased STEM skills, the Council of Australian Governments (COAG)—in its 2018 report: *Optimising STEM Industry-School Partnerships: Inspiring Australia's Next Generation*[1]—recommends partnerships between government, industry associations and education authorities in order to develop and promote a better understanding of the STEM skills required:

- to solve real world problems
- to advance in careers that may not seem to need mathematical or more general STEM skills, and
- to provide guidance on ways of engaging under-represented groups such as women

With a focus on Australian data from teachers and students in Choose Maths schools, this report reviews and examines likely causes—including maths anxiety and lower confidence in the mathematical abilities of female students and primary teachers—of the lower interest, participation and achievement of girls and young women in mathematics and it proposes methods for addressing and remediating these barriers.

1 Education Council (2018). *Optimising STEM Industry-School Partnerships: Inspiring Australia's Next Generation Final Report*. Retrieved from (educationcouncil.edu.au/site/DefaultSite/filesystem/documents/Reports%20and%20publications/Publications/Optimising%20STEM%20Industry-School%20Partnerships%20-%20Final%20Report.pdf)

Maths anxiety is an impediment to achievement. It begins in early primary school and affects girls more than boys. Though no evidence exists of differences in mathematical ability between boys and girls, gender disparity in mathematics performance is evident from Year 3, but the gap could have started earlier. The gender gap in self-confidence with regard to mathematical ability widens around the time maths anxiety begins to develop and is accompanied by a decrease in positive attitudes and engagement in mathematics of girls.

Evidence from research and Choose Maths data shows that change is possible: in improving teachers' mathematical skill base and reducing their maths anxieties, and in increasing students', and in particular, girls' confidence in their abilities and impacting on their attitudes towards and engagement in mathematics.

The negative impact of teachers with maths anxiety on their same-gender primary students' attitudes, beliefs and on their mathematical achievement is well documented. Of significant concern, these findings demonstrate an urgent need for action on the side of teacher educators and governments to:

- provide in-service teachers with access to ongoing support
- equip pre-service teachers with solid knowledge of mathematics and good teaching practices
- empower teachers and students with methods to reduce maths anxiety and increasing self-efficacy

Reducing maths anxiety in teachers and, in particular, female students, has the potential to increase confidence in abilities, interest and engagement resulting in a flow-on effect on achievement and participation.

Contents

This report was edited for CHOOSEMATHS by Inge Koch from the Australian Mathematical Sciences Institute (AMSI).

Cover by Dr Marcus Volz (visualisation of submissions for the Choose Maths Awards by postcode area).

CHOOSEMATHS is a joint initiative of AMSI and the BHP Foundation. CHOOSEMATHS.ORG.AU

Suggested citation:

Koch, I. (Ed) (2019). *Choose Maths Gender Report: Mathematics and Gender: Are Attitudes and Anxieties Changing towards Mathematics?* Melbourne: Australian Mathematical Sciences Institute.

ISBN: 978-0-7340-5555-2 (PRINT)

ISBN: 978-0-7340-5556-9 (DIGITAL)

Further queries regarding permissions and availability: media@amsi.org.au

Australian Mathematical Sciences Institute

Highlights

1

Maths anxiety of 15-year-old students has grown to about 33 per cent over the last 15 years

2

Strategies which reduce the negative effect of maths anxiety on performance are beginning to show positive effects

3

Maths anxiety starts early in primary school

4

Maths anxiety is an impediment to achievement

5

Achievements of maths anxious students often fall short of their abilities

6

The gender gap in mathematics performance is much smaller than that in confidence and maths anxiety

7

Higher levels of maths anxiety in teachers are related to lower achievements especially of same-gender students

8

Interventions which address attitudes, beliefs and confidence building of teachers and students have been shown to be effective

9

Mentoring and Choose Maths Days are effective in engaging students' interest in mathematics

Recommendations

Supporting our Students

Strengthen students' beliefs in their mathematical abilities and increase their enjoyment of mathematics through:

- Improving access to learning resources with a focus on aptitude and engagement to decrease maths anxiety
- Increasing access to positive role models
- Disconfirming traditional gender stereotypes and strengthening girls' interest in STEM through career awareness
- Increasing access to Choose Maths Days and Choose Maths Mentoring, particularly for girls, to increase students' confidence and interest in mathematics

Supporting our Teachers

Support pre-service and in-service teachers by:

- Ensuring pre-service teachers can gain a solid knowledge of mathematics and access to effective teaching methods and practices to meet students' needs
- Providing all teachers with better information about the effects of maths anxiety, stereotype threat and low self-confidence on student achievement
- Increasing access to information and strategies to support teachers in reducing their own maths anxiety and that of their students
- Providing common training to primary and secondary pre-service and in-service teachers to support transition of their students from primary to secondary school
- Improving access to positive reappraisal and growth mindset resources to support mathematics learning, and to increase the enjoyment and engagement of students

Supporting our Parents

Promote parents supporting their children in learning mathematics by:

- Providing better information regarding the effect of maths anxiety, traditional gender stereotypes and low self-confidence on student achievement, especially for girls
- Contributing to positive home learning environments through the development of resources to support parents in fostering positive appraisal and growth mindset learning
- Encouraging stronger communication between teachers and parents to affect change in attitude and behaviour towards mathematics
- Empowering parents to support learning through access to mathematical activities that encourage engagement and interest of their children in mathematics

Main Findings

Maths Anxiety: Students, Pre-Service and In-Service Teachers

Maths anxiety affects brain activity, and results in a 'performance deficit' which can lead to achievement below actual abilities (Section 2.2)

Maths anxiety starts in the early years of school and is an impediment to achievement (Section 2.3.1)

Environmental non-genetic factors play a greater role in development of maths anxiety than genetic risk factors (Section 2.3.1)

Maths anxiety in 15-year-old students has increased from 2003 to 2012 among all students and the gender gap has widened over time (Section 2.3.4)

Teachers have some of the strongest influence on student achievement (Section 2.3.5)

High maths anxiety in teachers may result in lower mathematical achievement in students (Section 2.3.5)

While there is no evidence linking maths ability to gender, girls are more maths anxious and less confident in their mathematical ability than boys (Section 2.3.5)

Pre-service teacher training should include knowledge of mathematics, as well as best teaching practices and methodologies proven to reduce maths anxiety (Section 2.5.4)

Stronger mathematical knowledge typically increases teacher confidence and reduces anxiety in teaching practices (Section 2.6)

Mathematics, Gender and Mathematics Education Workshop 2018

Maths anxiety and gender stereotypes have equal impact on performance (Section 3.2.2)

Developing an appreciation of mathematics and its beauty may encourage students to choose maths (Section 3.2.3)

Appropriate intervention may effectively address maths confidence and attitudes in both teachers and students (Section 3.2.4)

Psychological strategies can be effective in reducing negative effects of maths anxiety on performance (Section 3.2.5)

Schools Outreach is effective in improving teachers' confidence and skill level (Sections 3.2.4 & 3.3.3)

Insight into the factors that influence student participation are required in order to increase their engagement with mathematics (Sections 3.2.6 & 3.2.7)

Choose Maths Research Symposium at MERGA 2018

Intervention based on growth mindset ideas are effective in changing, in particular, girls' attitude to and confidence in mathematics (Section 4.3.1)

Previous mathematics achievements, according to teachers' beliefs, are the most influential factors in students choosing mathematics (Section 4.3.2)

Choose Maths Days for Year 9 and 10 Students in Australian Universities and Schools in 2018

Choose Maths Days had the strongest positive effect on female student engagement and enjoyment of mathematics (Section 5.4.1)

Student attitudes to mathematics can be more positively influenced in Year 9 than Year 10 (Section 5.4.1)

More than 25 per cent of students surveyed following Choose Maths Days said they planned to take higher mathematics courses in Year 11 and Year 12 as a result of participation in these events (Section 5.4.2)

1 Introduction

Women and girls are severely under-represented in science, technology, engineering and mathematics (STEM), with mathematics, computer science, physics and engineering most affected by this inequality. The life sciences are an exception to this pattern of female under-representation – at least as far as girls and young women in secondary and tertiary education are concerned. As well as being the central enabler within STEM, mathematics is a powerful discipline in its own right.

AMSI's Choose Maths project with the BHP Foundation addresses this under-representation of women by aiming to increase participation of girls and young women in mathematics and cognate disciplines across the pipeline from school and university education to the workforce. Funded until 2019, the project has a staff of 18 including 11 experienced primary and secondary teachers. Choose Maths comprises the four components A to D below:

A. Mathematics-Ready Teacher Professional Development

- AMSI Specialists (experienced primary and secondary teachers, referred to as Schools Outreach Officers) working in 120 schools in 13 regions across regional and urban Australia to deliver:
  - Mathematics-ready primary and secondary school teachers armed with strategies to encourage increased participation of students, particularly girls
  - Enhanced teacher knowledge and confidence in mathematics and in techniques that will enhance girls' experience of mathematics at school
  - Dissemination of key messages to a wide stakeholder base

B. Women in Mathematics Career Awareness Campaign

- A nation-wide awareness campaign drawing on behaviour-change strategies with the following results:
  - An educated Australian public, excited with the knowledge of the importance of mathematics and an understanding that mathematics enhances career options and is a critical choice pathway to STEM
  - Positive parental influence on student choices leading to more students, especially girls, choosing to study mathematics and STEM-related careers
  - Removal of the gender stereotype tightly held by Australians with regard to mathematics

Figure 1.1 The components of Choose Maths and interaction with research

C. Inspiring Women in Mathematics Network

- A role-model network, established to nurture:
  - School girls and young women inspired to seek the opportunities mathematics offers
  - Increased number of girls who choose to study Year 11 and Year 12 mathematics

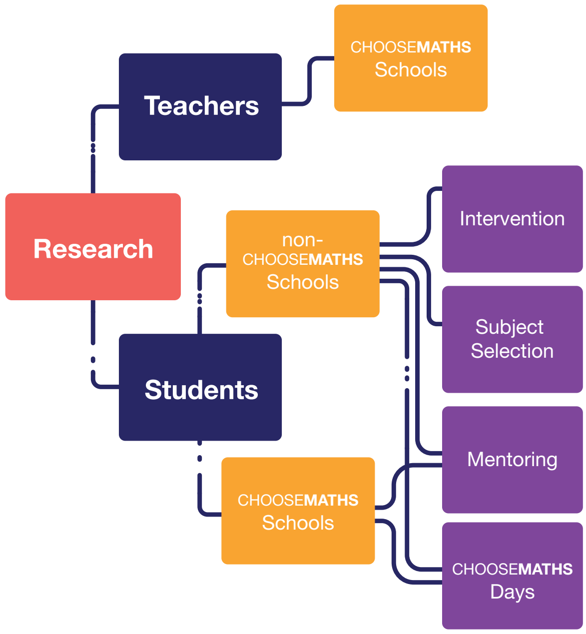
D. The Annual BHP Awards for Excellence in the Teaching and Learning of Mathematics (now known as the Choose Maths Awards)

- The Choose Maths Teacher Awards reward innovative and creative teachers who are highly successful in motivating and inspiring students in mathematics
- The Choose Maths Student Awards celebrate mathematical achievement, creativity and excellence in Australian schools. The awards encourage students to get creative as they step beyond the classroom to bring their understanding of mathematics to life

Choose Maths Research interacts with the four components shown in Figure 1.1 and informs future directions and priorities.

Figure 1.2 provides a more comprehensive view of the Choose Maths research including students and teachers beyond the Choose Maths schools, and other components such as the subject selection surveys of Year 10 and 11 students, the mentoring of Year 9 and 10 students, and the Choose Maths days at universities and schools.

Figure 1.2 Choose Maths research, students and teachers



The much lower participation rate of girls in advanced mathematics subjects and more generally the under-representation of women in mathematics can be traced back to the early years of primary school when the gender gap in mathematics performance becomes apparent. The causes of this difference are not clearly understood, however it appears that maths anxiety and lack of confidence in girls plays an important role in decreasing girls' interest and enjoyment of mathematics well beyond the primary school years. Maths anxiety has been shown to be a barrier to achievement, and the gender gap in mathematical confidence is larger than disparities in interest and achievement in primary school. These findings suggest that interventions which reduce anxiety and increase confidence in girls should begin early and be ongoing.

In this report we look at mathematics, gender, attitudes and beliefs of students and teachers from different perspectives with the aim of improving our understanding of how to increase the enjoyment of students in mathematics while decreasing negative attitudes, especially of girls. We complement the more theoretical ideas with Australian data, including the analysis of findings from Choose Maths schools and Choose Maths activities.

This report includes contributions from a variety of stakeholders across different platforms. The opinions expressed in individual sections are those of the authors and do not necessarily represent the opinions of AMSI or the editor of this report, but contribute to the body of knowledge on addressing and reversing disengagement trends and increasing participation of girls in mathematics.

Section 2 reviews research findings of maths anxiety in students, pre-service and in-service teachers, and looks at the transmission of maths anxiety from teachers to students. We examine relationships between maths anxiety and other concepts such as gender stereotypes, confidence and impact on achievement and we provide evidence of the negative effect of maths anxiety on brain activity. Choose Maths data from primary teachers provides evidence of maths anxiety and the need to address math anxiety in pre-service and in-service teachers. We also propose recommendations and strategies from the literature which can reduce maths anxiety in teachers and students.

In June 2018 the first Choose Maths workshop took place in Melbourne with the theme: *Mathematics, Gender and Mathematics Education*. Stakeholders from mathematics education, including practitioners, academics in mathematics and mathematics education, and representatives from departments of education and government, all contributed to the success of the workshop with presentations on maths anxiety, attitudes, beliefs, and practical ways of motivating girls in the classroom.

The papers of the invited speakers are presented in Section 3, along with the workshop program and the survey responses of the workshop participants. Participants valued most strongly the opportunity to meet people from outside their normal 'boundaries' with shared aims, and expressed strong support for a similar workshop in 2019.

Section 4 showcases a research initiative of Choose Maths: the research symposium presented at the *Mathematics Education Research Group of Australasia (MERGA)* in July 2018. With the permission of the conference organisers we include the three peer reviewed symposium papers, which cover attitudes and confidence in students based on data from intervention lessons and surveys of students in Choose Maths schools, gender gaps in participation and performance in Australian schools over the last decade, and the participation (or lack thereof) of women in the STEM workforce. Section 4 also includes the opinion of the discussant and a rejoinder.

Section 5 describes another initiative: *Choose Maths Days*, held primarily for female Year 9 and Year 10 students. These events were piloted in 2017 and extended in 2018 to more schools and universities around Australia, aiming to raise mathematical aspirations and enjoyment of girls and to provide information on careers involving mathematics. The events demonstrating the biggest impact on students' reported levels of mathematics enjoyment were those targeting students with lower levels of mathematics enjoyment and future aspirations. Year 9 students were also more influenced than Year 10 students. We will continue these activities in 2019, using the results from these surveys to focus the target audience and tailor the activities for maximum effect.

Inge Koch, Editor

2 Maths Anxiety: Students, Pre-Service and In-Service Teachers

Inge Koch
Australian Mathematical Sciences Institute

Maths anxiety has been shown to be an impediment to achievement. It starts in early primary school, affects girls more than boys, increases until about age 15 and then remains constant unless remediated. Female primary school pre-service teachers with maths anxiety are likely 'causes' affecting behaviour and attitudes especially of female primary students.

This report provides a review of relationships between maths anxiety, attitudes, beliefs and achievement with emphasis on students, pre-service and in-service teachers. It includes approaches that have been employed in addressing maths anxiety in students and pre-service teachers. An analysis of data from Choose Maths schools shows evidence of maths anxiety and perceived inadequate pre-service training among primary teachers.

The findings from the literature and the Choose Maths data analysis are of concern and demonstrate the need for action on teacher education and on reduction of maths anxiety in pre-service teachers and students.

2.1 Introduction

For over six decades maths anxiety has been regarded as an impediment to achievement and performance in particular of female students. The extent of maths anxiety in the US was estimated to range from about 25 to 80 per cent for college students, with the high end observed among community college students, see Beilock and Willingham (2014), Jones (2001) and Yaeger (2012).

Advances in psychology, neuroscience and functional magnetic resonance imaging (fMRI) have enabled researchers to gain a deeper and better understanding of brain activities and processes related to maths anxiety. The available knowledge and research findings which relate to the effect of maths anxiety on teachers and students are a cause for concern.

Women and young girls are more often affected by maths anxiety than boys. We now know that positive and negative attitudes of female primary teachers have a much larger influence and effect on female students than female teachers on boys or male teachers on either group of students. Around 80 to 95 per cent of primary teachers are female. While the proportion of maths anxious female primary teachers is not known and will vary from school to school, maths anxious female teachers affect behaviour and attitudes especially of young female students.

Maths anxiety is not restricted to individuals with low mathematical ability; there are highly maths anxious high-achieving individuals and similarly there are individuals at the other end of the spectrum who do not suffer from maths anxiety.

Many research publications, comprehensive reviews and reports have dealt with the phenomenon of maths anxiety and related ideas, and their psychological constructs. The purpose of this report is

A. to review and draw on available research and knowledge in the context of students, teachers, and parents without delving too deeply into psychology or behavioural theories

B. to present findings from the analyses of Australian teacher survey data we collected in the Choose Maths primary schools in 2017

C. to make recommendations on approaches for addressing maths anxiety

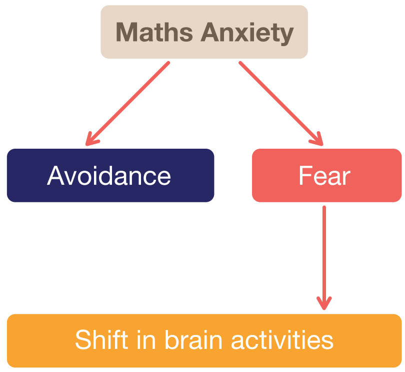
Reducing maths anxiety in teachers and, in particular, in female students has the potential to increase students' confidence in their abilities, their interest and hence also their engagement with mathematics.

2.2 Maths Anxiety, Fear, Avoidance and Brain Activity

Hembree (1990) defines maths anxiety as 'an adverse emotional reaction to mathematics or the prospect of doing mathematics'. Hembree's research focused on a meta-analysis of 151 studies and has been cited more than 1550 times since its publication.

Various definitions of maths anxiety have emerged since Hembree's 1990 publication; these range from '*a feeling of uncertainty and uneasiness when asked to do mathematics*' to '*a phenomenon where individuals suffer from the irrational fear of mathematics to the extent that they become paralysed in their thinking and are unable to learn or be comfortable with mathematics*' and also include '*a feeling of tension, apprehension or fear that interferes with mathematical learning and performance'*. For details see Chang and Beilock (2016), Gresham (2018) and references therein. We use Hembree's definition here.

Figure 2.1 Expressions of maths anxiety



Maths anxiety presents in different ways which have been characterised by fear and avoidance of mathematics as shown in the diagram in Figure 2.1, or by its cognitive and affective dimensions, see Buckley et al. (2016) and Dowker et al. (2016). Anxiety and fear are expressions of an individual's reaction when he or she anticipates carrying out a mathematical task. The level of anxiety or fear experienced can range from a feeling of not being comfortable to paralysing fear. Avoidance is a common reaction to experiencing negative feelings such as fear, and by avoiding a task, a person cannot be shown to be unsuccessful or to fail.

Cognitive and affective aspects of maths anxiety refer to concern or fear about an individual's performance, that is, the fear of not being successful, and to emotions such as tension that one may experience in a testing situation. Both naturally lead to avoidance of the anxiety-inducing prospect or activity.

Maloney and Beilock (2012) suggest that maths anxiety affects a person's cognitive resources. Their hypothesis is supported by neuroscience and fMRI research. These findings demonstrate that maths anxiety is simultaneously associated with hyperactivity in the right amygdala regions of the brain where processing of negative emotion occurs, and with reduced activity in posterior parietal and dorsolateral prefrontal cortex regions that are involved in mathematical reasoning (Young et al., 2012). This shift in brain activity appears to be specific to maths anxiety. In their study of general anxiety in 7 to 9-year-old children, Young et al. did not observe this shift. Lyons and Beilock (2011) found similar results for adults, again based on fMRI data.

Maths anxiety causes a shift in brain activity which results in a performance deficit and lower achievement

The findings of Young et al. (2012) show maths anxiety disrupts and divides working memory resources and that individuals with higher levels of maths anxiety have less working memory to focus on mathematical activities. The shift in brain activity of maths anxious individuals and the reduction of working memory resources adversely affect mathematical performance.

The concept of 'working memory resources' has been adopted by psychologists and educators as a model for understanding and explaining the effect of maths anxiety and its potentially drastic effects on mathematical performance. Pletzer et al. (2015) show that with increasing levels of maths anxiety the activity in the frontal regions are increased—at the cost of a reduction in the other regions. They offer the following interpretation of their findings: the 'performance deficit' of highly maths anxious individuals is not the result of lower mathematical ability, but the consequence of an impairment of their processing efficiency. The effect of maths anxiety on mathematical performance is also captured in Chang and Beilock (2016) and Ramirez et al. (2018). The latter paper refers to this idea as a 'disruption account' or 'reduced competency account', and their findings agree with those reported here.

Neuroscientists have been investigating brain activity based on fMRI images to determine differences between the genders. Some researchers found evidence that male brains showed more connectivity within lobes and within each hemisphere, while female brains showed more connectivity between the hemispheres, see Buckley (2016) and references therein, but these findings have been questioned by others. From the point of view of maths anxiety which is more common in girls than boys, it would be interesting to find out if the shift in brain activity arising from maths anxiety is favoured by better connectivity between the hemispheres.

The vicious spiral

Expressed in their fears and emotions, the presence of maths anxiety in an individual:

- may negatively impact brain activity including in regions related to mathematics
- can lead to avoidance of mathematical activities and increase fear

As a consequence, by avoiding the doing or learning of mathematics the feeling of fear increases and results in a vicious downward spiral of increasing fear and avoidance and reduced mathematical processing activity in the brain.

2.3 Developing Maths Anxiety

2.3.1 The Onset of Maths Anxiety

Maths anxiety begins during childhood and develops in the early years of primary school. It increases with increasing age of the child until it reaches a peak around Years 9 or 10, then plateaus out and persists throughout the school years and beyond. Maths anxious adults—including teachers and parents—pass on their attitude, negative feelings and fear about mathematics, see Hembree (1990).

Maths anxiety starts in early primary school. Environmental non-genetic factors contribute more to the development of maths anxiety than genetic risk factors

Some researchers argue maths anxiety in young children arises from numerical or spatial processing difficulties, resulting in flow-on effects on mathematics more generally, see Maloney (2019) and references therein. According to Ramirez et al. (2018) the development of maths anxiety in students is governed by how they appraise, perceive and interpret previous mathematical experiences, their teachers and themselves. They refer to this approach as an 'interpretational account'. Their point of view captures the effect of early achievement and one's mathematical experience on later maths anxiety: students may view or interpret their mathematics performance as a means for assessing their ability to be successful in mathematics, with low ability potentially creating fear and avoidance of mathematics. Appraisal theory has the potential for directing appraisal in a positive-adaptive way and could lead to overcoming the negative responses associated with maths anxiety.

In an empirical study on 514 twins aged 12, Wang et al. (2014) linked the development of maths anxiety to a combination of nature and nurture: genetic risk factors contribute about 40 per cent towards maths anxiety and environmental non-genetic factors make up the rest. The different percentages associated with genetic and non-genetic factors do not take into account the actual mathematical ability of an individual, however the 60 per cent contribution from non-genetic factors suggests that large reductions in maths anxiety can be achieved through the use of appropriate methods in the early school years.

Maths anxiety is most commonly identified through questionnaires in which students or adults are asked how they feel about specific situations involving mathematical tasks. Maths anxiety exists on a continuous spectrum ranging from no maths anxiety to paralysing fear when anticipating mathematical tasks, and there is no clear cut-off between individuals who do not present with maths anxiety, and those who feel a minor anxiety regarding specific tasks, see Ramirez et al. (2018) and references therein.

2.3.2 Parental Influences on Maths Anxiety

Children frequently assisted with homework by parents with high levels of maths anxiety in turn have greater levels of maths anxiety and learn less mathematics relative to their peers. These findings suggest that during those homework-helping situations, highly maths anxious parents may be communicating negative attitudes and beliefs about mathematics to their children, and that their children, in turn, internalise these negative attitudes and beliefs through endorsement of stereotypes. See Maloney (2019) in Section 3 (p. 36).

Maths anxious parents can contribute to the maths anxiety of their children when helping with mathematics homework

Buckley et al. (2016) note that parental perceptions and particularly the perceptions of mothers are linked to children's beliefs in their mathematical ability, their career choices and their susceptibility to the negative effects of stereotype threat, the endorsement of traditional gender stereotypes, and the point of view that mathematics is a male domain.

Strong and high-achieving mothers can also have a negative effect on their daughters: the fear of not being able to emulate their mother's achievements can cause fear and avoidance especially when facing mathematical challenges.

2.3.3 Developmental Trajectory of Maths Anxiety

The increase in maths anxiety with age is typically accompanied by a decrease in positive attitudes towards mathematics. Factors that contribute to an increase in maths anxiety include negative attitudes of teachers, parents and other students, social stereotypes, low self-esteem, difficulty in doing and learning mathematics or prior negative learning experiences, test anxiety and the experience, fear or threat of failure, as well as maladaptive appraisal of these experiences. Negative attitudes of maths anxious female adults, whether this be mothers or teachers, reinforce traditional stereotypes in young female students, impact on the individuals' confidence and attitude and indirectly 'nurture' students' maths anxiety (Buckley et al., 2016; Chang & Beilock, 2016).

The gender gap in maths anxiety is much larger than that in achievement, and is largest around the transition from primary to secondary school

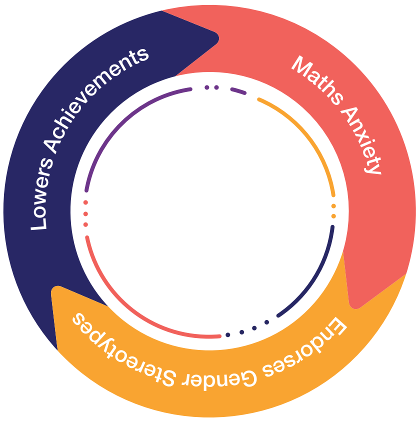
Other researchers' findings disagree with some of these factors, suggesting that students' inability to handle frustration, possibly combined with poor teaching techniques in the early school years, may cause or contribute to maths anxiety (Devine et al., 2012; Gresham, 2018).

Two specific time periods appear to be significant to the development and increase in maths anxiety:

- the early years of elementary/primary school
- transition from primary to secondary school

In a US study of elementary teachers and their students, Beilock et al. (2010) found that children are more likely to emulate the behaviour and attitudes of same-gender adults instead of opposite-gender adults. At the end of their year-long study Beilock et al. were able to show that the higher the maths anxiety of the female teacher, the lower the girls'—but not the boys'—achievements in mathematics. Beilock and colleagues do not claim that the maths anxiety of female teachers directly produced maths anxiety in their female students; rather, as shown in the diagram in Figure 2.2 right, maths anxiety of teachers encourages and endorses traditional gender stereotypes in their young female students which impacts on girls' achievements. A lower achievement typically impacts on and increases maths anxiety. For details see Maloney (2019) in Section 3.2.2. The study of Beilock et al. (2010) examines how maths anxiety of female teachers can be passed on to female students and provides valuable insight, though based on a moderate sample (17 elementary teachers, 52 boys and 65 girls in their classes).

Figure 2.2 Passing on and increasing maths anxiety



The endorsement of negative attitudes and the potential adverse effect induced by maths anxious female mathematics teachers on young girls is of great concern.

O'Keeffe et al. (2018) focus on the transition from primary to secondary school as a time period when students are particularly vulnerable (Hanewald, 2013; Maguire & Yu, 2015). Their student surveys form part of a larger study of students in STEM projects designed and carried out in collaboration with the South Australian Department for Education and Child Development (DECD).

Maths anxiety of female teachers encourages and endorses traditional gender stereotypes in female students

O'Keeffe et al conducted online surveys in South Australia, with a total of 618 Year 7 and 622 Year 8 students completing the surveys—a 70 per cent response rate. Questions were based on 13 items relating to mathematical self-efficacy, self-concept and maths anxiety, with some questions differing for primary and secondary students. Their findings included:

- the belief in their mathematical capabilities decreased at a similar rate for boys and girls from Year 7 to Year 8
- female Year 7 and Year 8 students were more likely to find mathematics difficult than the boys
- the greatest difference between boys and girls was reflected in the girls' higher level of maths anxiety in Year 7 and Year 8

In most Australian jurisdictions the transition from primary to secondary school occurs between Years 6 and 7. In South Australia students attend primary school until the end of Year 7. This discrepancy in the year of transition time is not likely to affect the results of O'Keeffe et al. in any material way.

Maths anxiety expresses itself in the avoidance of mathematics and is therefore likely to be one of the factors that influence students' subject choices in the last years of secondary school in Australia. The link between maths anxiety and senior school subject selection is beyond the scope of this report. We refer the interested reader to Li (2019) in Section 3, who describes the survey instruments developed to gain better insight into the factors that influence students' subject selection for Years 11 and 12, and enabling the development of methods addressing the lack of engagement and participation of girls in higher levels of mathematics.

2.3.4 Maths Anxiety and PISA Findings

The Programme for International Student Assessment (PISA) examined students' attitudes and motivation towards mathematics in its 2012 cycle, where mathematics constituted the major domain. Findings of the questions related to maths anxiety show an increase in maths anxiety especially among female students compared to the 2003 cycle (Thomson et al., 2014). The PISA results confirm that Australian scores on self-concept, attitude and motivation are similar to or slightly higher than the OECD average. The mean scores of 15-year-old girls were higher in all comparable countries than those of boys, with higher scores representing higher levels of maths anxiety. The index of maths anxiety, based on standardised student responses, allows comparisons between different cohorts. The analysis also shows:

- Australian female students reported a level of intrinsic motivation to learn mathematics that was below the OECD average
- Australia and New Zealand have the largest gap (or difference) in the maths anxiety index between male and female students
- Male students believe they are more competent in mathematics than female students

In Australia the largest gap in the maths anxiety index occurs between boys and girls, and this gap is almost twice as large as the next largest gap which occurs between indigenous and non-indigenous students. Further, the index increases with decreasing socio-economic background of students. For details see Table 7.22 of Thomson et al. (2014).

A comparison of the proportions of maths anxious students in the 2003 and 2012 PISA cycles indicates that maths anxiety among 15-year-old girls and boys has grown in Australia and many comparable OECD countries since 2003. Current estimates, based on the 2012 data, put it at 33 per cent of 15-year-old students. The higher level of maths anxiety of students observed in co-educational schools compared to single-sex schools that was observed in PISA 2003 appears to have been replaced by a slightly higher maths anxiety of students in single-sex schools in 2012 (Stoet et al., 2016). The reasons for these changes from 2003 to 2012 are not well understood. The PISA report also shows that the higher maths anxiety of girls observed by O'Keeffe et al. (2018) in Year 7 and 8 students persisted in the 15-year-old cohort.

Maths anxiety in 15-year-old students has increased from 2003 to 2012 among boys and girls

Other factors influencing students' beliefs in their mathematical competency may include their perceptions of the degree of control they have over their ability and performance, as well as future career choices and directions.

2.3.5 From Pre-Service Education to In-Service Teaching

Maths anxiety increases during primary school until around the middle of secondary school and then remains constant. Depending on the chosen career of an individual, maths anxiety may not matter greatly in adult life; however, it does not disappear unless remediated, and the inherent negative attitudes are still passed on to others including children.

Pre-service teachers belong to the cohort of adults with possibly latent maths anxiety. According to their responses in the teacher surveys conducted by the Australian Council for Educational Research (ACER) for Choose Maths in 2017, more than 30 per cent of primary teachers in Choose Maths schools have not been exposed to or trained in mathematics content or teaching methodology. For details see Table 2.1 (p. 23). Some primary education degrees (bachelor, masters, graduate diploma etc) at Australian universities only require students to take courses in mathematics teaching methodology, and the content and number of courses as well as the mathematics entry level requirements differ between institutions.

Irrespective of the different university degree regulations, it is of concern that only 61 per cent of teachers in the Choose Maths surveys who are trained to teach mathematics at primary school level feel that their training has been adequate. Section 2.6 and Table 2.1 provide details.

Maths anxiety increases as pre-service teachers become in-service teachers. Higher levels of maths anxiety in teachers are related to lower mathematics achievements of their students

Female students majoring in primary education exhibit a higher level of maths anxiety than their male counterparts, and students with maths anxiety in a primary education degree typically avoid mathematics courses unless they are compulsory. However, once they are in the classroom, they have to teach mathematics to impressionable primary students.

Pre-service teachers identified as having a high level of maths anxiety take their maths anxiety to their classrooms. The research of Gresham (2018) on female teachers during their pre-service training, and later as in-service teachers, shows that their maths anxiety increases when they become in-service teachers. Their negative experiences with and limited knowledge of mathematics, combined with their feeling of being ill-prepared when they graduate, affects their mathematics teaching and student learning. Such teachers are not likely to enjoy teaching mathematics. Maths anxiety, lack of confidence and inadequate education during teaching degree programs can lead to poor teaching practices. These contribute more to maths anxiety than the actual content of the subject. Geist (2015) further points out that:

- The greater the confidence of teachers' knowledge of mathematics the more they like mathematics
- The more confident teachers are in their mathematical ability, the higher they rate the importance of teaching mathematics in preschool and early primary school

Combined with the conclusions in Smith (2010) that teachers are one of the most influential factors impacting students' achievements, it becomes mandatory to provide pre-service teachers with adequate training to improve both their factual knowledge and their enjoyment of mathematics, as well as their engagement in teaching mathematics well.

The link between teachers with maths anxiety and their students has more recently been studied in Ramirez et al. (2018). They conclude that higher levels of maths anxiety in their cohort of ninth grade teachers are related to lower achievements in mathematics by their students. Their findings are similar to those described by Beilock et al. (2010), outlined in Section 2.3.3. Unlike Beilock et al. who made the link to lower performance via stereotype threat, the more recent study of Ramirez et al. focuses on students' perception of a teacher's integration of growth mindset ideas (Boaler, 2015) and mathematics performance.

Findings about the impact of teachers' attitudes on students' achievements are of concern and demonstrate the urgent need for action on the side of teacher-educators and governments to provide pre-service teachers with a solid knowledge of mathematics, good teaching practices and an understanding of how to positively influence student learning. Current and future teachers require adequate access to methods for reducing their own and their students' maths anxiety and increasing self-efficacy. Support needs to be available for in-service teachers on a regular basis, including furthering mathematical knowledge through professional development or appropriate further qualifications.

US studies have shown that maths anxiety of pre-service primary teachers in a first mathematics content course decreases during the semester, and so does simultaneously the accuracy of the students' self-assessed mark and actual mark for test questions, see Jameson and Fusco (2014), Christopher (2018) and references therein. These authors regard the self-assessed mark as an expression of the student's self-efficacy. The decrease in maths anxiety in their longitudinal study is not strong, indicating that more needs to be done to decrease maths anxiety of pre-service teachers before they complete their education or teaching degree.

2.3.6 Impact of Gender

Traditionally mathematics has been regarded as a male domain and this point of view is still apparent in frequently held gender stereotypes. To examine whether attitudes and beliefs about mathematics have changed, Forgasz et al. (2004) designed survey instruments which better capture the attitudinal changes that have occurred over the last 30 years than the previously used mathematical attitude scales. Their analyses of more than 700 responses from male and female secondary students in Australia and 123 US students show most students agree that mathematics is gender neutral, but differences in boys' and girls' beliefs exist on a subscale. The authors observe that their results were inconsistent with previous research which could indicate that a change in perception regarding mathematics and gender occurred over the 20-30 years to 2004.

The gender gap in mathematical confidence is much larger than differences in mathematical interest or achievement of primary school children

Dowker et al. (2016) report on contradictory findings regarding gender differences in maths anxiety of young students. Some researchers could not find any gender difference in maths anxiety of young primary school children while others including Beilock et al. (2010) observe that maths anxiety exhibited by young female students is fostered by their teachers' gender beliefs and anxieties regarding mathematics, and maths anxiety is more common in girls than boys. For primary and older school students the findings of O'Keeffe et al. (2018) and in PISA 2012 show that girls report higher levels of maths anxiety (Buckley et al., 2016).

Ganley and Lubienski (2014) examined the impact of gender in a longitudinal study involving 7040 students from third to eighth grade, which focused on relationships between confidence, interest and achievements. They found that gender differences in mathematical confidence are much larger than differences in mathematical interest or achievement of primary school children; however the three concepts are mutually reinforcing. The small gap in performance of third grade students suggests that girls' lack of confidence in their mathematical ability may be unwarranted at that age. By eighth grade the gender gap in confidence has reduced to about the same size as the gap in performance and interest. Ganley and Lubienski note that the strongest predictor for later confidence is prior confidence. Confidence is also a predictor for later mathematical performance, while current performance and interest predict students' later interest, especially for girls.

Ganley and Lubienski's research raises the question whether and how much these early gender differences in confidence affect girls' achievements in later school years, and the authors suggest that intervention especially for girls should begin early and be continued in order to create a positive and lasting effect on confidence, attitude, interest, achievement and career decisions.

The findings of Frome and Eccles (1998), Hyde (2005) and Hyde (2014) agree with those of Ganley and Lubienski. However, instead of considering gender differences and the effect of gender on maths anxiety, Hyde (2005) and Hyde (2014) propose a 'gender similarity hypothesis' which they examine in 46 meta-analyses. Hyde claims that males and females are similar on most—but not all—psychological variables and looks at the cost of gender differences on reinforcing stereotypes and of parents' lower expectations for their daughters' mathematical abilities which can undermine girls' confidence in their ability to succeed in mathematics. She points out that the gender difference in mathematics performance is very much smaller than the gap in mathematical self-confidence and maths anxiety.

Hyde's gender similarity ideas are supported by behavioural and neuroimaging studies which show that there is no evidence that males have higher aptitude for mathematics than females (Spelke, 2005). The focus on performance, which is easy to measure, often obscures the ability perspective of individuals. By contrast, a focus in teaching on emphasising aptitude, engagement, and building of confidence instead of achievement and performance could lead to a decrease in maths anxiety and stereotype threat in particular in female students.

2.4 Maths Anxiety, Confidence, Performance and Ability

In this section we review relationships between maths anxiety, stereotype threat, confidence constructs such as self-concept and self-efficacy, attitude, performance, achievement and ability. Since these terms are not always defined in the same way, we include the definitions used here in the Appendix following Section 2.7.

We will only distinguish between confidence, self-confidence, self-efficacy and self-concept when research has shown different relationships of these constructs with the other maths anxiety-related concepts. In his seminal paper Bandura (1986) defines different confidence-related terms. Since then this publication has been cited more than 75,000 times. For more recent accounts of confidence-related ideas see Pajares and Miller (1994) and Bong and Skaalvik (2003).

2.4.1 Maths Anxiety, Stereotype Threat and Ability

Beilock et al. (2010), Maloney and Beilock (2012) and Maloney (2019) explore negative attitudes and stereotypes that are frequently associated with mathematics, their relationship with maths anxiety and how maths anxiety is transmitted. Children learn from adults and, as part of this learning and emulation, they internalise their parents' and teachers' attitudes and beliefs about mathematics. Such beliefs and attitudes include traditional gender stereotypes that may be latent, but can be activated in children by maths anxious parents and teachers with negative attitudes towards mathematics.

Section 2.3.3 describes the findings of Beilock et al. (2010) that maths anxiety in parents and teachers may not directly cause maths anxiety in children but instead the path may lead via stereotype threat especially by same-gender adults in receptive children. Combined with early perceived or real difficulties in processing mathematical ideas such as numbers or spatial concepts, these difficulties can lay the foundation on which stereotypes are endorsed. Once children adopt gender stereotypes about women and mathematics, their attitudes and beliefs influence their behaviour towards mathematics resulting in avoidance and a growing fear of mathematics. As previously discussed in Section 2.2, fear and avoidance of mathematics can affect the working memory and lead to reduced mathematical processing activity in the brain. As a result, individuals with maths anxiety perform more poorly than their abilities suggest.

The relationship between maths anxiety, stereotype threat and achievement that Beilock et al. (2010) put forward is supported by research based on fMRI imaging of brain activity. However other researchers, including Ganley et al. (2013) and Dowker et al. (2016), report inconsistent findings questioning:

- the relationship between maths anxiety and stereotype threat
- the effect of stereotype threat on girls' performance

To reconcile the differing opinions and obtain a deeper understanding of the relationships and the group of people that are more at risk of stereotype threat, more research is required. However, we briefly consider whether there actually exists a contradiction between the respective findings.

Beilock et al. (2010) consider 117 second grade students and their 17 teachers. The study of Ganley et al. (2013) is based on 931 students from fourth to twelfth grade, so has, on average, about the same number of students in each year as Beilock et al. have in their study of second grade students. The research of Ganley et al. provides more specific insight into conditions under which stereotype threat is likely to occur, and its effect on the performance of school students of different ages. Their findings point to inconsistencies in the effect of stereotype threat on girls' mathematical performance and the need for more research.

Endorsement of traditional gender stereotypes in children affect their attitudes and beliefs about mathematics and can result in avoidance and fear of mathematics

In young children it is not easy—and may indeed not be possible—to separate stereotype threat and the beginnings of maths anxiety. This could partially account for the differences and inconsistencies. Another possibility is that the effect of endorsing gender stereotypes in early primary school decreases with increasing age of the students—possibly as a consequence of active intervention or of encountering more positive role models. These ideas suggest that addressing stereotype threat in young children could be effective in decreasing the maths anxiety and its consequences on engagement and performance.

2.4.2 Maths Anxiety, Confidence and Achievement

In primary school, girls appear to have less confidence in their mathematical abilities than boys (Ganley and Lubienski, 2014), and the gap widens at a time when maths anxiety begins to develop. Self- efficacy is closely linked with maths anxiety, and it is often not possible to determine which comes first—a low confidence or maths anxiety. In his control-value theory of achievement emotions, Pekrun (2006) argues that low confidence occurs before students experience maths anxiety. However, it seems undisputed that low confidence and maths anxiety negatively impact each other (Dowker et al., 2016) and both negatively affect students' enjoyment of mathematics.

Low self-confidence affects performance and increases maths anxiety

Poor or low self-concept of an individual's mathematical ability has a stronger effect on increasing maths anxiety than maths anxiety has on self-concept, see Ahmed et at (2012), Ramirez et al. (2018) and references therein. To appreciate why there is such a powerful effect of confidence on maths anxiety, we note that individuals with low self-concept of their ability frequently develop dysfunctional perceptions of themselves that negatively affect their appraisal of their abilities. Further low self-confidence increases the vulnerability regarding negative attitudes and stereotypes, which in turn affects performance and subsequently increases maths anxiety.

Our beliefs of our ability—more than what we are actually capable of achieving—govern our behaviour. Students with high self-efficacy are more likely to show greater interest, engagement, commitment and perseverance as they have a higher expectation of their success, while individuals with low self-concept are more likely to cease their efforts and thereby increase their potential to fail, compared to high-efficacy individuals of the same ability who tend to learn and achieve more (Galwardo, 2015). Recent findings indicate that self-efficacy is a predictor of perseverance and ultimately performance in mathematics, and it is possibly a better predictor of these than gender, mathematics background, or maths anxiety (O'Keeffe et al., 2018).

The effects of low confidence and low belief in one's ability are of concern, as they hide actual ability and disadvantage individuals with low self-efficacy. In contrast, students' enjoyment of mathematics has a positive effect on their confidence in their ability, and confidence and enjoyment are closely linked to a student' engagement with the subject which, combined with increased effort, will result in improved performance and further increase confidence in one's own ability (Ma, 1999).

These findings suggest that effort should be expended on building and improving confidence of students, and part of the confidence building could be achieved by employing methods and activities that increase students' enjoyment of mathematics.

The reciprocal relationship between confidence and maths anxiety also applies to pre-service and in-service teachers. Teachers who are interested in their subject areas can impact students' interest in the subject and establish a positive relationship between teacher and students' enjoyment and engagement, and students who enjoy mathematics have higher self-confidence in their mathematical abilities. Students who have effective and confident mathematics teachers demonstrate higher motivation and expectations of their own performance which in turn results in improved achievements, see Smith (2010) and references therein. Because of the impact female primary teachers have on female students it is therefore vital that maths anxiety and confidence building are addressed repeatedly during the pre-service training of teachers.

2.4.3 Maths Anxiety, Performance and Ability

In very young children there is almost no relationship between maths anxiety and performance; however, a relationship develops during the primary school years, see Devine et al. (2012). The latter authors, who study students in Year 7, 8 and 10, point out that negative correlation between maths anxiety and students' performance increases with age, and this correlation is stronger for girls than for boys.

Figure 2.2 (p. 14) shows the spiral of maths anxiety, stereotype threat and lower performance. Not included in this figure is the powerful effect of confidence—or its lack—on maths anxiety and other factors. Whether directly or otherwise, maths anxiety, stereotype threat and confidence impact on students' performance, and become impediments to achievement, see Hoffman (2010), Maloney and Beilock (2012) and Dowker et al. (2016) and references therein. Combined with the shift in brain activity described in Section 2.2 (p. 12) and the reduced working memory resources of individuals with maths anxiety, the performance and achievements of maths anxious students often fall short of their actual abilities.

Maths anxiety, stereotype threat and confidence impact on students' performance, and become impediments to achievement. Achievements of maths anxious students often fall short of their actual abilities

Reports offer conflicting opinions regarding gender differences in mathematical performance and achievement. Unlike the no difference results of Devine et al. (2012), results from PISA, Trends in International Mathematics and Science Study (TIMSS) and the Australian National Assessment Program—Literacy and Numeracy (NAPLAN) show that the mean mathematics scores of boys are higher than those of girls by Year 3 (see Li and Koch, 2017 and references therein). These findings are consistent with those of Ganley and Lubienski (2016) who draw attention to the absence of a gap when students begin school and the emergence of a gap in the early school years.

Dowker et al. (2016) note that the avoidance factor associated with maths anxiety acts as a greater block to mathematical learning than deficiencies in curricula or teachers' (in)adequate training. These implications are cause for concern and require action since teachers with higher levels of maths anxiety may pass on these negative feelings to their students.

The emerging gender gap in performance in the early years of school is not mirrored by a gender gap in ability; Spelke (2005) and Hyde (2014) support their findings of no evidence that boys have higher aptitude for mathematics than girls with behavioural and neuroimaging studies. It is easy to measure performance and to calculate the gap in the mean performance, however, from the perspective of supporting our students in their attitudes and learning, it is important to focus on their ability and encourage a classroom environment that allows students to develop and reach their potential.

2.5 Addressing and Remediating Maths Anxiety

We turn to approaches or methods that have worked in alleviating or remediating specific phenomena connected to maths anxiety.

At present there are no known preventative interventions for maths anxiety.

2.5.1 Approaches Relating to Early Experience of Maths Anxiety

Some researchers argue that maths anxiety may stem from a basic deficit in numerical processing skills in young children (Maloney & Beilock, 2012). A number of avenues have proved to be valuable for addressing these deficits which are detailed in the next few paragraphs.

Improving basic mathematical skill of students could strengthen their belief in their abilities and decrease maths anxiety

A focus on improving basic numerical or mathematical skills of young students could strengthen belief in their own abilities at an early age before loss of confidence and enjoyment of mathematics. Interventions including intensive programs or one-on-one cognitive tutoring that are designed to improve students' mathematical skills may be effective at reducing maths anxiety, as evidenced by fMRI scans, see Ramirez et al. (2018) and references therein.

Presenting mathematical problems within a less formal and rule-bound framework may assist students with fear of mathematics, and help those with high maths anxiety to perform more like students who are less affected by maths anxiety (Devine et al., 2012). A less formal and less rules-focused teaching approach does not imply that it is any less rigorous or less correct, but may simply present another way of looking at mathematical problems.

To address the avoidance aspect of maths anxiety parents can help by engaging in mathematics-related activities with their children—rather than helping with homework. Activities could include positive appraisal to counteract their children's fear and to increase the engagement of their children, as well as using growth mindset approaches building on the importance of learning from mistakes, such as treating mistakes as enhancing the understanding rather than regarding mistakes as failure which can lead to a debilitating mindset (Boaler, 2015).

For secondary students Maloney (2019) proposes expressive writing as an intervention to reduce maths anxiety. For details see Section 3 (page 30). The effect of such interventions can be enhanced by teachers and students adopting the growth mindset approach of Boaler (2015).

2.5.2 Approaches to Dealing with Stereotype Threat

Maths anxiety of teachers, parents and other role models can lead to stereotype threat, especially in young female students, which results in a negative spiral toward lower achievement and increased maths anxiety of the students.

Disconfirming of traditional gender stereotypes and interventions to reduce stereotype threat need to start early in primary school

Exposing students to role models who disconfirm traditional female stereotypes can reduce this threat especially when combined with high-quality teaching and learning approaches. Maloney and Beilock (2012) propose strategies that emphasise regulation and control of negative emotions. Such strategies could involve positive reappraisal to overcome the negative responses associated with maths anxiety. Adaptive appraisal can reduce stress and increase self-efficacy, which may constitute an important factor in directing students away from perceived negative prior mathematical experiences (Ramirez et al., 2018).

In Section 3.2.5 (page 46) Buckley (2019) describes interventions that have been developed for teachers, but they can be applied to female students, too. These approaches aim to reduce or eliminate stereotype threat in women and female students by using professional learning and teaching to understand the phenomena, including strategies to manage and alleviate maths anxiety.

An important point is timing: it is essential that the chosen approaches are employed from the early years of primary school and that they are repeated in later school years rather than applied as 'once-only'. Addressing stereotype threat in young children can effectively decrease maths anxiety and its consequences on engagement and performance.

2.5.3 Increasing Self-Confidence

Girls' self-concept in their mathematical abilities is lower than that of boys of the same age. While there is no evidence that girls have less aptitude for mathematics than boys, girls appear to lose confidence in their abilities compared to boys during the first years of primary school, and girls' interest in mathematics decreases from that time onwards.

The focus on improving girls' confidence and belief in their abilities needs to start early and be ongoing. Teaching should focus on emphasising ability not just performance

Section 2.4.2 emphasises the strong effect of low self-concept on maths anxiety. Further, self belief about their ability affects cognitive functioning and learning. Improving female students' confidence and belief in their mathematical abilities is therefore incumbent. Interventions targeting girls should begin early and be continued throughout the school years in order to create a positive and lasting effect on confidence, attitude, interest, achievement and career decisions. Interventions employed by Choose Maths with students from Year 5 onwards are described in Koch (2019a) in Section 3.2.4 (p. 42) and Koch (2019b) in Section 4 (p. 71).

Simple interventions can impact students' confidence as the following example of Cohen and Garcia (2014) shows. In a study of US secondary school students, half the students received the extra sentence 'I am giving you this feedback because I believe in you' in addition to receiving the critical feedback that was given to all students. A year later, students who received the extra feedback achieved higher grades not observed in the other half.

Mathematics is often seen and taught as rule-based which may be connected with poor teaching practices, a lack of mathematical knowledge, inadequate preparation of pre-service teachers, or a fixed mindset approach to mathematics. As any mathematician knows, mathematics is a highly creative discipline focused on trial and error, on finding patterns, and seeing connections and similarities. Making mistakes and learning from mistakes is an intrinsic part of mathematics.

Successful teaching methods should focus on emphasising aptitude and engagement instead of achievement and performance. By including these aspects in their teaching approaches, teachers can help students to acquire the confidence to face challenges, make mistakes, and become creative in their thinking about mathematics, as well as increase students' enjoyment of mathematics.

Building and improving self-confidence in female students should not be restricted to the school environment—it needs to engage parents as well. Parents can be provided with access to and information regarding mathematics-related activities to engage in with their children to increase enjoyment of mathematics.

2.5.4 Improving Pre-Service and In-Service Mathematics Education

Maths anxiety affects teachers' assessment of their own mathematical ability. The more mathematics teachers know, the more confident they become in their mathematical ability and, as a consequence they rate the importance of the teaching mathematics to young children more highly (Geist, 2015).

To direct teachers' impact on students' achievements in a positive way, action by teacher-educators and governments is needed. Pre-service teachers require a solid knowledge of mathematics, and a variety of effective mathematics teaching methods and practices to be able to influence student learning and meet students' needs. Pre-service teacher education must address improving classroom performance by implementing strategies for alleviating maths anxiety and improving mathematical self-concept. Including more of these ideas into pre-service teacher education is expected to increase students' enjoyment of mathematics and limit their own maths anxieties as well as avoiding the transmission of their maths anxiety to the classroom.

Maths anxiety often increases when pre-service teachers graduate and become primary teachers. New in-service teachers, in particular, require adequate access to methods for reducing their own and their students' maths anxiety and increasing their self-efficacy. Support for teachers in these areas needs to be both available and accessible, taking the form of professional development, enrolling in courses, or through interventions. In Section 3.2.5 Buckley (2019) describes interventions that have been developed for primary teachers, but can also be applied to female students. These approaches aim to reduce or eliminate maths anxiety in women and female students using professional learning and teaching to understand the phenomena including strategies to manage and alleviate maths anxiety.

Pre-service teachers require a solid knowledge of mathematics, effective mathematics teaching methods, and good strategies for addressing maths anxiety and improving self-concept

Options such as providing financial support or time off for enrolling in a postgraduate studies, such as a Master of Mathematics Education, can contribute considerably to a teachers' overall improvement and increase their confidence in their mathematical knowledge (Gresham, 2018).

2.6 Maths Anxiety in Choose Maths Primary School Teachers

The Wave 1 Choose Maths survey of teachers, conducted in 2016, provides information about educational background, training and experience of teachers, their level of confidence and competence regarding mathematics content and teaching of the mathematics curriculum, as well as their competence in curriculum documentation. A total of 85 schools were part of Choose Maths at the time the survey was distributed to schools, this number increased to 120 schools by the end of 2016 and has remained constant since then (Underwood, 2017, and Koch & Li, 2017).

A review of the responses from the Wave 1 survey indicated necessary changes to some questions as well as allowing responses on a finer scale. As a result, a direct comparison between the 2016 survey and the Wave 2 survey conducted in 2017 is not possible for some questions. The Wave 2 Choose Maths survey collected information about teachers' Choose Maths participation in 2016, and this information will enable comparisons between groups of teachers who differ in their participation status in Choose Maths over the two years.

We focus here on survey questions related to maths anxiety, confidence and competence of the 764 primary teachers who responded to the 2017 survey which corresponds to a response rate of about 62 per cent. Survey questions relating to the effectiveness of the Choose Maths professional development in the 120 schools are described in Koch (2019a) in Section 3.2.4.

Of interest is the relationship between teachers' pre-service mathematics education, their assessment of the adequacy of their degree(s) in preparing them for the mathematics they teach and their confidence and competence regarding different teaching-related issues. The numbers and percentages of teachers and their assessment of being adequately or not adequately trained to teach primary school mathematics are summarised in Table 2.1 below.

Table 2.1 Teachers with adequate/not adequate pre-service training

	totals		adequately trained		not adequately trained	
all	764		435	57%	250	33%
primary	593	77.6%	363	**61%**	211	36%
both	63	8.2%	43	68%	19	30%

In Table 2.1 and in the following discussion, 'primary' or 'primary trained' refers to 'trained to teach mathematics at primary school level', and 'both' or 'trained in both' refers to 'trained to teach mathematics at both primary and secondary school level'. In each case the training refers to their university education. Among the respondents there were 16 teachers trained to teach secondary mathematics, 31 who were trained to teach neither primary nor secondary school mathematics, and 61 who did not respond to this question. Table 2.1 and Figures 2.3 to 2.5, below, focus on those teachers who state they *were* trained to teach primary mathematics as part of their university education.

It is of concern that only 61 per cent of teachers who have been trained to teach primary level mathematics think they are adequately trained. We looked at how this is reflected in their confidence or competence.

Teachers with better knowledge of mathematics are more confident and less anxious about their teaching

Figure 2.3 (p. 24) shows responses to the following survey items

A. Enjoy teaching mathematics

B. Do not feel tense when teaching mathematics

C. Teach mathematics well

D. Feel knowledgeable about and on top of the mathematics content you teach

For each survey item (a)–(d) above, teachers indicated their level of agreement by choosing a number out of 11, where 1 indicates lowest agreement and 11 highest agreement. The results for each survey item are shown in the 6 panels above the survey item label in Figure 2.3. In each panel the height of the bars at each level of agreement (1 to 11) shows the proportion of teachers that chose a particular level of agreement. The left three figure panels for each survey item corresponds to teachers who are 'primary trained' and the right three figure panels for each survey item correspond to 'trained in both'. This arrangement allows an easy comparison of the two cohorts that were trained differently.

The different colours used in the figure panels correspond to different groups within the cohorts: dark blue refers to all teachers in their respective cohort, green refers to the proportion of teachers within a cohort that feel adequately trained, and the light blue represent the proportion of teachers within a cohort that do not feel adequately trained.

Figure 2.3 Teachers' self-assessment about teaching mathematics

Comparison of responses by teachers with primary training only and teachers with both primary and secondary training. In each panel of 6 graphs, the group on the left are 'primary trained' and the group on the right are 'trained in both'. Dark blue row: all teachers in the cohort; green row: teachers who feel adequately trained; light blue row: teachers who do not feel adequately trained. Level of agreement from 1 (low) to 11 (high).

A comparison between the 'primary trained' and the 'trained in both' teacher cohorts shows that the latter cohort consistently answered the survey questions with higher levels of agreement ok. This pattern persists for the two subsets adequately and not adequately trained. A comparison between the adequately and not adequately trained subgroups within each cohort ('primary' and 'both') across the four questions shows that teachers who feel adequately trained also think that they perform better in these four aspects of teaching.

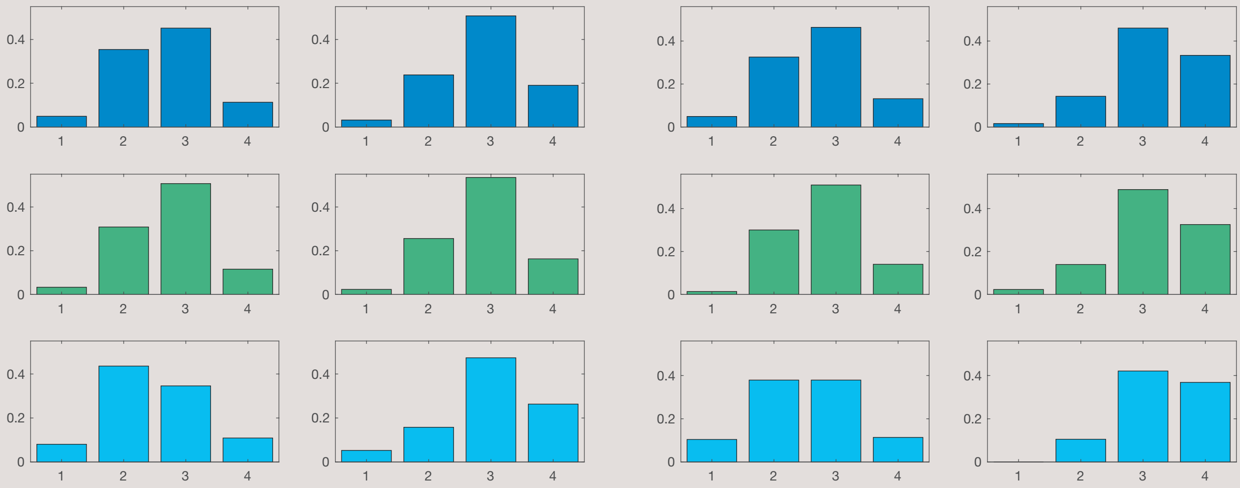
A possible interpretation of the survey results is that teachers trained to teach both primary and secondary school level mathematics are more confident in their knowledge, and hence less anxious about their teaching.

This is further illustrated in Figure 2.4 which looks at the survey items

E. Confidence in incorporating proficiencies, fluency, understanding and/or communicating into the Australian curriculum: mathematics content area
F. Developing mathematics assessment tasks

The four possible answers to these two survey questions are 1 – not confident, 2 – somewhat confident, 3 – confident and 4 – very confident. Figure 2.4 shows proportions of teachers for each of the four responses, again split into the 'primary trained' and 'trained in both' cohorts, following the same general colour scheme as in the previous figure.

Figure 2.4 Teachers' self-assessment about broader issues with teaching mathematics



E. Confidence with mathematics curriculum

F. Developing assessment tasks

Comparison of responses by teachers with primary training only and teachers with both primary and secondary training. In each panel of 6 graphs, the group on the left are 'primary trained' and the group on the right are 'trained in both'. Dark blue row: all teachers in the cohort; green row: teachers who feel adequately trained; light blue row: teachers who do not feel adequately trained. Responses from 1 (not confident) to 4 (very confident).

The higher bars for responses 'somewhat confident' of the 'primary trained' teachers who do not think they are adequately trained (third row) is noticeable in both Figures 2.4 (e) and (f) with a mode occurring at 2 – 'somewhat confident', compared to teachers who think they are adequately trained and shown in green. The difference is less clear for the two subgroups of the 'trained in both' teachers. As in Figure 2.3 the difference appears to be the additional knowledge of mathematics.

The effect of teachers' belief that they lack knowledge or training can be seen in the panels of Figure 2.5 which shows the responses of teachers to the questions

Teachers without adequate knowledge of mathematics feel less confident in their teaching

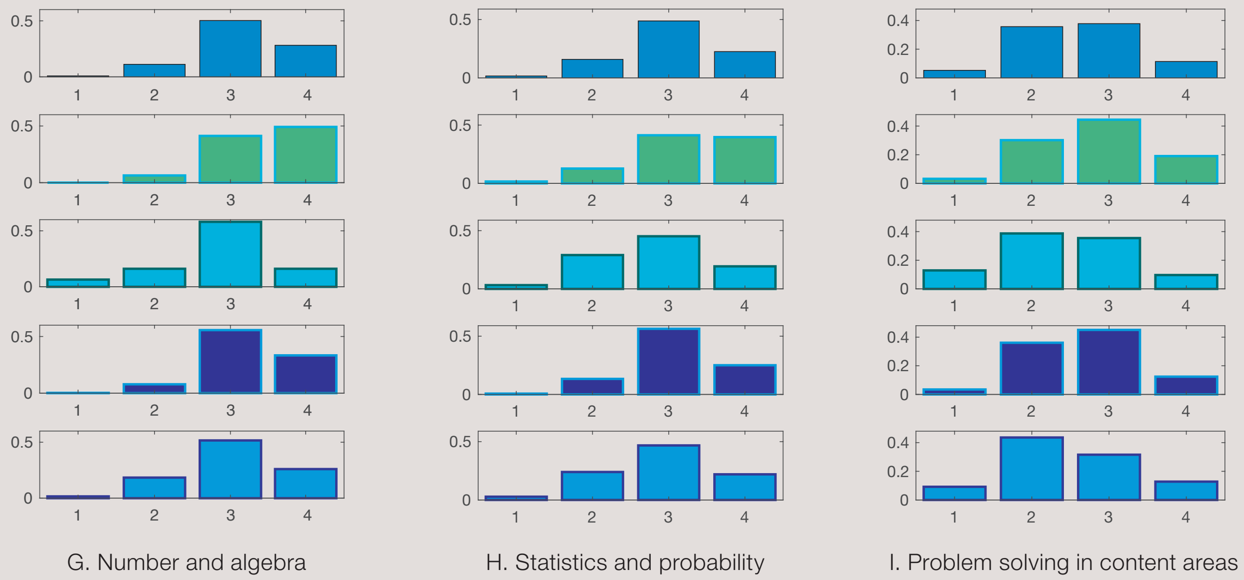
G. Do you feel confident when teaching 'Number and algebra'?

H. Do you feel confident when teaching 'Statistics and probability'?

I. Do you feel confident incorporating proficiencies, problem solving and reasoning into content areas?

The four possible answers are 1 – not competent, 2 – somewhat competent, 3 – competent and 4 – very competent. In Figure 2.5 the rows show the responses of the following cohorts: top row all teachers surveyed, second row 'trained in both' teachers, third row: teachers trained neither for primary nor secondary mathematics, fourth row: teachers who believe they are adequately trained, and last row: teachers who believe they are not adequately trained.

Figure 2.5 Teachers' self-assessment about teaching mathematical content areas



First row: all teachers, second row: 'trained in both' teachers, third row: teachers trained neither for primary nor secondary mathematics, fourth row: teachers who believe they are adequately trained, and last row: teachers who believe they are not adequately trained. Responses from 1 (not competent) to 4 (very competent).

2.7 Summary and Recommendations

Maths anxiety is known to start early in primary school and to affect girls more than boys. It increases with age through primary and most of secondary school and then remains constant. Maths anxiety in 15-year-old boys and girls has increased since around 2000 and the gender gap has widened during those years.

In maths anxious pre-service teachers the maths anxiety typically increases when they become in-service teachers. Negative attitudes of maths anxious teachers have a strong influence on same-gender students, and with over 90 per cent of female primary teachers in the Australian primary schools, teachers have a strong impact on young female students, including reinforcement of traditional gender stereotypes.

Maths anxiety has been shown to be an impediment to achievement. Its two components, fear and avoidance, affect individuals, their beliefs, and performance in different ways:

- Fear due to maths anxiety shifts activities in the brain away from the regions that are involved in mathematical reasoning. This reduces the available working memory resources and results in a 'performance deficit', that is, individuals perform below their mathematical ability levels
- Low self-concept of an individual's mathematical ability has a strong effect on increasing maths anxiety. Avoidance combined with low levels of confidence negatively impact on an individual's effort in learning and doing mathematics with natural consequences on performance
- Maths anxiety of teachers can cause stereotype threat in students, and endorsing those stereotypes leads to lower achievements, which in turn affects the individual's confidence and increases maths anxiety
- Maths anxiety, lack of confidence and inadequate preparation and mathematics education of teachers can lead to poor teaching practices, which can contribute more to maths anxiety of students than the actual content of the subject

Recommendations

Findings about teachers' impact on students' achievements are of concern and demonstrate the urgent need for action on the side of teacher-educators and governments to provide:

- Training and support to ensure pre-service teachers are equipped with a solid knowledge of mathematics and good teaching practices, including how to influence student learning
- Adequate access to methods to support existing and pre-service teachers in reducing both their own and their students' maths anxiety and increasing their self-confidence

Support for teachers in these areas needs to be available for in-service and needs to include access to more mathematical knowledge through professional development or appropriate further qualifications. Reducing maths anxiety in teachers and in female students will have the potential to increase students' confidence in their abilities, their interest and hence their enjoyment and engagement with mathematics.

Gender differences in mathematical confidence are much larger than gender differences in interest or achievement in primary school, demonstrating a need for interventions which increase girls' confidence. These interventions should start early and be continued throughout primary and secondary education to create a positive and lasting effect on confidence, attitude, interest, achievement and career decisions. Such interventions should include:

- A focus on emphasising aptitude, engagement, and building of confidence in teaching instead of achievement and performance
- A focus on teaching with a growth mindset framework, directing students' reappraisal in positive directions and teaching students the power of learning from mistakes and adopting a 'failure-as-enhancing' mindset

2.8 Appendix: Concepts related to Maths Anxiety

Some of the definitions below are general, but we typically refer to them in relation to mathematics. We use the more common term 'ability' instead of 'capability'.

Stereotype threat is the effect or impact of (traditional) stereotype(s) on attitude and behaviour. It occurs when stereotypes are activated and negatively impact on an individual. Typical examples are gender-based stereotypes relating to women and mathematics.

Confidence or **self-confidence** refers to an individual's positive self-image, his or her self-esteem or self-assurance.

Self-efficacy is an individual's belief of his or her capacity to perform and succeed at specific tasks, or the individual's belief in their innate ability to achieve goals. Often used as synonym for confidence.

Self-concept refers to the totality of an individual's perception of him or herself, his or her attitudes and opinions and comprises physical aspects, academic and social self-concept; sometimes also used synonymously with self-perception of ability or with confidence.

Performance relates to the level of success in specific tasks or tests.

Achievement is an overall and longer-term measure of the level of success in the execution of different mathematical tasks.

Capability is the ability to generate an outcome. Typically used as synonym for an individual's ability.

Aptitude refers to an individual's potential and innate ability to acquire knowledge and skills.

2.9 References

Ahmed, W., Minnaert, A., Kuyper, H., & van der Werf, G. (2012). Reciprocal relationships between math self-concept and math anxiety. *Learning And Individual Differences*, *22*(3), 385-389.

Bandura, A. (1986). Social foundations of thought and action. *Englewood Cliffs, NJ*, *1986*.

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, *107*(5), 1860-1863.

Beilock, S. L., & Willingham, D. T. (2014). Math anxiety: can teachers help students reduce it? Ask the Cognitive Scientist. *American Educator*, *38*(2), 28.

Boaler, J. (2015). *Mathematical Mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass.

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1-40.

Buckley, S. (2016). *Changing Minds: Discussions in neuroscience, psychology and education*. Gender and sex differences in student participation, achievement and engagement in mathematics. Australian Council for Educational Research.

Buckley, S., Reid, K., Goos, M., Lipp, O. V., & Thomson, S. (2016). Understanding and addressing mathematics anxiety using perspectives from education, psychology and neuroscience. *Australian Journal of Education*, *60*(2), 157-170.

Buckley, S. (2019). Anxiety and engagement in mathematics: Barriers to mathematical teaching and learning and the way forward. Section 3, *Gender Report 2019*. Melbourne, Vic.: Australian Mathematical Sciences Institute

Chang, H., & Beilock, S. L. (2016). The math anxiety-math performance link and its relation to individual and environmental factors: a review of current behavioral and psychophysiological research. *Current Opinion in Behavioral Sciences*, *10*, 33-38.

Christopher, B. A. (2018). *The Relationship Between Calibration, Mindset, Mathematics Anxiety and Achievement in Pre-Service Elementary Teachers*.

Cohen, G. L., & Garcia, J. (2014). Educational theory, practice, and policy and the wisdom of social psychology. *Policy Insights from the Behavioral and Brain Sciences*, *1*(1), 13-20.

Devine, A., Fawcett, K., Szűcs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions*, *8*(1), 33.

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics anxiety: what have we learned in 60 years?. *Frontiers in Psychology*, *7*, 508.

Forgasz, H. J., Leder, G. C., & Kloosterman, P. (2004). New perspectives on the gender stereotyping of mathematics. *Mathematical Thinking and Learning*, 6(4), 389–420.

Frome, P. M., & Eccles, J. S. (1998). Parents' influence on children's achievement-related perceptions. *Journal of Personality and Social Psychology, 74,* 435–452.

Galwardo, A. G. (2015). *Motivational and affective factors that influence learning*. retrieved from (slideshare.net/AmariHimeMai06/self-concept-and-self-efficacy.)

Ganley, C. M., Mingle, L. A., Ryan, A. M., Ryan, K., Vasilyeva, M., & Perry, M. (2013). An examination of stereotype threat effects on girls' mathematics performance. *Developmental Psychology*, *49*(10), 1886.

Ganley, C. M., & Lubienski, S. T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences*, *47*, 182-193.

Geist, E. (2015). Math anxiety and the "math gap": How attitudes toward mathematics disadvantages students as early as preschool. *Education*, *135*(3), 328-336.

Gresham, G. (2018). Preservice to inservice: Does mathematics anxiety change with teaching experience?. *Journal of Teacher Education*, *69*(1), 90-107.

Hanewald, R. (2013). Transition between primary and secondary school: why it is important and how it can be supported. *Australian Journal of Teacher Education*, *38*(1), n1.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 33-46.

Hoffman, B. (2010). "I think I can, but I'm afraid to try": The role of self-efficacy beliefs and mathematics anxiety in mathematics problem-solving efficiency. *Learning and Individual Differences*, *20*(3), 276-283.

Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist*, *60*(6), 581.

Hyde, J. S. (2014). Gender similarities and differences. *Annual Review of Psychology*, *65*, 373-398.

Jameson, M. M., & Fusco, B. R. (2014). Math anxiety, math self-concept, and math self-efficacy in adult learners compared to traditional undergraduate students. *Adult Education Quarterly*, *64*(4), 306-322.

Jones, W. G. (2001). Applying psychology to the teaching of basic math: a case study. *Inquiry*, *6*(2), 60-65.

Koch, I. & Li, N. (2017). Teacher confidence, education and experience: choose maths teacher survey 2016. *AMSI Choose Maths Research No 1.* Melbourne, Vic.: Australian Mathematical Sciences Institute

Koch, I. (2019a). How confident are female students and how anxious are their teachers in their mathematical abilities? Section 3, *Gender Report 2019.*

Koch, I. (2019b). Attitude towards mathematics and confidence in mathematical abelity of students – Can it change? Section 4, *Gender Report 2019.*

Li, N. & Koch, I. (2017). *Choose maths gender report: participation, performance, and attitudes towards mathematics*. Melbourne: Australian Mathematical Sciences Institute.

Li, N. (2019). Understanding motivation behind mathematics enrolment choice in senior secondary schools: Questionnaire design. Section 3, *Gender Report 2019.*

Lyons, I. M., & Beilock, S. L. (2011). Mathematics anxiety: separating the math from the anxiety. *Cerebral cortex*, *22*(9), 2102-2110.

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education*, 520-540.

Maguire, B., & Yu, M. (2015). Transition to secondary school. In Australian Institute for Family Studies (Ed.), *The Longitudinal Study of Australian Children Annual Statistical Report* 2014, 83—104. Melbourne, Vic.: Australian Institute of Family Studies

Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: who has it, why it develops, and how to guard against it. *Trends in cognitive sciences*, *16*(8), 404-406.

Maloney, E. A. (2019). Negative emotions in the math classroom: anxiety and stereotype threat, Section 3, *Gender Report 2019.*

O'Keeffe, L., White, B., Panizzon, D., Elliot, K., & Semmens, A. (2018). Mathematics anxiety: Year 7 and 8 student perceptions. In *MERGA 2018*.

Pajares, F., & Miller, M. D. (1994). Role of self-efficacy and self-concept beliefs in mathematical problem solving: A path analysis. *Journal of Educational Psychology*, *86*(2), 193.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational psychology review*, *18*(4), 315-341.

Pletzer, B., Kronbichler, M., Nuerk, H. C., & Kerschbaum, H. H. (2015). Mathematics anxiety reduces default mode network deactivation in response to numerical tasks. *Frontiers in human neuroscience*, *9*, 202.

Ramirez, G., Shaw, S. T., & Maloney, E. A. (2018). Math anxiety: Past research, promising interventions, and a new interpretation framework. *Educational Psychologist*, 1-20.

Smith, L. J. (2010). *The relationship among mathematics anxiety, mathematical self-efficacy, mathematical teaching self-efficacy, and the instructional practices of elementary school teachers*, PhD thesis, University of Southern Mississippi, Hattiesburg, USA

Spelke, E. S. (2005). Sex differences in intrinsic aptitude for mathematics and science?: a critical review. *American Psychologist*, *60*(9), 950.

Stoet, G., Bailey, D. H., Moore, A. M., & Geary, D. C. (2016). Countries with higher levels of gender equality show larger national sex differences in mathematics anxiety and relatively lower parental mathematics valuation for girls. *PloS one*, *11*(4), e0153857.

Thomson, S., De Bortoli, L. J., & Buckley, S. (2014). *PISA 2012: How Australia measures up*. Camberwell, Australia: Australian Council for Educational Research.

Underwood, C. (2017). *Evaluation of Choose Maths program*, Australian Council for Educational Research.

Wang, Z., Hart, S. A., Kovas, Y., Lukowski, S., Soden, B., Thompson, L. A., ... & Petrill, S. A. (2014). Who is afraid of math? Two sources of genetic variance for mathematical anxiety. *Journal of Child Psychology and Psychiatry*, *55*(9), 1056-1064.

Yeager, D. S. (2012, April). Productive persistence: A practical theory of community college student success. In *Annual Meeting of the American Educational Research Association,* Vancouver, Canada.

Young, C. B., Wu, S. S., & Menon, V. (2012). The neurodevelopmental basis of math anxiety. *Psychological Science*, *23*(5), 492-501.

3 Mathematics, Gender and Mathematics Education Workshop 2018

Melbourne 19-21 June, 2018

Inge Koch
Australian Mathematical Sciences Institute

Gilah Leder
Monash University and La Trobe University

3.1 Introduction

Women are severely under-represented in science, technology, engineering and mathematics (STEM) in schools, university and the workforce, with mathematics being the enabling discipline for the other areas, as well as a discipline in its own right.

The Choose Maths program of the Australian Mathematical Sciences Institute (AMSI) aims to address and affect this under-representation of women by:

- motivating and engaging girls and young women to learn and study more mathematics and for longer
- increasing the proportion of women entering and pursuing STEM-related disciplines and careers
- improving career aspects and paths for young women in STEM-related jobs and industries

For more information about Choose Maths see Section 1 (p. 8).

As part of the its multilevel approach, Choose Maths held its first three-day workshop, Mathematics, Gender and Mathematics Education, in June 2018. The topic and theme of the workshop were chosen to enhance and complement our initiatives and to bring together and engage with different stakeholder groups.

Workshop aims: Develop and advance practical strategies to:

- address maths anxiety of students and teachers
- increase students' confidence
- affect teachers' and students' attitudes towards mathematics

It was intended that findings from the workshop would inform Choose Maths Outreach and lead to longer-term policy proposals.

Participants: The approximately 35-40 attendees included university researchers from mathematics, statistics, education, psychology, science and engineering, mathematics teachers with experience in engaging girls, and government and department of education representatives. This combination of participants with diverse interests and expertise enabled progress towards the aims of the workshop through research presentations, practical sessions on motivating girls and focused workshop discussions.

Program Outline

There were 10 invited presentations with 8 contributed talks making up the balance. Three workshop sessions provided participants with the opportunity to discuss issues in greater depth with others.

	Tues 19 June 2018	**Wed 20 June 2018**	**Thur 21 June 2018**
9:00		Dr Sarah Buckley, ACER	Dr Ning Li, AMSI Choose Maths
10:00	Welcome & Intro	Ms Ashley Stewart, Head of Mathematics, Newton Moore Senior High School, WA	Contributed Talks Dr Liz Stojanovski, University of Newcastle; Ms Vanessa Fay, Australian Science and Mathematics School, SA
11:00	Prof. Emerita Gilah Leder, Monash & La Trobe University	Mr Peter Chandler, Maths Mentor Coordinator, Penrhos, WA	Working Groups
12:00	Assistant Prof. Erin Maloney, Ottawa University, Canada	Ms Nadia Abdelal, Ms Jacinta Blencowe, Ms Anna Bock, Ms Helen Booth, Mr Marcus Garrett, Ms Vicky Kennard, Ms Cass Lowry, Ms Leanne McMahon, Ms Janine McIntosh, Mr Michael O'Connor, AMSI Choose Maths	Working Groups
14:15	Prof. Peter Grootenboer, Griffith University	Contributed Talks Assoc. Prof. Linda Galligan, University of Southern Queensland; Dr Emily Cook, Swinburne University; Ms Rebecca Marrone, University of South Australia	Reports from Working Groups & Planning
15:30	Executive Director Assoc. Prof. Inge Koch, AMSI Choose Maths	Dr Naomi Ingram, University of Otago, NZ	Conclusion
16:30	Contributed Talks Dr Donna Salopek & Dr Diana Combe, UNSW; Dr Pauline Carter, DECD, South Australia; Dr Katherine Dix, ACER	Working Groups	
18:00	Welcome reception	Workshop dinner	

The following sections contain the invited papers presented at the workshop—starting with the methodological papers in the order they were presented (section 3.2), followed by the presentations that dealt with practical applications (section 3.3). The opinions presented, in the workshop papers are those of the individual authors and may not represent the views of the organisers, Inge Koch and Gilah Leder.

Section 3.4 covers the participants and their responses to the papers presented at the conference.

3.2 Invited Presentations: Methodology

3.2.1 Gender and Mathematics a Moving Target?

Gilah Leder
Monash University and La Trobe University

Gender differences in mathematics learning continue to attract attention—from educators, researchers, and stakeholders. Current data on gender differences in mathematics learning are presented, as are situational and personal factors invoked to explain these differences. Concern about the declining proportion of secondary and tertiary students choosing to study rigorous mathematics options and the physical sciences is also raised.

Introduction

Historically, mathematics has been regarded as a male domain, that is, an area in which males outperform females. According to Mckinnon (1990, p. 347): "There are perhaps only three or four women until the nineteenth century who have left behind a name in mathematics. Women were lucky to receive any education at all" (Mckinnon, 1990, p. 347). Such a gloomy assessment can be countered to some extent with evidence gleaned from an English publication, the *Ladies' Diary* or *Women's Almanack*, launched some 300 years ago, in 1704. For reasons that today can only be surmised, three years later editor John Tipper began adding mathematical problems to the *Diary's* content. The initiative proved successful:

In 1708 the author receiv'd several letters from the fair sex, and inserted, besides the enigmas, four arithmetical questions: which so well pleas'd the fair ones, that in 1709 he received several excellent questions and answers, which he publish'd, and you'll find in 1710 began generally to please. (Beighton, 1714)

Until its final issue in 1840, mathematical problems continued to be published in the *Ladies' Diary.*

Thanks to the decision by successive editors of the *Diary* to reward early and elegant solutions with a copy of the following year's publication, and a listing of the names (Leybourn's Index) of those who proposed and answered the questions, evidence of females' mathematical contributions to the *Diary* can be traced. Reflecting on the quite remarkable history of this publication, Perl (1979, p. 36) argued that the "existence of the *Ladies' Diary* … indicates that stereotypes about the inability of women to understand and enjoy mathematics were less strongly believed in the 18th century than they are today". From careful inspection of Leybourn's list and other sources it can be inferred that many of the female contributors to the mathematical section of the *Ladies' Diary* were the wives, daughters or other close relative of men engaged in mathematical pursuits (see e.g., Costa, 2000; Leder, 1980; Perl, 1979). Given an appropriate milieu and academic and personal support, it appears that in the eighteenth and nineteenth centuries there were females who were attracted to, and capable of, engaging in mathematical pursuits. Before focusing further on the importance of environmental factors and support from "critical others", it is appropriate to sketch a brief summary of current research findings on gender and mathematics learning.

Current views on gender differences in mathematics learning

While the presence of gender differences in mathematics learning is challenged by some researchers, small gender differences in favour of males continue to be reported in a variety of settings: for certain content domains and topic areas assessed through large scale tests, when timed assessment tasks are used, when achievement in post-compulsory mathematics courses is considered, and among high-achieving students (see, e.g., Leder & Forgasz, 2018). As well, on a range of affective/attitudinal measures about mathematics and about themselves as mathematics learners, females' views regarding future success have frequently been found to be less functional than those of males'.

The evidence—selected snapshots

Data from the *Programme for International Student Achievement* (PISA), from the *Trends in International Mathematics and Science Study* (TIMSS) surveys, and from Australia's *National Assessment Program—Literacy and Numeracy* (NAPLAN) test illustrate the muted scope and direction of relatively small but persistent gender differences in performance on these instruments.

PISA

Mathematical literacy was a particular focus in the 2003 and 2012 PISA surveys distributed in countries which are part of the Organisation for Economic Co-operation and Development [OECD]. In both of these testing years, gender differences were found in the mean mathematics performance scores. Among the 65 countries participating in PISA 2012, males outperformed females in 38, and females outperformed males in five (OECD, 2013). The difference in the mean score in favour of males was 11 points, with the gap in favour of males exceeding the equivalent of half a year of schooling in only six countries; within gender-group differences are invariably far greater than between group differences. The gender gap favouring males was, however, greatest among the highest-achieving students.

Possible gender difference in affect have also been explored in the PISA surveys:

PISA and other studies find that girls have less belief in their own abilities in mathematics and science, and are plagued with greater anxiety towards mathematics, than boys—even when they perform just as well as boys... What all of this evidence suggests is that gender disparities in drive, motivation and self-beliefs are more pervasive and more firmly entrenched than gender differences in mathematics performance. (OECD, 2015, p. 68)

TIMSS

Turning to the TIMSS tests, provocative nuanced differences emerge when students' performance is considered by content domain. At the grade 4 level, boys performed better than girls on *number* items in 21 countries while the mean score for girls was higher than for boys in seven countries (see Mullis et al., 2016). For *geometric shapes and measures*, the mean score for boys was higher than for girls in 14 countries but higher for girls than boys in nine countries. For *data display*, girls out performed boys in 13 countries; boys did better than girls in two countries. Inconsistencies in gender differences in performance by content domain were also found for students in eighth grade. In *number*, on average, boys did better than girls in 17 countries; girls did better than boys in four countries. In contrast, on *algebra* domain items, girls did better than boys in 21 countries, and boys did not outperform girls in any countries. Girls also did better than boys on *geometry* items in eight countries; boys outperformed girls on items in this domain in two countries. Further, for *data and chance*, boys outperformed girls in six countries, and girls outperformed boys in seven countries.

NAPLAN

Data from the numeracy component of the NAPLAN test are also worth noting. The 2017 results published by the Australian Curriculum, Assessment and Reporting Authority [ACARA] (2017) revealed that at each year level the mean NAPLAN score for males was higher than for females and that a higher proportion of males than females recorded a score that placed them in the highest band category. Yet, as shown in Table 3.1, a higher proportion of females than males were deemed to have performed at or above the national minimum level. Thus a verdict about which group "is better" at mathematics can vary, depending on which aspect of the NAPLAN results is referenced.

Table 3.1 NAPLAN (Australian) numeracy data for 2017 by gender

	Mean NAPLAN score		% at or above NMS[1]		% at or above highest band	
Year	**M**	**F**	**M**	**F**	**M**	**F**
3	412.5	406.2	94.8	96.1	19.0	15.2
5	497.9	489.6	94.8	95.9	10.9	7.2
7	555.8	551.8	94.6	96.2	14.3	11.3
9	595.5	588.3	95.3	96.3	8.9	6.4

[1]*National Minimum Standard*

A further comment

Summary data from large scale national and international test are invariably reported in the media. As shown by Forgasz and Leder (2011), such media reports often—inadvertently or perhaps to comply with space constraints—fail to present the complexities of within group variations in performance. Simplified reporting of results that emphasize gender differences in performance can perpetuate pre-conceived societal stereotypes and can influence students' beliefs about their own likely success in mathematics achievement and the value to them of that achievement.

Explanations for gender differences in mathematics learning

Research on gender differences in a range of settings and endeavours is pursued unabated. Multiple explanations are put forward for the modest but persistent patterns of gender differences favouring males in mathematics learning outcomes (see Table 3.2).

Table 3.2 Variables linked with gender differences in mathematics learning outcomes (adapted from Leder, 1993)

Learner-related variables		**Environment-related variables**	
Cognitive Development:		Society	
Spatial ability	Verbal ability	Law	Peers
Beliefs		Media	Cultural expectations
Confidence	Sex-role congruence	Home	
Usefulness of mathematics		Parents	Socioeconomic status
Motivation		Siblings	
Fear of success		School	
Attributional style		Teachers	Textbooks
Learned helplessness		Organisation	Assessment
Mastery orientation		Curriculum	Peers
Performance following failure		…	

Different theoretical and value-driven perspectives have been used to shape and guide research on this issue. The models proposed typically contain a range of interacting factors, both intra-personal and environmental. Included among the latter are the school culture, social mores, and the values and expectations of peers, parents, and teachers. Leder's (1993) model of variables implicated in gender differences in mathematics learning outcomes, broadly captured in Table 3.2, foregrounds some of the important influences.

Learner-related and environment-related factors contribute to the gender differences in mathematics learning

That a diverse range of personal and affective variables has been linked to gender differences in mathematics learning is illustrated in Table 3.2. Represented is a plethora of overlapping constructs devised and used by those working in the field. Of the various elements listed, the focus here is on one embedded in the expectancy-value theory of motivation. Briefly, within this framework it is hypothesised that how hard an individual strives to reach a particular goal is influenced by the value he/she assigned to that goal and his/her expectation of reaching the goal. (See, for example, Atkinson (1964) for early studies on this construct). However, in experimental work it appeared that cues likely to spur males to strive towards a stated goal yielded inconsistent results when research participants comprised females. In an attempt to explain the gender-linked conflicting findings on achievement motivation, the M-s or "fear of the consequences of success" concept (often unhelpfully shortened to "fear of success", or simply FS) was put forward. If achievement in a certain setting is considered to be more congruent with the male than the female role then for females might success in that setting produce anxiety which in turn might have an adverse effect on their performance? Could females capable of doing well in mathematics, reputedly a male domain, and who want to aim for success in mathematics be at the same time concerned about "the potential negative consequences of that success: "loss of one's sense of femininity and self-esteem regardless of whether anyone finds out about the success or not, and/or social rejection because of success" (Horner, 1968, pp. 16–17). Some five decades ago Horner's theoretical construct aroused much interest and continues to be cited and invoked in research until the present.

Final comments

After four decades of consistent research on gender and mathematics there seems to be:

- Limited consensus on the size and direction of gender differences in mathematics performance
- There is much variation in the explanations put forward to account when gender differences are found

Given the current pervasive focus on gender equity issues, the #MeToo campaign, and the debate on quota systems in government, political, and educational systems, should the notion now be dismissed of a possible tension between aiming for success in mathematics (or other spheres of endeavour) and the negative (social and personal) consequences thought likely to be associated with that success? Should the link between affective factors, such as FS and anxiety, and gender differences in mathematics performance and participation continue to be explored? And how should such work be framed?

Crucially, there continues to be alarm about the declining proportion of secondary and tertiary students choosing to study rigorous mathematics options and the physical sciences. Our challenge, it is widely acknowledged, is not to favour or focus on one group at the expense of another, but rather to stem the drift away from non-compulsory mathematics routes.

A postscript

The decline in the proportion of students electing to study mathematics when this is no longer compulsory and the scarcity of appropriately qualified mathematics teachers were forcefully highlighted, again, in the popular print media less than one month after the workshop. As reported in one of Melbourne's daily newspapers:

Education Minister Simon Birmingham will today announce the drastic move to tackle the plummeting number of enrolments in science, technology, engineering and mathematics (STEM) subjects. …Uptake in intermediate and advanced maths has dropped by 33 per cent over two decades. ...(E)very high school should have access to specialist science and maths subjects…primary school students also needed to be taught by more science and maths specialists to "inspire their interest in the sciences". (Galloway, 2018, p. 9)

References

Australian Curriculum, Assessment and Reporting Authority [ACARA] (2017). *National Assessment Program—Literacy and Numeracy Achievement in Reading, Writing, Language Conventions and Numeracy: National Report for 2017.* Retrieved from (nap.edu.au/docs/default-source/default-document-library/naplan-national-report-2017_final_04dec2017.pdf?sfvrsn=0)

Atkinson, J. W. (1964). *An introduction to motivation.* Oxford, England: Van Nostrand.

Beighton, H. (1714). Editorial. *The Ladies' Diary.*

Costa, S.A. (2000). *The Ladies" Diary: Society, gender and mathematics in England, 1704-1754* (Unpublished doctoral dissertation). Cornell University, Ithaca, NY, USA.

Forgasz, H. J., & Leder, G.C. (2011). Equity and quality of mathematics education: Research and media portrayals. In B. Atweh, M. Graven, W. Secada, & P. Valero (Eds.), *Mapping Equity and Quality in Mathematics Education* (pp. 205-222). Dordrecht, the Netherlands: Springer.

Galloway, A. (2018, July 9). Maths slide fight. Schools forced to have specialist STEM staff. *The Herald Sun*, p. 9,

Horner, M.S. (1968). *Sex differences in achievement motivation and performance in competitive and non-competitive situations* (Unpublished doctoral dissertation). University of Michigan, USA.

Leder, G. C. (1993). Gender differences: An overview. In E. Fennema & G. C. Leder (Eds.), *Mathematics and Gender* (pp. 1-9). Brisbane, Australia: Queensland University Press.

Leder, G. C., & Forgasz, H. J. (2018). Measuring who counts: Gender and mathematics assessment. *ZDM Mathematics Education*, 50(4), 687-697.

Mackinnon, N. (1990). Sophie Germain: or was Gauss a feminist? *Mathematical Gazette, 74(470), 346-351. Doi:10.2307/3618130*

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics.* Retrieved from Boston College, TIMSS & PIRLS International Study Center website: retrieved from timssandpirls.bc.edu/timss2015/international-results/)

OECD. (2013). *PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy.* Paris: OECD Publishing. Retrieved from (dx.doi.org/10.1787/9789264190511-en)

OECD (2015). *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence, PISA*. OECD Publishing. Retrieved from (dx.doi.org/10.1787/9789264229945-en)

Perl, T. (1979). The ladies' diary or woman's almanack, 1704-1841. *Historia Mathematics, 6, 36-53.*

3.2.2 Negative Emotions in the Classroom: Anxiety and Stereotype Threat

Erin A. Maloney
University of Ottawa

Mathematics anxiety and stereotype threat are important attitudinal factors that influence people's interest and success in mathematics. These phenomena are discussed here, paying particular attention to how they relate to engagement and performance in mathematics-related courses and careers. I conclude by highlighting promising interventions, which can be used by teachers and students, to reduce maths anxiety and stereotype threat and lead to increased involvement and success in mathematics courses and careers.

Introduction

To be successful in mathematics, one needs conceptual understanding, procedural fluency, strategic competence and a willingness to engage in adaptive reasoning (NRC, 2001). Given how cognitively complex mathematics is, the host of negative attitudes and stereotypes that are so frequently associated with mathematics, and the importance of mathematical ability in predicting academic and financial success (e.g., Bishop, 1989; Boissiere, Knight & Sabot, 1985; Rivera-Batiz, 1992), it is easy to understand how mathematics education remains such an important issue in the fields of both education and psychology.

When working to understand the factors that influence success in mathematics, it is important not to overlook the role that negative emotions can play. Indeed, anxiety can impact student performance on in-class assessments and standardised tests as well as decisions regarding which career paths to pursue (e.g., Hembree, 1990). In the present review, I summarise key findings from psychological and neuroscience research, highlighting, specifically, the negative effects of anxiety on mathematics performance. I also discuss a related phenomenon — stereotype threat, whereby people underperform relative to their ability merely because they are aware of a negative stereotype about how they should perform (e.g., a female student aware of the stereotype that ''boys are better than girls at mathematics''). I discuss how these two phenomena appear to impact performance via the same mechanism. Importantly, I also discuss key advancements in our understanding of effective interventions that can be employed in the classroom to help reduce the negative consequences of anxiety on maths performance.

Etiology of Mathematics Anxiety

Maths anxiety is believed to be caused both by cognitive factors (e.g., less precise representation of number) and socio-environmental factors (e.g., exposure to negative attitudes and beliefs about mathematics; Maloney & Beilock, 2012). Studies examining the numerical and spatial abilities of maths anxious adults demonstrate that higher maths anxious adults perform less well than their lower-maths-anxious peers on tasks thought to index basic numerical and spatial abilities and representations, such as counting, magnitude comparison, and mental rotation (Ferguson, Maloney, Fugelsang, & Risko, 2015; Maloney, Risko, Ansari, & Fugelsang, 2010; Maloney, Ansari, & Fugelsang, 2011; Maloney, Waechter, Risko, & Fugelsang, 2012). Maloney and colleagues argue that maths anxiety first starts with difficulties in numerical and/or spatial processing and that these difficulties lead to difficulties with mathematics, which, in turn, leads to maths anxiety (for a review, see Maloney, 2016).

With respect to socio-environmental factors, a host of studies have suggested that students' experiences inside and outside of the classroom play an important role in the development of maths anxiety. For example, in a recent study examining the intergenerational transmission of maths anxiety, Maloney et al. (2015), Maloney and colleagues reported that when parents were higher in maths anxiety and frequently helped their children with their mathematics homework, over the course of a school-year, their children were higher in maths anxiety and learned less mathematics relative to their peers, whose parents were either higher in maths anxiety but did not help frequently with mathematics homework or who were lower in maths anxiety. These data suggest that during those homework-helping situations, highly maths anxious parents may be communicating negative attitudes and beliefs about mathematics to their young children and that their children, in turn, internalize these negative attitudes and beliefs.

While children can internalize negative attitudes and beliefs about mathematics from their parents, the negative experiences children undergo in the classroom may also influence a child to develop maths anxiety. Consistent with this theory, interviews and focus groups with adults consistently link the development of maths anxiety to perceived negative experiences with school teachers (Chapline, 1980; Chavez & Widmer, 1982; Markovits, 2011). It is believed that teachers may lead students to develop maths anxiety by their overreliance on specific pedagogies (Chapline, 1980; Chavez & Widmer, 1982; Markovits, 2011), such as too much emphasis on rote learning (Trujillo & Hadfield, 1999; Vinson, 2001) and presenting lessons in a strongly dogmatic manner (Ball, 1990).

Researchers have also investigated whether teachers' own attitudes about mathematics can contribute to the development of maths anxiety in their students. Consistent with the idea that teachers' attitudes and beliefs can impact their students' own attitudes and beliefs, Beilock, Gunderson, Ramirez, and Levine (2010) demonstrated that, at the school-years' end, the more maths anxious a teacher was, the lower her female students' mathematics achievement was, and the higher the likelihood that they would endorse the stereotype that "boys are good at mathematics, and girls are good at reading." These data provide support to the theory that a teacher's maths anxiety can impact their students' attitudes about mathematics, but note that Beilock, Gunderson, Ramirez, and Levine (2010) did not report on whether highly maths anxious teachers impacted the students` own maths anxiety.

Stereotype Threat

Stereotype threat refers to the phenomenon whereby individuals perform more poorly than would be expected given their ability on a task when a relevant negative stereotype is made salient in the performance situation (Steele & Aronson, 1995). For example, women and girls perform worse when the stereotype that women are bad at mathematics is made salient than when it is not (Spencer, Steele, & Quinn, 1999). It is believed that the poor performance results from concern that if an individual fails, then they might be viewed as confirming a negative social stereotype.

How Anxiety and Stereotype Threat Impact Performance

Although maths anxiety and stereotype threat are distinct constructs with differing etiologies, these two phenomena are thought to impact performance in the same way. Specifically, maths anxiety and stereotype threat are thought to cause negative thoughts and ruminations and these thoughts and ruminations use up important cognitive resources that are needed to perform well on a mathematics task. Essentially, when one is doing a mathematics test and is feeling anxious, or nervous about confirming a negative stereotype, they are doing two things at one; (1) dealing with these negative thoughts and ruminations and (2) doing the mathematics (see Maloney et al., 2015). As a result, their performance suffers.

Maths anxiety and gender stereotypes have equal impact on performance

Tools for Combatting Maths Anxiety and Stereotype Threat

Given that maths anxiety and stereotype threat can both cause people to underperform in mathematics and avoid mathematics, researchers have long looked for a way to reduce anxiety and stereotype threat. Particularly promising are interventions that are designed to reduce negative thoughts and ruminations. One such intervention that has proven very promising involves the use of expressive writing. In this paradigm, students write about an upcoming test for approximately 10 minutes immediately before they take the test (e.g., Ramirez & Beilock, 2011). The theory is that having the students engage in an expressive writing exercise will reduce the intrusive thoughts that result from anxiety related to performance. This will, in turn, free up the cognitive resources that are needed for the mathematics task. This strategy of expressive writing has been shown to be helpful with students in high school (Ramirez & Beilock, 2011) as well as undergraduate adults (Park, Ramirez, & Beilock, 2014).

Intervention based on expressive writing appear promising in reducing negative emotions

Another way to alleviate anxiety is to teach anxious students to reappraise their arousal. There are at least two ways that students can be taught to reappraise their anxiety when under stereotype threat. For example, Jamieson, Mendes, Blackstock, and Schmader (2010) had students come into the laboratory and take a practice test for an upcoming high stakes test.

Half of the students were told that arousal actually helped with performance (the reappraisal condition), while the other half was told nothing (the control condition). The students in the reappraisal condition scored higher than their peers in the control condition both on the practice test on the actual high stakes test that occurred months later. In another study, Johns, Schmader and Martens (2005) demonstrated that by simply teaching women about the stereotype threat and the anxiety that it might produce, we can eliminate the effect. In other words, simply teaching the women about stereotype threat allowed them to reappraise the arousal that they felt (most likely attributing the arousal to stereotype threat rather than attributing it to a high degree of pressure to succeed), and consequently inoculated them against stereotype threat.

Preventing Maths Anxiety and Stereotype Threat

There are currently no known interventions designed to prevent its onset. This is, in large part, because the exact etiology of maths anxiety remains unknown. That said, Maloney and colleagues' research, indicating that maths anxiety may stem from a basic deficit in numerical processing, suggests that children who present with poor number processing skills may be the most likely to develop maths anxiety. As such, it may be particularly important to identify those children who begin schooling with weaker numerical and spatial skills and work to boost their lower-level skills early. Further, research by Beilock et al. (2010), demonstrating that teachers with high maths anxiety can transmit their stereotypes to their students, suggests that interventions to decrease a teacher's level of maths anxiety may result in the reduction of poor attitudes about mathematics in hundreds of students over the course of her career. Fortunately, teaching pre-service teachers to focus on how children learn mathematics rather than teaching them the actual mathematics content that they need to know can lead to a reduction in the pre-service teachers own maths anxiety (Tooke & Lindstrom, 1998). Furthermore, given that maths anxious teachers can influence their students in terms of endorsement of negative gender stereotypes about girls and mathematics, girls in the classrooms of female maths anxious teachers may be more likely to experience stereotype threat. As such, teaching both teachers and students reappraisal techniques may help to prevent young girls from falling prey to the negative consequences of stereotype threat as it pertains to mathematics and, consequently, increase the number of girls who go one to succeed in mathematics and mathematics-related careers.

References

Ball, D. L. (1990). Breaking with experience in learning to teach mathematics: The role of a preservice methods course. *For the Learning of Mathematics, 10(2), 10-16.*

Beilock, S. L., Gunderson, E. A., Ramirez, G., & Levine, S. C. (2010). Female teachers' math anxiety affects girls' math achievement. *Proceedings of the National Academy of Sciences*, 107(5), 1860-1863.

Bishop, A. J. (1989). Mathematical Enculturation: A Cultural Perspective on Mathematics Education. *Journal for Research in Mathematics Education*, 20(4), 367-70.

Boissiere, M., Knight, J. B., & Sabot, R. H. (1985). Earnings, schooling, ability, and cognitive skills. *The American Economic Review*, 75(5), 1016-1030.

Chapline, E. B. (1980). *Teacher Education and Mathematics: Program Development and Evaluation*. Retrieved from (eric.ed.gov/?id=ED186272)

Chavez, A., & Widmer, C. C. (1982). Math anxiety: Elementary teachers speak for themselves. *Educational Leadership, 39(5), 387-388.*

*F*erguson, A. M., Maloney, E. A., Fugelsang, J., & Risko, E. F. (2015). On the relation between math and spatial ability: *The case of math anxiety. Learning and Individual Differences*, 39, 1-12.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21, 33-46.

Jamieson, J. P., Mendes, W. B., Blackstock, E., & Schmader, T. (2010). Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *Journal of Experimental Social Psychology*, *46*(1), 208-212.

Johns, M., Schmader, T., & Martens, A. (2005). Knowing is half the battle: Teaching stereotype threat as a means of improving women's math performance. *Psychological Science*, *16*(3), 175-179.

Maloney, E. A., (2016). Math anxiety: Causes, consequences, and remediation. K. R. Wentzel & D. B. Miele (Eds.), *Handbook of Motivation at School* (2nd ed., 408–423). New York, NY: Routledge., 408-423.

Maloney, E. A., Ansari, D., & Fugelsang, J. A. (2011). The effect of mathematics anxiety on the processing of numerical magnitude. *The Quarterly Journal of Experimental Psychology, 64(1), 10-16.*

Maloney, E. A., & Beilock, S. L. (2012). Math anxiety: Who has it, why it develops, and how to guard against it. *Trends in Cognitive Sciences*, 16(8), 404-406.

Maloney, E. A., Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2015). Intergenerational effects of parents' math anxiety on children's math achievement and anxiety. *Psychological Science*, 26(9), 1480-1488.

Maloney, E. A., Risko, E. F., Ansari, D., & Fugelsang, J. (2010). Mathematics anxiety affects counting but not subitizing during visual enumeration. *Cognition*, 114(2), 293-297.

Maloney, E. A., Sattizahn, J. R., & Beilock, S. L. (2014). Anxiety and cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, 5(4), 403-411.

Maloney, E. A., Waechter, S., Risko, E. F., & Fugelsang, J. A. (2012). Reducing the sex difference in math anxiety: The role of spatial processing ability. *Learning and Individual Differences*, 22(3), 380-384.

Markovits, Z. (2011). Beliefs hold by pre-school prospective teachers toward mathematics and its teaching. *Procedia-Social and Behavioral Sciences*, 11, 117-121.

National Research Council, & Mathematics Learning Study Committee. (2001). *Adding it up: Helping children learn mathematics*. National Academies Press. doi:10.17226/10434

Park, D., Ramirez, G., & Beilock, S. L. (2014). The role of expressive writing in math anxiety. *Journal of Experimental Psychology: Applied*, 20(2), 103.

Ramirez, G., & Beilock, S. L. (2011). Writing About Testing Worries Boosts Exam Performance in the Classroom. *Science*, 331, 211-213

Rivera-Batiz, F. L. (1992). Quantitative literacy and the likelihood of employment among young adults in the United States. *Journal of Human Resources*, 27(2), 313-328.

Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, 35(1), 4-28.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology*, *69*(5), 797.

Tooke, D. J., & Lindstrom, L. C. (1998). Effectiveness of a mathematics methods course in reducing math anxiety of preservice elementary teachers. *School Science and Mathematics*, *98*(3), 136-139.

Trujillo, K. M., & Hadfield, O. D. (1999). Tracing the roots of mathematics anxiety through in-depth interviews with preservice elementary teachers. *College Student Journal,* 33(2), 219-219.

Vinson, B. M. (2001). A comparison of preservice teachers' mathematics anxiety before and after a methods class emphasizing manipulatives. *Early Childhood Education Journal*, 29(2), 89-94.

3.2.3 Learning Mathematics: The Start of a Beautiful Friendship

Peter Grootenboer
Griffith University

In considering how we can encourage more students to participate and engage with mathematics, it is important to think about what it is we are wanting learners to choose, and who are being asked to join them in this mathematics community. Some of these issues are discussed in this paper. How school students can be encouraged to develop a beautiful friendship with mathematics—to “choose maths”—is also considered.

The What of Mathematics Education

Although everyone has spent many years studying mathematics at school, and mathematics is ubiquitous, there seems to be little clarity amongst mathematics educators and the general public about what mathematics actually is! In the Australian curriculum (ACARA), there are the following comments about mathematics:

- Learning mathematics creates opportunities for and **enriches the lives of all Australians**
- It develops the numeracy capabilities that all students **need in their personal, work and civic life**
- Mathematics has its own **value and beauty** and the Australian Curriculum: Mathematics aims to instil in students **an appreciation of the elegance and power** of mathematical reasoning
- Mathematical ideas have **evolved across all cultures** over thousands of years, and are **constantly developing**
- Mathematics is composed of multiple but interrelated and interdependent concepts and systems which students **apply beyond the mathematics classroom**
- It encourages teachers to help **students become self-motivated, confident** learners through inquiry and active participation in challenging and engaging

Aspects of these direct quotes have been highlighted in bold to emphasise some of the features and nature of mathematics, and although these are all included in the nationally mandated curriculum, one wonders whether they would be familiar to the students in Australian mathematics classrooms. It would seem likely that students would be willing to choose mathematics if they experienced it as something that enriches their lives, and has value and beauty, but it seems that this is not the case for many. Students often see mathematics as primarily about numbers, and times tables as the most important aspect to be learned (memorised). Also, they view people as either having a ‘maths brain’ or not (and mostly not!), and while mathematics is seen as very important, it is also perceived as dull, boring, and useless in real life. What is perhaps troubling, is that students mostly learned these things through their school education—the very place you would hope that students would learn that mathematics is vibrant, exciting, interesting, and used widely and extensively (Grootenboer & Marshman, 2017).

For mathematics educators, maybe it is time for us to revisit mathematics and engage in mathematical practices ourselves—not the teaching of mathematics, but actually being mathematicians ourselves. In this way as mathematics teachers, researchers and educators, we can overtly rekindle an appreciation for the beauty and fascination of mathematics that captured us and caused us to commit our professional lives to sharing it with others.

The Who of Mathematics

The erroneous view of mathematicians and mathematics teachers as nerdy and socially inept is almost proverbial, as is illustrated by the picture, shown on the right, drawn by a preservice primary school teacher when asked to sketch a mathematics teacher.

This negativity seems to be a perennial problem that does not appear to afflict other subject disciplines, nor is it helped by common perceptions as portrayed in the general media. Thus the current AMSI Choose Maths campaign that highlights a range of female role models involved in mathematics could be very important. Certainly steps need to be taken to give a more diverse and accurate depiction of the broad community of mathematicians.

Given the perceptions of mathematicians and mathematics teachers, it is perhaps not surprising that students do not see themselves as associated with the mathematics community. So, apart from providing welcoming and relatable faces of mathematics (e.g., through the AMSI program), it is also important that they see mathematics as connected to their life worlds. It is widely known that mathematics is ubiquitous (although perhaps not to students) and so it is likely that mathematics is related to, and integral to, most fields of interest and endeavour—it would seem to be important that students can actually see and experience this!

Learning Mathematics: The Start of a Beautiful Friendship

In thinking about how we might encourage more students to choose mathematics, perhaps we need to think about mathematics education in different ways. While learning mathematics is certainly about developing mathematical knowledge and skills, it is also about developing values and beliefs about the subject, and an appreciation for its beauty and usefulness. To this end, I quote Parker Palmer below:

To encourage students to choose maths, developing values and beliefs about and an appreciation for the beauty of mathematics are needed

The teacher, who knows [mathematics] well, must introduce it to the students in a way one would introduce a friend. The students must know why the teacher values [mathematics], how [mathematics] has transformed the teacher's life. By the same token, the teacher must value the students as potential friends, be vulnerable to the ways students may transform the teacher's relationship with [mathematics], as well as be transformed. If I am invited into a valued friendship between two people, I will not enter unless I feel that I am valued as well. (Palmer, 1993, p. 104)

The teacher may love [mathematics] in a possessive way that prevents the students from entering in. The teacher may be so possessive of [mathematics], and of his or her relation to it, that students are required to accept the subject on the teacher's own terms, discouraged or forbidden from assessing [mathematics] and finding their own relation to it. Here the teacher's enthusiasm is not an invitation but a demand. (Palmer, 1993, pp. 104-105)

Inviting students into a friendship with mathematics in our classes is a way to help students seem themselves as knowers and doers of mathematics, and to engage in the mathematics community.

References

Grootenboer, P., & Marshman, M. (2017). *Mathematics, affect and learning: Middle school students' beliefs and attitudes about mathematics education*. Singapore: Springer

Palmer, P. (1993). *To know as we are known: Education as a spiritual journey*. New York: HarperCollins

3.2.4 How Confident are Female Students and How Anxious are their Teachers in their Mathematical Abilities?

Inge Koch
Australian Mathematical Sciences Institute

Maths anxiety and a lack of confidence in their mathematical ability affect teachers and their students negatively when teaching mathematics and have adverse effects on students' enjoyment of and engagement in mathematics. Attitudes towards mathematics and confidence in their mathematical abilities can be changed through appropriate intervention. We show that positive change can be achieved for teachers and students as a consequence of the Choose Maths professional development for teachers and classroom interventions for students.

Introduction

Section 1 provides an outline of Choose Maths and describes the four components of the program, indicating how Choose Maths Research interacts with the four components. See Figure 1.2 in Section 1. In this paper we look more closely at the interactions between Choose Maths Research and the teachers and students in the Choose Maths schools and discuss findings which relate to the effectiveness of teacher professional development (PD) and student interventions.

Teacher Professional Development and Self-Assessment

The eight Outreach Officers—all experienced mathematics teachers—in AMSI's Choose Maths team provide schools outreach, mathematics support, professional development and they conduct student model lessons and interventions during eight annual visits to the 120 schools. Some examples of their work are provided in 'The AMSI Way—Schools Outreach' in Section 3.3.3. Typically a proportion of teachers was assigned by the head teacher or principal to participate in the Choose Maths activities for the year. For a more detailed description of the outreach and teacher surveys, and in particular the Wave 1 surveys from 2016 see Koch and Li (2017).

We measure the effectiveness of schools outreach through teacher surveys administered by the Australian Council for Educational Research (ACER). In Wave 2 in 2017, 764 primary and 206 secondary teachers, which corresponds to a response rate of about 64 per cent, participated in the ACER surveys. We illustrate the effect of the schools outreach for primary teachers in their responses on the extent to which they feel:

A. Confident when teaching mathematics (1 low, 11 high level of confidence)
B. Tense when teaching mathematics (1 very tense, 11 not tense)

Our emphasis focuses on differences in the responses between teachers in the Choose Maths schools who participated in the offered activities and those who did not both in 2016 and 2017. Table 3.3 shows the number of teachers in each group; 'yes' in the table refers to participation in that year, 'no' refers to no participation in that year, so 193 participated in both years, while 306 participated in neither year. We refer to the latter group as the 'neither'. Only 714 teachers responded to the participation question of the survey.

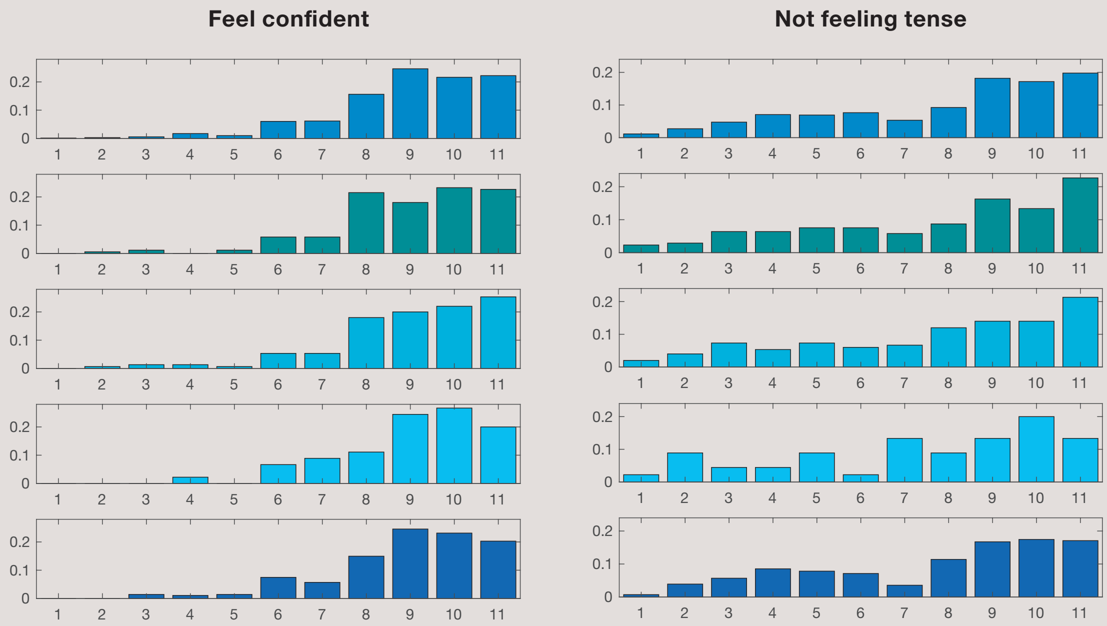
Table 3.3 Participation in Choose Maths activities in 2016 and 2017

714 responses	2016 yes	2016 no
2017 yes	193	165
2017 no	50	306

Teachers' confidence can be improved through appropriate and ongoing outreach and professional development

Questions A and B above are part of 11 criteria relating to competence, confidence, attitudes and practice of teaching mathematics in primary schools. Figure 3.1 shows the survey responses of the 714 teachers and the four subgroups listed in Table 3.3. From top to bottom the five panels for each question correspond to the following groups of teachers: all (top), yes-both: participating in Choose Maths in 2016 and 2017 (second), 2017 yes: participating in 2017 only (third), 2016 yes: participating in 2016 only (fourth), and finally the neither group. Each panel in Figure 3.1 shows the proportion of teachers on the vertical axes who responded with a particular number 1 to 11, shown on the horizontal axes. This number indicates the extent to which they felt confident or tense respectively. Figure 2.3 in Section 2 also looks at the question of feeling tense when teaching but considers the subsets of teachers who believe their mathematics training is or is not adequate. Since the 'trained to teach primary mathematics' teachers form the largest cohort among all primary teachers, the top plot on the right in Figure 3.1 is almost the same as the third plot from the left and in the top row in Figure 2.3. The other plots in the same column, however, differ as they refer to different subsets of teachers.

Figure 3.1 Choose Maths primary teachers' self-assessment



Groups of teachers from top to bottom: all; participating in 2016 and 2017; in 2017; in 2016; not in either year.

Level of agreement from 1 (low) to 11 (high).

It is worth pointing out that the levels for the neither teachers (bottom panel) could be too high: this group has not been affected by the 'dip in confidence' which occurs with a new program or training such as the PDs (see Fullan 2001 p. 40).

Findings

1. Schools outreach is effective in increasing teachers' confidence when teaching mathematics; and has decreased the feeling of being tense when teaching mathematics

2. Teachers who participated in 2017 show more confidence/feel less tense than those who only participated in 2016 suggesting that the ongoing 'treatment'—here the active engagement with Choose Maths—is important

Student Interventions

Differences between boys' and girls' average NAPLAN results are evident in Year 3, the first year students participate in NAPLAN tests: Boys have a higher average mark in numeracy than girls; see Figure 8 in Li and Koch (2017). The gap between the average marks in numeracy increases by Year 5 and then remains about constant. The distribution of marks of boys is wider than that of girls for every NAPLAN test and year, and because of this distributional difference we cannot conclude that the performance of boys is higher than that of girls.

The difference in average marks and in the shape of the distribution of marks does **not** imply that boys are mathematically more able than girls. Instead we ask the question: What are potential reasons or causes for the differences in the results? Partial answers relate to students' confidence in their abilities. Low confidence typically results in lower engagement and effort and likely in lower marks.

Since late 2016 we have conducted classroom interventions and surveys in Choose Maths schools which consist of a short pre-survey, two mathematics-related activities and a short post-survey. The interventions and survey instruments are described in Section 4 (Koch, 2018). Here we look at the results of about 2500 Year 5 students and questions 4–6 of the survey as follows:

- Q4 *Pre:* When I think about maths I would describe myself as
  Post: After the lesson today I feel
  - Responses: not confident (1)/neutral (2)/confident (3)/very confident (4)
- Q5 *Pre:* When I think about maths I feel
  Post: After the lesson today I feel
  - Responses: bored (1) /neutral (2)/somewhat enthusiastic (3) / enthusiastic (4)
- Q6 *Pre:* I have a maths brain
  Post: My brain allows me to learn new maths
  - Responses: disagree (D)/agreed (A)

Tables 3.4 to 3.6 show the percentage transition or movement from the pre-survey responses to the post-survey responses separately for boys and girls and for each of the three questions. These transitions tell us how the students moved as a result of the intervention activities and thereby tell us whether and by how much we can affect students' attitude and behaviour. This is important to understand in order to affect change.

Table 3.4 Percentage changes in students' level of confidence

boys

	1	2	3	4	pre
1	**34.2**	22.4	23.7	19.7	***8.0***
2	4.9	**30.9**	43.5	20.6	***23.6***
3	7.3	8.1	**46.4**	38.3	***36.5***
4	4.0	5.0	13.6	**77.4**	***31.9***
post	***7.8***	***13.7***	***33.4***	***45.1***	

girls

	1	2	3	4	pre
1	**30.0**	38.0	21.0	11.0	***9.2***
2	4.8	**39.4**	37.1	18.7	***32.6***
3	2.7	10.0	**47.2**	40.1	***40.7***
4	5.8	7.9	14.2	**72.1**	***17.5***
post	***6.4***	***21.8***	35.7	36.1	

To interpret Table 3.4 correctly, note that the numbers 1 – 4 in the grey-shaded fields in row 2 and in the 'post' columns refer to the four answer categories listed with the questions above. The bold columns, labelled 'pre' show the percentages for each possible answer in the pre-survey, and the last row of the table shows the percentages—in bold—that were obtained in the post-survey for each possible answer, so 32.6 per cent of female students were neutral in the pre-survey compared to 21.8 per cent in the post-survey. Where did these 10.8 per cent percentage points of students go as a consequence of the intervention activities? The fourth row and columns 9 – 12 of the table provide the answer: 39.4 per cent of the initial neutral group stayed the same, 4.8 per cent became less confident, while 37.1 per cent felt confident and 18.7 per cent felt very confident after the activities. This large move in the positive direction shows the increase in confidence as a consequence of the mathematical activities during the lesson.

Interventions have been shown to be effective in changing attitudes of students towards and increasing confidence in mathematics

Table 3.5 has a similar interpretation to that of Table 3.4 and refers to Q5 of the survey. Table 3.6 has the possible answers D-disagree and A-agree and refers to Q6.

Table 3.5 Percentage changes in students' level of enthusiasm

boys

	1	2	3	4	pre
1	**40.2**	27.4	15.9	16.5	***18.0***
2	10.7	**27.4**	36.3	25.6	***18.4***
3	5.8	9.5	**45.3**	39.4	***36.5***
4	7.2	3.9	13.4	**75.5**	***31.9***
post	***13.4***	***14.1***	***27.6***	***44.9***	

girls

	1	2	3	4	pre
1	**40.3**	30.4	19.3	10.0	***17.1***
2	6.0	**39.9**	40.0	14.5	***23.4***
3	4.8	10.4	**36.9**	47.9	***35.3***
4	6.2	3.1	13.7	**77.0**	***14.2***
post	***11.5***	***19.0***	28.9	40.6	

Table 3.6 Percentage changes in students' attitude to mathematical ability—disagree (D), agree (A)

boys			
	D	A	pre
D	**22.9**	77.1	***37.7***
A	4.6	**95.4**	***62.3***
post	11.5	88.6	

girls			
	D	A	pre
D	**18.4**	81.6	***46.8***
A	4.4	**95.6**	***53.6***
post	10.9	89.1	

Histograms of the pre- and post-survey results relating to Q4 and Q6—the bold columns and rows—can be seen in Koch (2018). The Year 5 cohort is the largest with about 2500 students out of a total of about 4500 students. For Years 6, 8 and 9 the results are similar to those presented above, but the confidence/enthusiasm levels are lower both before and after the surveys than for Year 5. The direction of change, however, is the same in all four years.

Findings:

1. The interventions have a positive effect on boys and girls. Girls start lower in terms of confidence, enthusiasm and their maths brain, but show a larger positive change than boys
2. The change in the most positive category in each question—second last row in each table—is smallest and well over 70 per cent of students from this group remained in the group
3. The movement away from the less confident/less enthusiastic groups (groups 1 and 2) is strong. Only 30-40 per cent remained in these groups, a small proportion of students lost confidence/enthusiasm (4–6 per cent) while more than half the students moved in a positive direction, by one or two levels as a result of the intervention
4. About 40 per cent of girls answering Q4 and 48 per cent of girls answering Q5 changed from the third group (confident/somewhat enthusiastic) to very confident/enthusiastic, and these percentages are larger than the corresponding percentages for boys
5. Most remarkable is the change in Q6; of the nearly 50 per cent of girls who answered D (disagree) to 'I have a maths brain', 81.6 per cent changed their answer as a consequence of the intervention and 89.1 per cent of girls compared to 88.6 per cent of boys agreed at the end of the intervention that they can learn mathematics

Summary

Ongoing professional development of teachers, as provided by the Choose Maths Schools Outreach, can effectively address and improve teachers' confidence and lessen anxiety in their mathematical abilities. Similarly, students and particularly girls, respond positively to confidence building and the effect on their attitudes towards and engagement in mathematics. Snapshots in time, as a result of Choose Maths classroom interventions of over 4500 students in Years 5 to 9, demonstrate such positive effects for boys and more strongly for girls, who started with a lower confidence and attitude level than boys.

References

Fullan, M. (2001). *Leading in a Culture of Change*. Wiley.

Collins, J. (2018). Choose Maths Days for Year 9 and 10 students in Australian universities and schools. Section 5, *Gender Report* 2019.

Melbourne, Vic.: Australian Mathematical Sciences Institute.

Koch, I., & Li, N. (2017). Teacher Confidence, Education and Experience: Choose Maths Teacher Survey 2016, *AMSI Choose Maths Research No 1*. Melbourne, Vic.: Australian Mathematical Sciences Institute

Koch, I. (2018). Attitude towards Mathematics and Confidence in Mathematical Ability of Students – Can it Change? Section 5, *Gender Report* 2019.

Li, N., & Koch, I. (2017). Choose Maths Gender Report: Participation, Performance and Attitudes Towards Mathematics, *AMSI Choose Maths Research No 2*. Melbourne, Vic.: Australian Mathematical Sciences Institute

3.2.5 Anxiety and Engagement in Mathematics: Barriers to Mathematical Teaching and Learning and the Way Forward

Sarah Buckley
Australian Council for Educational Research

Barriers to improving mathematics learning are examined briefly in this paper. Initially gender is discussed, including the ethical implications of research that seeks to show that girls and boys learn differently. The focus of the paper is on maths anxiety and an intervention that has been developed for primary teachers. The intervention is in the form of a professional learning program that is designed to help teachers understand more about maths anxiety using research from psychology, education and neuroscience. The program also includes strategies for teachers to manage and alleviate any maths anxiety that they experience themselves or to help them reduce the negative impact of anxiety on their students' or colleagues' learning and teaching. The model and approach that have driven the development of the program are also discussed.

Introduction

The Australian Government's National Innovation and Science Agenda emphasises the need to improve education and participation in the fields of STEM. Mathematics is often considered the entry point to STEM learning and the most recent 2015 results from the Programme for International Student Assessment show that Australian students' mathematical literacy scores are declining (Roberts, 2014; Thomson, De Bortoli & Underwood, 2016). Researchers have highlighted multiple factors that can lead to disengagement with mathematics and poorer learning outcomes (Buckley, 2016). Being female was once considered a biological factor with arguments made about deficiencies in women's cognitive capacity to complete mathematical tasks. While research on neuroplasticity illustrates the adaptability of the brain and how it can change and respond to environmental factors (Fine, Jordan-Yang, Kaiser & Rippon, 2013), some researchers continue to investigate structural and functional differences between female and male brains (e.g., Ingalhalikar et al., 2014). Other researchers highlight the ethical implications of this type of research and how it can perpetuate the idea that girls and boys learn differently (e.g., Eliot, 2013; Fine, 2013). These ethical considerations are important given gender stereotypes about females having poor ability and discouraging interest and participation in mathematics are still endorsed within the community (Good, Rattan & Dweck, 2012; Forgasz & Leder, 2017).

A significant barrier to mathematical learning is maths anxiety, which is reported, on average, at higher levels by females (Devine et al., 2012; Thomson, De Bortoli & Buckley, 2013). Researchers have also shown that primary teachers can experience high levels of maths anxiety, which can negatively impact on teaching practices (Gresham, 2018; Hembree, 1990; Philipp, 2007).

Addressing mathematics anxiety

In 2017, our team at the Australian Council for Educational Research, in collaboration with researchers from Curtin University and the University of Limerick, were given a grant by the Sidney Myer Fund to develop and evaluate a professional learning program designed to address maths anxiety in primary teachers. This was awarded based on our previous research conducted in the Science of Learning Research Centre where we worked with pre-service teachers to help them understand and address maths anxiety during an interactive workshop.

In 2018, we began the program with a pilot sample of Victorian primary schools. Two key aspects of the program include our model and our approach.

Our model

Our model for maths anxiety separates it into two parts: anxiety in the moment (or state maths anxiety) and long-term anxiety (or trait maths anxiety) (Buckley et al., in press; Buckley et al., 2016). Anxiety in the moment is the type of maths anxiety felt when performing a mathematics task whereas long-term maths anxiety is a persistent tendency to be fearful of mathematics. Separating anxiety into these two parts is important because each has a different impact on learning. Anxiety in the moment impacts on learning and teaching in the short-term (e.g., performance on a mathematics task) while long-term anxiety effects learning and teaching in the long-term (e.g., participation in mathematics courses, careers and opportunities). Differentiating these two parts of maths anxiety is also important because different strategies can be used to alleviate each type of anxiety.

Our approach

We use a psychological approach to addressing maths anxiety, which has been recommended in recent research reviews (e.g., Buckley et al., in press; Maloney, Schaeffer & Beilock, 2013) for multiple reasons. Firstly, research shows that psychological strategies can reduce the negative effects of maths anxiety on performance (Beilock, Schaeffer & Rozek, 2017; Buckley et al., 2016). Secondly, because psychological strategies can reduce and manage the symptoms of maths anxiety they can be used on an on-going basis. This is particularly beneficial for pre-service teachers who often receive extensive support within their pre-service teacher education program to address maths anxiety and then move into the field where support can be varied. And thirdly, because a psychological approach can complement a content knowledge approach to reducing anxiety (Buckley et al., in press). A content knowledge approach is the most common way of addressing maths anxiety in education and is the strategy often used to address anxiety in pre-service teacher education programs. By building content (and pedagogical content knowledge), the rationale is that pre-service teachers will become more confident in their ability to learn and teach mathematics and indirectly this will reduce maths anxiety (Bursal & Paznokas, 2006; Sloan, 2010). This approach is part of the solution. However, simultaneously direct strategies to address maths anxiety are also important. Psychological strategies to deal with maths anxiety allow individuals to identify, regulate and reduce their maths anxiety removing it as a barrier and allowing initiatives designed to build content knowledge and engagement with mathematics to be as effective as possible.

Our program

Our program is designed to help primary teachers better understand maths anxiety and how it impacts on learning using research from education, psychology and neuroscience. Across the six-month program, psychological strategies are presented to teachers and they are provided the opportunity to master these strategies to deal with their own maths anxiety or that of students and/or colleagues. We emphasise that these strategies will increase the ability to control and regulate mathematics learning and teaching (targeting anxiety in the moment), and help to identify and challenge negative beliefs or patterns of thinking that might contribute to feeling low control over mathematics learning and teaching (targeting long-term anxiety).

Psychological strategies can reduce negative effect of maths anxiety on performance

References

Beilock, S. L., Schaeffer, M. W., & Rozek, C. S. (2017). Understanding and Addressing Performance Anxiety. In A.J. Elliot, C.S. Dweck & D.S. Yeager (Eds.), *Handbook of Competence and Motivation: Theory and Application*, (pp.155-172). New York: The Guilford Press.

Buckley, S. (2016). Gender and sex differences in student participation, achievement and engagement in mathematics. *Changing Minds: Discussions in neuroscience, psychology and education, Issue 1*. Melbourne: Australian Council for Educational Research.

Buckley, S., Reid, K., Goos, M., Lipp, O. V., & Thomson, S. (2016). Understanding and addressing mathematics anxiety using perspectives from education, psychology and neuroscience. *Australian Journal of Education*, 60(2), 157-170.

Buckley, S., Reid, K., Lipp, O. V., Goos, M., Bethune, N., & Thomson, S. (in press). Addressing mathematics anxiety in primary teaching. In *Learning under the Lens – Applying findings from the Science of Learning to the Classroom*. Routledge – Taylor & Francis Group.

Bursal, M., & Paznokas, L. (2006). Mathematics anxiety and preservice elementary teachers' confidence to teach mathematics and science. *School Science and Mathematics*, 106(4), 173-180.

Devine, A., Fawcett, K., Szücs, D., & Dowker, A. (2012). Gender differences in mathematics anxiety and the relation to mathematics performance while controlling for test anxiety. *Behavioral and Brain Functions*, 8(33), 1-9.

Eliot, L. (2013). Single-sex education and the brain. *Sex Roles*, 69(7-8), 363-381.

Fine, C. (2013). Is there neurosexism in functional neuroimaging investigations of sex differences? *Neuroethics*, 6(2), 369–409.

Fine, C., Jordan-Young, R., Kaiser, A., & Rippon, G. (2013). Plasticity, plasticity, plasticity… and the rigid problem of sex. *Trends in Cognitive Sciences*, 17(11), 550–551.

Forgasz, H. J., & Leder, G. C. (2017). Persistent gender inequities in mathematics achievement and expectations in Australia, Canada and the UK. *Mathematics Education Research Journal*, 29(3), 261-282.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700.

Gresham, G. (2018). Preservice to Inservice: Does Mathematics Anxiety Change With Teaching Experience? *Journal of Teacher Education*, 69(1), 90-107.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 21(1), 33-46.

Ingalhalikar, M., Smith, A., Parker, D., Satterthwaite, T. D., Elliott, M. A., Ruparel, K., Hakonarson, H., Gur, R.E., Gur, R.C. & Verma, R. (2014). Sex differences in the structural connectome of the human brain. *Proceedings of the National Academy of Sciences*, 111(2), 823–828.

Maloney, E. A., Schaeffer, M. W., & Beilock, S. L. (2013). Mathematics anxiety and stereotype threat: Shared mechanisms, negative consequences and promising interventions. *Research in Mathematics Education*, 15(2), 115-128.

Philipp, R. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester Jr (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 257-315). Reston, VA: National Council of Teachers of Mathematics.

Roberts, K. (2014). *Engaging more women and girls in mathematics and STEM fields: The international evidence*. Retrieved from on July 30, 2018 retrieved from amsi.org.au/wp-content/uploads/2014/08/RobertsGenderSTEMreport2014.pdf)

Sloan, T. R. (2010). A quantitative and qualitative study of math anxiety among preservice teachers. *The Educational Forum*, 74(3), 242-256.

Thomson, S., De Bortoli, L., & Buckley, S. (2013). *PISA 2012: How Australia measures up*. Melbourne: Australian Council for Educational Research.

Thomson, S., De Bortoli, L., & Underwood, S. (2016). *PISA 2015: Reporting Australia's results*. Melbourne: Australian Council for Educational Research.

3.2.6 Students' Mathematical Journeys: Affect, Identity and Gender

Naomi Ingram
University of Otago

In this paper, an examination of students' relationships with mathematics is informed by affective and identity research. By analysing the perceptions of a class of 31 adolescents, five interacting elements of students' relationships with mathematics emerged: students' views, feelings, mathematical knowledge, identities, and habits of engagement. These elements contributed to the context within which students engaged in mathematics and resulted in unique learning experiences. Over time, students' dynamic relationships with mathematics, and their resulting engagement, led to some students thriving and others being vulnerable to non-participation in mathematics.

Affect and Identity

My longitudinal research connected affect and identity frameworks to explore secondary students' relationships with mathematics over their mathematical journeys. *A relationship with mathematics* is the dynamic connection between a student and the subject of mathematics. Understanding students' relationships with mathematics is vital because they are on the "brink of deciding whether to pursue mathematical studies" (Nardi & Steward, 2003, p. 346). This paper reports on these relationships as one aspect of a larger study (Ingram, 2011). The students' relationships with mathematics provided a framework for a closer examination of students' engagement (Ingram, 2013), the influence of the parents and teachers, and to explore the tensions between social and mathematical identities (Ingram, 2008). Gender was not an explicit part of my research, however, understanding what makes some students thrive and others vulnerable to non-participation is useful in considering why female students are not more fully participating in mathematics courses and careers.

Affect is an umbrella term used to describe a range of aspects of the human mind that go beyond cognition (Hannula, 2012) such as beliefs, feelings, emotions, motivation, anxiety, engagement, and identity. I needed to capture the complex interactions between the elements and the range of intensities along the continuum of negative to positive affect, and therefore I needed to holistically research across affective elements, rather than focus on one, such as anxiety.

The concept of students' relationships with mathematics has strong connections to notions of mathematical identity found in affective research. Many researchers in mathematics education (e.g., Boaler, 2000) are informed by Wenger (1998) who defined *identity as a constant becoming of who one is in a particular social context. Op 't Eynde, De Corte, and Verschaffel* (2006) similarly define identity, connecting it with affect.

[Students'] understanding of and behaviour in the mathematics classroom is a function of the interplay between who they are (their identity), and the specific classroom context. Who they are, what they value, what matters to them in what way in this situation is revealed to them through their emotions. (p. 194)

Sfard and Prusak (2005) dispute any process of defining identity as 'who one is'. They see identity formation as a form of communicational practice. In their view, identities are the stories that surround a person that are reifying (the transformation of an action into a state), endorsable, and significant. Sfard and Prusak usefully link affect and identity by suggesting there is likely to be a sense of unhappiness in a person when there is a perceived and persistent gap between a student's actual (the 'I am' stories) and designated identities (their 'I should be' stories).

Methodology

The 31 students in my study attended a co-educational secondary school in New Zealand. Students' spoken identities (as informed by Sfard and Prusak, 2005) were gathered, as well affective responses (informed by Evans, 2000) such as verbal expressions of feelings, the use of metaphors, negative or positive self-talk, body language, avoidance and resistance. Other data collected was students' reflections on their experiences, their views of mathematics, and the language they used to describe mathematics. This data was drawn from observations of mathematics and English classes, teacher and student interviews, metaphors for mathematics, drawings of mathematicians, personal journey graphs, questionnaires, exercise books, assessment results, reports, prizes, and attendance. What students said was important, rather than the researcher or teacher's perceptions of what was going on in the classroom. Decision-making permeated the process of data collection and analysis. The data was analysed using a grounded theory approach of constant comparison to seek, refine and understand the interrelationship of the emerging elements of a students' relationship with mathematics. A data analysis software package NVivo (QSR International, 2006), helped to manage the large data set and aid the analysis.

Students' relationships with mathematics

The students' described their relationships with mathematics as having the following elements.

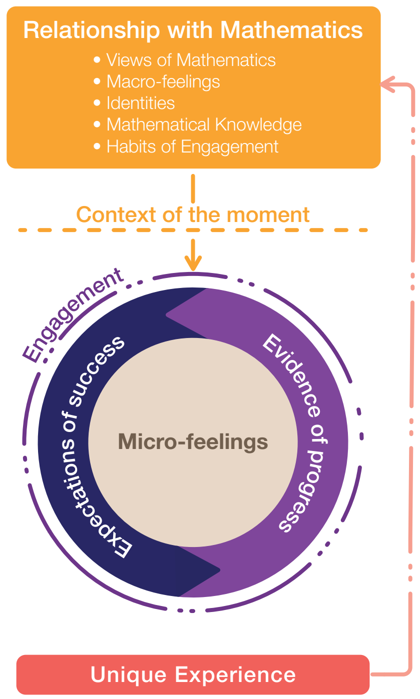
1. **Views of mathematics:** Subjective conceptions the students held to be true about mathematics. The students had views about the nature, uniqueness, importance and difficulty of mathematics and perceptions of how boring the subject was.
2. **Macro-feelings:** A student's overall feelings about the subject of mathematics. These feelings contributed to the context within which they engaged in a specific mathematical activity. When a student had negative macro-feelings for the subject of mathematics, they were more likely to have negative *micro-feelings*; the feelings they experience during each mathematical situation.
3. **Identities:** The students each had a unique set of identities related to their view of their mathematical ability. They had designated identities—overall expectations about mathematics, which included commonly held expectations of class placement, individual expectations related to class positioning and how they expected the subject to contribute to their future life. They also had actual identities—perceptions of how good they were at mathematics, which developed through their interactions with others, and through their experiences of success and failure when they engaged in the mathematics.
4. **Mathematical knowledge:** The students had different levels of mathematical knowledge, which students talked about in relation to their knowledge of facts and mathematical rules that they knew "off by heart".

5. **Habits of engagement:** The students engaged in mathematics in habitual ways that developed over time. Among these were the students' pathways of engagement—the ways they usually engaged in the mathematical tasks. They each had a clear set of engagement skills, including concentration, cooperation, independence, perseverance, integrity, intimacy, utilisation of feelings, and reflection.

These elements in the students' relationship with mathematics contributed to the context within which they engaged in mathematical tasks. Furthermore, when the students engaged in a mathematical task, they were each situated in a unique context of the moment. Even when they were experiencing the same classroom conditions—the same teacher, at the same time of day—the students each interpreted the context in a unique way. Students' engagement in the mathematical task was therefore determined by the complex negotiation between elements of their relationship with mathematics and individual interpretations of the context of the moment.

The process of change in students' relationships with mathematics is summarised in Figure 3.2. During students' engagement in the task, they collected evidence of their progress. They experienced micro-feelings as they interpreted whether or not their progress met their expectations of success. In Figure 3.2, the students' expectations and evidence of progress are represented within a circle to show that they surround a student's micro-feelings, and the arrows around this circle show that students' progress can alter expectations of success or vice versa. The way the students engaged in the task contributed to their individual experiences and performances.

Figure 3.2 Students' relationships with mathematics



These experiences were interpreted in relation to his or her relationship with mathematics and these interpretations reinforce or, if sufficiently powerful or repeated often enough, altered their dynamic relationship. Students who had completed a task successfully may have expected to do so. Others may have given up quickly and did not attempt to understand it further. There was little change in aspects of their relationship with mathematics as a result. Some students may have completed a task successfully after several attempts, gaining new knowledge and gaining confidence in that particular type of problem. Others may have faced particular trouble with the task, when normally they find mathematics easy. Their experience may have been powerful because their difficulty was in front of the class. For these students, elements of their relationship with mathematics may alter. New, important or personally significant mathematics learning experiences further build up or alter students' relationships with mathematics. These relationships with mathematics are therefore constantly changing and re-negotiated during every learning experience in the classroom.

Students' mathematical journeys

This framework of elements within students' dynamic relationships with mathematics was used to analyse the mathematical journeys of 31 students over two years as they continued to participate—or not—in mathematics (Ingram, 2011).

Understanding students' relationships with mathematics is needed to support their participation in mathematics

Thriving students had multiple motivational factors, enjoyed mathematics, had an incremental view of intelligence, felt confident in their ability, and had effective engagement skills. The students who were vulnerable to participation at times during their journey had tenuous motivational factors, generally disliked mathematics, had an entity view of intelligence (a fixed mindset), were unconvinced of the importance of mathematics, and had ineffective engagement skills.

To support girls' continued participation in mathematics, educators need to be explicit with their students about the importance of affective factors in learning and aspects of their own and their students' relationships with mathematics, particularly engagement skills. Teachers need to get to know their students, ensure all students experience confusion and have the skills to deal with it. They need to ensure students have an incremental view of their intelligence through their feedback, and by using flexible groupings without fixed streaming.

References

Boaler, J. (2000). Introduction: Intricacies of knowledge, practice, and theory. In J. Boaler (Ed.), *Multiple perspectives of mathematics teaching and learning*. Westport, CT: Ablex Publishing.

Evans, J. (2000). *Adults' mathematical thinking and emotions*. New York: RoutledgeFalmer.

Hannula, M. (2012). Exploring new dimensions of mathematics-related affect: Embodied and social theories. *Research in Mathematics Education*, 14(2), 137-161.

Ingram, N. (2008). Who a student sits near to in maths: Tension between social and mathematical identities. *Paper presented at the Navigating currents and charting directions*, Brisbane.

Ingram, N. (2011). *Affect and identity: The mathematical journeys of adolescents*. (PhD doctoral dissertation), University of Otago, New Zealand.

Ingram, N. (2013). Mathematical engagement skills. Paper presented at the Mathematics Education: Yesterday, Today and Tomorrow. *Proceedings of the 36th annual conference of the Mathematics Education Research Group of Australasia* Melbourne.

Nardi, E., & Steward, S. (2003). Is mathematics T.I.R.E.D? A profile of quiet disaffection in the secondary mathematics classroom. *British Educational Research Journal*, 29(3), 345-367.

Op 't Eynde, P., De Corte, E., & Verschaffel, L. (2006). Accepting emotional complexity: A socio-constructivist perspective on the role of emotions in the mathematics classroom. *Educational Studies in Mathematics*, 63, 193-207.

QSR International. (2006). *NVivo 7*. QSR International Pty Ltd.

Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as a culturally shaped activity. *Educational Researcher*, 34(4), 14-22.

Wenger, E. (1998). C*ommunities of practice: Learning, meaning, and identity.* Cambridge, UK: Cambridge University Press.

3.2.7 Understanding Motivation behind Mathematics Enrolment Choice in Senior Secondary Schools: Questionnaire Design

Ning Li
Australian Mathematical Sciences Institute

A theoretical model is proposed as the basis for developing an instrument to investigate factors that may influence mathematics enrolment choice in senior secondary schools in Australia. The rationale for the model construction is explained.

Introduction

Mathematics is mandatory in Australian schools up to the end of Year 10, and is still required in some states in Year 11, but not beyond that. To accommodate individual needs and to encourage engagement, various levels of mathematics are offered in each state and territory. These levels are categorised as elementary, intermediate and advanced. Elementary mathematics does not contain calculus and is not intended to provide a foundation for tertiary studies that involve mathematics. In contrast, intermediate or advanced mathematics may be required as entry to university courses where mathematics is an integral part of the discipline.

For the reader's convenience, in this paper Year 10 is referred to as the point when students make their subject choices although—as pointed out above—in some states mathematics is compulsory during (part of) Year 11.

Low participation in mathematics by secondary students, and in particular girls, has been of concern to the nation. On one hand, there is a high demand for a mathematically skilled, more gender balanced workforce (Office of the Chief Scientist, 2017). On the other hand, participation rates in intermediate and advanced mathematics continue to decline (Forgasz, 2006; Barrington & Evans, 2016; Li & Koch, 2017). Despite the overall yearly participation in mathematics appearing to be stable, at a rate as high as 87 per cent, more than 60 per cent of participants are enrolled in elementary level mathematics only. Over time, students have steadily shifted away from advanced and intermediate towards elementary level mathematics. Moreover, the participation has been persistently lower for girls than boys at all levels of enrolments (Li & Koch, 2017, Figure 5).

Research examining factors relating to mathematics enrolment in secondary school education has led to an improved understanding of enrolment patterns. However, an exploration of factors underlying the enrolment decision is desirable, as it may shed light on how participation in higher level mathematics can be increased.

What factors drive students to continue or discontinue mathematics beyond Year 10? What factors differentiate between students who select and those who avoid advanced mathematics? What is the role of gender in the choice of enrolment?

To answer these questions requires a survey instrument that can generate adequate numbers of responses. Many studies have examined the influence of affective factors on task performance, achievements, and participation in mathematics (Pajares & Graham, 1999; Watt & Bornholt, 2000; Leder & Forgasz, 2002; Marat, 2005). In particular, the motivation and engagement scale (MES) for high school students (Martin, 2001; Liem & Martin, 2012) has been designed and used to measure motivation of high school students. It covers a broad range of questions relating to motivation and school learning in general. A ready-to-use instrument that elicits specific reasons for mathematics enrolment choices seems to be lacking, hence, the development of a new survey instrument is needed.

A Theoretical Model

The task of understanding what factors have led students to respond differently in subject selection falls to psychology research, which deals with the science of behaviour. Motivation theories in particular have great relevance for the developmental avenue of students continuing with mathematics, because motivation directs and energises actions (Eccles & Wigfield, 2002).

Numerous psychological theories in the literature have attempted to explain, from different angles, the motivation for academic achievement. From the social cognitive perspective, I identified several of these to form a '5-block hierarchical model'. The central constructs identified are:

A. direct reasons to keep or drop mathematics in senior high school
B. students' self-concept and self-efficacy with regards to mathematics
C. perceived values of mathematics and of studying mathematics
D. students' level of maths anxiety
E. experience in learning mathematics

In the hierarchy, Block a) sits on the top and it is based on Blocks b), c) and d) which, in turn, are supported by Block e). The lowest layer in the model, e), covers major sources for the middle layer: students' mastery experience, interpreted vicarious experience, and experience with receiving social persuasion from significant others (Bandura, 1996). While it is recognised that these constructs exert mutual influence on each other within and across layers, the directional influence from the lower to the upper layer is the focus of this study.

Rationale for the Model

Based on my understanding and interpretation of the definition, motivation refers to the reasons individuals have for behaving in a specific manner in a given situation (see for example, Middleton & Spanias, 1999). An understanding of these reasons requires insight into how they are formed. Suppose one is capable of demonstrating a certain behaviour. That capacity, however, will not lead to any activity unless one is willing to use it. The willingness to exercise a capacity is acquired through an internal mechanism that can impel the capacity into action, if the mechanism stems from a desire to satisfy some need. This process is referred to as motivational process, and the resultant action is referred to as a goal-directed behaviour or motivated behaviour. From this definition we can derive that an individual's motivation to demonstrate a certain behaviour depends on:

A. the individual's perception of his/her capability to demonstrate the behaviour
B. the perception of whether and to what extent the behaviour, once performed, can satisfy the need
C. the perception of how desirable the outcome can be

Formation of these personal perceptions involves a sequence of self-evaluations, some gained from prior personal experience and some inferred from observation of others with similar experiences. Based on this understanding of motivational processes I selected a few theories from a range that are available in the literature for my questionnaire design, including the type-of-need theory, or goal theory that directly examines the type of motivational reasons; the self-concept theory and the self-efficacy theory that determine how individuals view their capacities as are required in part a) of the motivational process; and the expectancy-value theory that investigates individuals' perception of whether the need can be satisfied and how desirable the outcome can be—see b) and c) above. I included maths anxiety as a block that differs from value, in order to highlight the potential influence that extreme emotion in mathematics can have on enrolment decisions.

Mathematics Self-Concept and Mathematics Self-Efficacy

In the psychology literature, a collection of different aspects about self have been studied and various terms of self-beliefs have been proposed. The main among these are: self-concept and self-efficacy. Largely overlapping, a distinction between the two concepts seems not always clear. Both require the cognitive process of self-evaluation, but self-concept focuses on one's self as a person, while self-efficacy focuses on one's capability to perform a specific task (Bong & Skaalvik, 2003; Lee, 2009).

Self-concept refers to self-perceptions about one's capability and competence (Byrne & Shavelson 1986). The mathematics self-concept refers to a person's judgement of self in relation to mathematics (Bong & Clark 1999). As Shavelson, Hubner, and Stanton (1976) and Marsh and Shavelson (1985) postulate, self-concept is hierarchical and multifaceted in nature. The literature generally posits that self-concept influences choice and direction of behaviour.

Positive self-concept is seen to create stronger motivation, clearer purpose and better strategies for approaching goals, persevering despite discouragement, and reaching higher levels of achievement. In contrast, negative self-concept is believed to undermine one's confidence, bias self-evaluation, and impair achievement.

Self-efficacy is another central construct dealing with self-beliefs in social cognition research. It refers more specifically to one's perception about one's capability to produce the desired outcome (Bandura, 1997). Efficacy expectation is developed as an operational mechanism for self-appraisal and self-regulation. Mathematics self-efficacy is one's judgement of one's ability and competence to perform a mathematics task successfully (Pajares, 1996). It produces performance outcomes through cognitive, motivational and selection processes (Pajares & Urdan, 1999). Previous research shows that given appropriate skills and adequate incentives, self-efficacy is seen to be a major determinant of people's choice of activities, how much effort they will spend, and how long they will sustain that effort. Hence, self-efficacy evaluation and expectations may provide an explicit basis for predicting the occurrence, and persistence of behaviour.

Bandura (1977) formally proposed and tested the theory that self-efficacy develops through enactive, vicarious, verbal persuasion, and emotive-based procedures, with the enactive experience, or mastery experience of performance accomplishments, being especially influential.

Efficacy Expectancy versus Outcome Expectancy

When introducing the construct of self-efficacy in his seminal article, Bandura (1977) elaborated that the cognitive self-evaluation process in self-efficacy comprises two distinct components: performance-efficacy expectancy and performance-outcome expectancy. An outcome expectancy is one's estimate that a given behaviour will produce certain outcomes. An efficacy expectancy is the belief that one can successfully execute the behaviour needed to produce the outcome. Both expectancies are essential components in the motivational mechanism. On one hand, outcome-expectancy alone will not produce the desired performance if the component capabilities are missing. Individuals can believe an action will produce a certain outcome, but if they do not believe themselves capable of performing the activity they will not initiate the action. In such a case, beliefs about the outcome expectancy have little effect on behaviour. On the other hand, the perception a person holds about his or her ability to perform a task alone is not likely to bring about the action. An individual may be capable of executing a task successfully, but may not attempt it because they see no benefit. Thus, efficacy-expectancy and outcome-expectancy are both needed to motivate a specific behaviour.

Expectancy-Value Theory

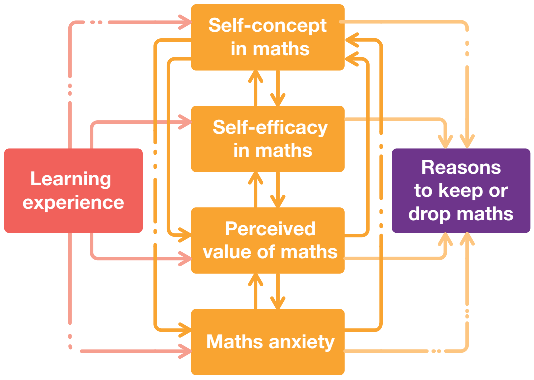
Eccles et al. (1983) further consolidated the component, outcome-expectancy, in Bandura's model (Bandura, 1977) and expanded it formally to include subjective task value (STV) in the development of her expectancy-value theory. This theory has become one of the most influential frameworks in education psychology for investigation of students' motivation. The expectancy-value theory comprises the point of view that choices are influenced by negative and positive task characteristics and that all choices have associated costs. Eccles defines four motivational components regarding task value: intrinsic value, utility value, attainment value, and cost (Eccles et al. (1983); Eccles & Wigfield (2002)). The intrinsic value is the enjoyment of the task. The utility value is one's perception of the usefulness of the task. The attainment value is the perceived personal importance of doing well on the task. Cost refers to the negative aspects associated with the engagement in the task (Jiang et al., 2018), including performance anxiety, fear of failure or of success, the amount of effort needed to succeed, and lost opportunities.

In Eccles and colleagues' model, expectations of successful performance influence achievement-related decisions. Performance expectations are influenced by task-related beliefs such as one's perceptions of competence or difficulty of a task, and an individual's goals and self-schema. This theory has been tested repeatedly in empirical studies, showing that expectancies and values are correlated with both academic performance and educational plans.

Maths Anxiety

Maths anxiety is the tendency to feel anxious or nervous when attempting to solve mathematical problems (Betz, 1978). It can be expanded into feelings of anxiety regarding mathematics classes and tests (Dew, Galassi, & Galassi, 1984). Girls are found, on average, to experience a higher level of maths anxiety than boys; and a higher level of anxiety is found to correlate with lower academic achievement, possibly by occupying working memories. Anxiety is usually discussed as either a state of temporary feeling or a trait-like concept. In the design of our questionnaire we have not treated it as a temporary affective arousal, rather we treat it as a feeling that is formed through one's interaction with mathematics over a period of time. Many studies in the literature focus on the relationship between maths anxiety and performance in mathematical tests or problem solving. The aim in our work is to explore how and to what extent maths anxiety predicts student's avoidance motivation and behaviour.

Figure 3.3 A mathematics enrolment choice motivation (MECM) model



In summary, the considerations mentioned above support the use of the model depicted in Figure 3.3 for the design of a questionnaire to investigate the enrolment choice motivation.

Scale Development

Given the theoretical model, our next step is the develop of items that can adequately measure the identified constructs. The item development in our work has been inspired by many existing scales including those developed by Plake and Parker (1982), Marsh and O'Neill (1984), Martin (2001), Suinn and Winston (2003), Marat (2005), Stevens and Olivárez (2005), Luttrell, Callen, Allen, Wood, Deeds, and Richard (2010), Ko and Yi (2011), Gogol et al. (2014) and Butler (2016). Some items are simply taken from the existing instruments, some are adopted and modified, and some new items are constructed. In designing the items we used responses to the open-ended question "What is the main reason for you to drop (or keep) mathematics in Year 11?" from a small sample of Year 10 & 11 students.

The measurement of self-efficacy in relation to maths enrolment choice motivation has been designed to comprise two sub-scales. One sub-scale measures situation-specific self-efficacy and the other measures topic-specific self-efficacy. The former corresponds to situations that we hypothesize to be challenging and predictive of enrolment choices. The situations we cover reflect student's self-regulated thoughts, behaviour and control in task management strategies that we regard as necessary for successful initiation and completion of Year 11 mathematics study. The latter sub-scale corresponds to various topics in mathematics that are required by the Australian Curriculum, Assessment and Reporting Authority (ACARA) for Years 10 and 11. The items in this sub-scale are framed to measure perceived, rather than demonstrated, competence so that students do not actually solve the problems in the items. Following the guidelines of Bandura (2006), all self-efficacy items are phrased as can do for the purpose of content validity.

Carefully designed models are required to learn about the factors that influence subject choices of students

In order to undertake a pilot study to test the designed questionnaire, research ethics applications were submitted to eleven authorities. At the time of writing this paper, two ethics clearance approvals have been granted and the survey instrument has been administered to four schools in Victoria. The average survey completion time is about 20 minutes. When enough data have been collected for each subgroup we are interested in, we will examine the psychometric properties of the instrument using statistical techniques, and then derive a shorter version of the survey for use in the major target sample.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84, 191-215.

Bandura, A. (1996). Social cognitive theory of human development. In T. Husen & T. N. Postlethwaite (Eds.), *International encyclopedia of education* (2nd ed., p. 5513-5518). Oxford: Pergamon Press.

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (Eds.). *Self-efficacy beliefs of adolescents*, (Vol. 5., p. 307-337). Greenwich, CT: Information Age Publishing.

Barrington, F. & Evans, M. (2016). *Year 12 mathematics participation in Australia - The last ten years. AMSI Publication, Research and Data.*

Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psycholog*y, 25, 441–448.

Bong, M., & Skaalvik, E. M. (2003). Academic Self-Concept and Self-Efficacy: How Different Are They Really? *Educational Psychology Review*, 15(1), 1-40

Butler, K.L. (2016). *Motivation for Mathematics: The Development and Initial Validation of an Abbreviated Instrument*. PhD Thesis, University of South Florida.

Dew, K. H., Galassi, J. P. & Galassi, M. D. (1984). Math anxiety: Relation with situational test anxiety, performance, physiological arousal, and math avoidance behavior. *Journal of Counseling Psychology*, 31, 580-583.

Eccles, J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.). *Achievement and achievement motivation* (pp. 75-146). San Fransisco, CA: W. H. Freeman.

Eccles, J. S. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53, 109–132.

Forgasz, H. J. (2006). *Australian year 12 mathematics enrolments: Patterns and trends – past and present*. Melbourne, Vic: International Centre of Excellence for Education in Mathematics [ICE-EM]. [Retrieved December 24, 2009 from (amsi.org.au/images/stories/downloads/pdfs/education/Mathematics_Enrolments.pdf)

Ko, H. K., & Yi, H. S. (2011). Development and validation of a mathematics anxiety scale for students. *Asia Pacific Education Review*, 12, 509-521.

Leder, G. C., & Forgasz, H. J. (2002). Measuring mathematical beliefs and their impact on the learning of mathematics: A new approach. In G. Leder, E. Pehkonen, & G. Toerner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp.95-113). Dordrecht, the Netherlands: Kluwer.

Liem, G. A. D. & Martin, A. J. (2012). The motivation and engagement scale: Theoretical framework, psychometric properties, and applied yields. *Australian Psychologist*, 47, 3-13.

Luttrell, V. R., Callen, B. W. , Allen, C. S., Wood, M. D., Deeds, D. G., & Richard, D. C. S. (2010). The Mathematics Value Inventory for General Education Students: Development and Initial Validation. *Educational and Psychological Measurement*, 70, 142-160.

Gogol, K., Brunner, M., Goetz, T., Romain, R., Ugen, S., Keller, U., Fischbach, A., Preckel, F. (2014). ''My Questionnaire is Too Long!'' The assessments of motivational-affective constructs with three-item and single-item measures. *Contemporary Educational Psychology*, 39(3), 188–205.

Jiang, Y., Rosenzweig, E. Q., & Gaspard, H. (2018). An expectancy-value-cost approach in predicting adolescent students' academic motivation and achievement. *Contemporary Educational Psychology*, 54, 139-152.

Lee, J. (2009). Universals and specifics of math self-concept, math self-efficacy, and math anxiety across 41 PISA 2003 participating countries. *Learning and Individual Differences*, 19, 355-365.

Li, N. & Koch, I. (2017). *Gender Report: Participation, Performance and Attitudes towards Mathematics*. Melbourne: Australian Mathematical Sciences Institute.

Marat, D. (2005). Assessing mathematics self-efficacy of diverse students from secondary schools in Auckland: implications for academic achievement. *Issues in Educational Research*, 15, 37-68.

Marsh, H. W. (1986). Verbal and Math Self-Concepts: An Internal-External Frame of Reference Model. *American Educational Research Journal*, 23(1), 129-149

Marsh, H. W., & O'Neill, R. (1984). Self Description Questionnaire III: The Construct Validity of Multidimensional Self-Concept Ratings by Late Adolescents. *Journal of Educational Measurement*, 21, 153-174.

Marsh, H. W., & Shavelson, R. (1985). Self-Concept: Its Multifaceted, Hierarchical Structure. *Educational Psychologist*, 20, 107-123.

Martin, A.J. (2001). The Student Motivation Scale: A tool for measuring and enhancing motivation. *Australian Journal of Guidance and Counselling*, 11, 1-20.

Middleton, J. A. A., & Spanias, P. A. (1999). Motivation for Achievement in Mathematics: Findings, Generalizations, and Criticisms of the Research. *Journal for Research in Mathematics Educatio*n, 30, 65-88.

Office of the Chief Scientist (2017). *The Australian Industry Group Strengthening school – Industry STEM skills partnerships Final Project Report*. Australian Government.

Pajares, F. (1996). Self-efficacy beliefs and mathematical problem solving of gifted students. C*ontemporary Educational Psychology*, 21, 325–344.

Pajares, F. & Graham, L. (1999). Self-Efficacy, Motivation Constructs, and Mathematics Performance of Entering Middle School Students. *Contemporary Educational Psychology*, 24, 124–139.

Pajares, F., & Urdan, T. (1999). Self-Efficacy, Motivation Constructs, and Mathematics Performance of Entering Middle School Students. *Contemporary Educational Psychology*, 24, 124–139.

Plake, B. S., & Parker, C. S. (1982). The Development and validation of a revised version of the mathematics anxiety rating scale. *Educational and Psychological Measurement*, 42, 551-557.

Shavelson, R. J., Hubner, J. J., & Stanton, G. C. (1976). Self-concept: Validation of construct interpretations. *Review of Educational Research*, 46, 407–441.

Stevens, T., & Olivárez, A. Jr. (2005). Development and evaluation of the Mathematics Interest Inventory. *Measurement & Evaluation in Counseling & Development*, 38, 141–152.

Suinn, R. M., & Winston, E. H. (2003). The mathematics anxiety rating scale, a brief version: psychometric data. *Psychological Reports*, 92, 167-173.

Watt, H. M. G., & Bornholt , L. J.(2000). Social categories and student perceptions in high school mathematics. *Journal of Applied Social Psychology*, 30, 1492-1503.

3.3 Invited Presentations: Practical Approaches to Motivating Female Students

3.3.1 Promoting Gender Equity and Aboriginal Participation in STEM at Newton Moore Senior High School in Bunbury, WA

Ashley Stewart
Newton Moore Senior High School

Outlined in this short paper are some of the activities we introduced at Newton Moore Senior High School to promote participation in STEM subjects and activities.

Promoting gender equity is not a women's issue, but a universal one. The work I have done at Newton Moore Senior High School is getting women and men in to be a part of our STEM projects and teaching our boys that girls and boys can have the same careers. I ran a Processing for Drawing session with a group of Aboriginal boys, which was run by two female professionals and three female mathematics teachers, thus making it clear that women have a variety of skills and abilities.

Looking at funding equity is important as well: seeing that the Clontarf Academy (boys) is one-third State, one-third Federal and one-third "Other" funding while the Girls Academy (Role Models, girls) attracts no state or federal funding. That is an issue that the government needs to take a look at.

Building relationships with students and parents can affect a change in attitudes and behaviour towards mathematics

When *bridging the gap* at my school I looked at teachers, primary students, high school students, parents and community members. In my mathematics department we have eight teachers of whom four are female. Breaking the gender stereotype is easier having so many amazing female role models to work with. A key concern in secondary mathematics teaching is out-of-area teaching, especially in regional areas which is my context. More of the untrained teachers happen to be female and having trained mathematics teachers can have a large impact on girls wanting to do mathematics because of the teachers' confidence in the area, as shown by data from AMSI research in 2017. I work with my teachers (male and female) to improve teacher quality, teachers' confidence and skills in mathematics and mathematics teaching, to achieve better student outcomes and promote mathematics to girls more effectively. Running mini mathematics sessions during mathematics staff meetings, running classpad (CP) professional learning (PL), funding out of area mathematics teacher training (lower school and methods), running STEM PL and supporting classrooms for STEM, CP use and any other curriculum needs. I have recently implemented spatial training for years 7 and 9. Spatial training works on understanding and interpreting direction, orientation, perspective, visualising 2D and 3D shapes, transformation and reflections. Constructing 3D shapes from small blocks. Mental construction of nets, orthographic and isometric drawings. Interactive with online modules, written work and blocks. We have only just started this but plan to monitor the effectiveness of the program in part through surveys of teachers and students and analysing data during the implementation of our programs (NAPLAN, OLNA, course results, ATAR, graduation and the fields our girls are entering). Spatial training helps students with problem solving, planning, visualisation and motivation to achieve in mathematics (other mathematics implications).

I have also started looking at primary school (even kindy age) students breaking the stereotype and to develop their spatial skills. Breaking the stereotype does not start at the high school level, starting at primary schools and even when students are in day-care and kindergarten is ideal. It is not just girls, it is getting boys on board as well. Introducing them to skills (spatial reasoning: puzzles, think3D!, video games), and career paths that were often considered gender specific. Introducing spatial skills in primary schools: running sessions at STEM fairs for primary students using MakeyMakey and think3D! and running sessions at primary schools using think3D! There is a large amount of evidence to show that girls struggle with spatial reasoning skills (more so in low-socioeconomic environments).

Then we start looking into what we can do for high school students. Bringing these stereotype breakdowns to high school. Examples are: introducing spatial skills to high school students using Dr. Sheryl Sorby's Higher Education services (materials: videos, software, hands on and written), running this for years 7 and 9 before NAPLAN and year 8 at the end of the year. Constantly reflecting on our work to improve the delivery of our spatial program and any other program we implement. Running STEM projects within mathematics classes at the end of Term 2 and Term 4. Running STEM projects specifically for Aboriginal girls to introduce them to the variety of career opportunities that are available to them or that could be available to them. My girls in these projects choose the ideas and I facilitate the mathematics behind it. I build my work on relationships with the students (boys and girls). This is extremely essential with my Indigenous students. This work has helped in affecting a change in attitude and behaviour towards mathematics through career awareness, supporting girls and young women with a strong mentoring network and celebrating the achievements of mathematics teachers and students. Attendance is frequently a barrier to success for our students. This year in term 2 we are running a STEM project on aeronautical engineering and making a competition out of it. Including the Education Support school in our STEM projects is exciting as well. These STEM projects and Spatial training help produce a positive change for students, especially girls, in mathematics.

The last idea is bridging the gap for parents. Putting in place support for parents by running parents' nights has been a great way to get parents involved in their students' mathematics work. I am involved in mentoring programs outside of my school and encouraging my staff to be a part of these as well: Choose Maths Mentoring and Innovators Tea party. I work supporting teachers in the SW region in primary and high schools by hosting and running a variety of PL for everyone.

3.3.2 Maths Mentor Presentation

Peter Chandler
Penrhos College

The Maths Mentor program, begun a decade ago at Penrhos College, is the focus of this paper. The setting, personnel involved, and the different elements and the program are all described in some detail.

Introduction

Recently we celebrated the 10th anniversary of our Maths Mentor Program. Over 120 past and present students attended. It was a great night and showed that the success of the program is based on the enthusiasm and commitment of so many past and present students. Enthusiasm is certainly contagious.

We have looked at many of the issues that Choose Maths covers over the past 10 years.

I teach at an independent, Uniting Church, K – 12 school for girls in Perth. We are good at sport, humanities, drama and music. We have a wide range of students, we value-add and do well overall.

I have been teaching for well over 40 years. I am an ordinary teacher, nothing special, I just keep turning up. The last 10 years have been amazing as I have been involved in the Maths Mentor Program. I have been able to make a significant contribution to the students and influenced the lives of many. I think I have the best job in the school.

In 2009 I was concerned about how we were handing extension in mathematics. The College prepared a report on our academic program and noted:

"Somehow in some way we are not engaging our best and brightest girls. They have the knowledge and the skill base, but their ability to use this to solve problems has declined. There is something missing and it would appear to be high level thinking skills or understanding and even their literal and inferential comprehension skills."

I reflected on this on what we could do about this in mathematics. So I put together a proposal to the school.

First, I outlined some of my concerns about mathematics:

- lack of an organised approach to extension in Middle and Senior School mathematics
- extension of top students left to the discretion of teachers and this was often ad hoc
- lack of involvement by students in competitions
- drop over several years in the numbers doing top courses in mathematics
- difficulty in handling very bright students
- mathematics considered uncool

I proposed an organised extension program for very able mathematics students. It would extend them, increase their knowledge and give them more mathematical tools to solve problems:

- students would be taken out of the top mathematics class once a week
- run regular after school classes
- establish contacts with the Universities
- improve participation in the various mathematics competitions
- improve interest of students in mathematics.
- give students more reasons to do mathematics

The school agreed. So, we started. We needed a name.

The Maths Mentor Program

Maths Mentor Program sounded good. Maths Mentors was a good name to call the teachers or others who would work with the students.

There would be two main parts of the Program:

- During class time—take students out of their normal mathematics class once a week for extension
- After school sessions—this is what I will mainly address in this article

The after school sessions

We started very slowly. Initially we had only a small number who attended the after school sessions (about three or four). Many others would have liked to have come but they were at sport, drama or some other co-curricular activities.

Ten years later we have over 80 students, mainly from Years 7 – 10, in the program. Students are proud to be in the Maths Mentor Program. Throughout the year we have an average of 50 – 60 girls on Monday afternoons, and nearly 15 girls on Tuesday mornings.

Students now attend after school sessions in preference to dance, music and sport. Something they did not do when we first started. The Dean of Curriculum chatted with me recently about the decline in sport due to the numbers in Maths Mentor. Is this the first time that mathematics has led to drop in girls playing sport?

So what has happened?

Maths Mentors

This year we have four teachers involved, one for each year level. They love to work with interested and enthusiastic girls. There are classrooms, one for each level.

We invite top university students to take regular small groups, normally on Tuesday mornings. This works very well as they are great role models.

For the last few years we have used two of our top past students who are both studying at university. Like CHOOSEMATH with their ambassadors, this really works. In the past the football or netball teams would invite their old boys/girls back to help coach. Why not mathematics?

Maths Mentor Captains

Over the years we have had several great student leaders. We have Sports, Academic, Drama

Maths mentoring is an effective way of engaging students' interest in mathematics

Captains. So, we now have Maths Mentor Captains. They roster themselves on each week and work with different year groups, especially the Year 7s. They help where needed and are always available to do last minute jobs. They are great role models and enthusiastic supporters of the Maths Mentor Program.

Visiting Mathematician Program

We have introduced a Visiting Mathematician Program. We invite a leading educator and mathematician to come and spend time working at the College. Their job is to inspire, challenge and to inform students and staff of the wonder of mathematics and where it can lead to. Master Classes are offered before and after school. This is a wonderful program and corresponds to our own Maths Week. The response from students, parents and teachers has been fantastic.

We run so many different activities including the following:

- Australia Maths Trust Courses—for the most part students love the challenge and AMT provides rigour
- Problem and Pizza Night
- Have Sum Fun competitions and Maths Games Days with local schools
- Holiday sessions
- Talks from universities
- Annual Maths Day for Year 9s—visit the UWA Engineering, Computing and Mathematics Departments and Data Analysis Australia
- We look out for other opportunities for the students, for example, the UWA Academy of Young Mathematicians, Women in Resources Seminar, Innovators' Tea Party

We never run out of ideas!

MATHS MENTOR MEET STEM

In 2014 we met with the education officer of the Harry Perkins Institute of Medical Research. We were offered an opportunity to participate in a ground-breaking new medical research program. This is an exciting new development. Students take part in a 10-week course working with top medical scientists and PhD students in a brand-new research facility. Our students examine some of the most complex health issues facing our nation—cancer, diabetes and Cardiovascular disease. This offers a great background to their mathematics, science and technology studies at school plus possible career options.

This is the first partnership between a school and medical research institute, certainly on our side of Australia, and we hope to establish more relationship with other organisations. Other states have similar research facilities. Check out these facilities and see if they are interested in offering courses.

Engineering

There are many opportunities for students, especially girls, in engineering. In Perth, UWA run a *Girls in Engineering Program* and most of the other universities run similar programs. The *Petroleum Club* provide mentors and programs for anyone interested in the oil and gas industry. *Women in Resources* provide opportunities for girls in the resource industry.

STEM

In Term 2 we have a program of STEM activities. Different years have different activities including 3-D printing, robotics and engineering. This is very popular with the younger students.

USA Space Camp and STEM tour

Every two years we offer the USA Space Camp and STEM Tour. The tour includes five days at Space Camp USA in Huntsville, Alabama where students take part in the Advanced Space Academy Program. We visit San Francisco, Washington and Orlando where we concentrate on various STEM experiences.

This is a very popular tour and gives students the opportunity to look at various STEM careers.

STEM in Residence Program

After the success of our Visiting Mathematician Program we decided to see if we could do the same with a STEM in Residence Program. Mentors are easy to find. Someone finishing a teaching degree often would like to have some work at a school. There are many in Perth who are changing from engineering to teaching and would be good mentors. Scientists in Schools, Mathematicians in Schools, parents, past students, retired workers can also be considered. Many businesses require their staff to act as mentors as part of their professional development program.

Work Experience

I look after some students with my contacts. Some work places, when they know I am visiting, get the students to do a presentation. This increases my contact with industry.

MathsNight@Penrhos

The highlight of the year is MathsNight@Penrhos. Nearly nine years ago we started MathsNight and it gets bigger and better every year. Some parents have commented that it is the most enjoyable school activity they attend for the year.

So, what is MathsNight?

It aims to promote mathematics. The program includes the following:

- The principal uses the night to announce some new initiatives or directions the school may take
- Student Presentations include reports on engineering, STEM programs, Penrhos Profs and Future Problem Solving, etc. The students also prepare a PowerPoint on Maths Mentor memories which is often very funny
- Every maths mentor student is recognised with a Maths Mentor certificate and a beautiful flower. Not sure if flowers would work with boys
- We wanted to provide an extra incentive for students to take part in more mathematical activities. So, we have various awards. These are based on what activities they have done throughout the year and the standards they have achieved
- Girls love badges and a special pi badge is given to students who have been fully involved in the program for over three years. Initially I thought we would get four or five a year but the last two years we have had double figures. This badge is treasured
- The top award goes to the Mathematician of the Year. She gets a trophy and her name on a special plaque
- We want students to choose suitable mathematics courses in Year 11 and 12 and we have guest speakers who have used maths in their careers. They are normally past students of our College. They speak about their lives at school, their further study and their careers. Students find these talks inspirational. We have had an ophthalmologist, the local business woman of the year, the Chief Scientist, the Governor of Western Australia, engineers, a stockbroker, a medical scientist, a physiotherapist specialising in treating cancer patients, and we even had a mathematics teacher

Recently I met a former student who is studying petroleum engineering at Curtin. She was inspired by the first guest speaker at MathsNight who was a petroleum engineer.

Often, we invite past students to join us on Tuesdays. This informal contact works well. The students ask them many questions. A recent study at Curtin University looked at why girls are not doing STEM. One of the reasons was lack of role models. We are certainly providing role models.

One aim of the Maths Mentor Program was to take away the nerd tag associated with doing mathematics. Some of our top students were often embarrassed if they received a mathematics award at assembly. Now it is not so much of a problem. Most students are proud to say they are in the Maths Mentor Program. There is some prestige attached to being a member. Many students now say their best subject is mathematics. This was not the case before. Maths at Penrhos is now considered cool.

One noticeable trend over the last few years is that more and more of our school leavers are choosing STEM courses when they leave school. With respect to our 2017 Leavers: about 70 per cent of the top 37 students and over 50 per cent of the total cohort are studying STEM. Over 90 per cent of students involved in Maths Mentor in the last six years have followed a STEM pathway.

Summary

Math Mentor is driven by the enthusiasm of mentors and students. We offer many exciting mathematics and STEM opportunities. Many of the activities we are involved in are out of school hours which gives the program flexibility.

As I said, I have the best job at the College as I work with highly motivated students and inspirational mathematics mentors. All our mathematics teachers comment on the enthusiasm that most of our students (not just the maths mentor students) have now towards mathematics. Students are not assessed, and they love to spend time involved in doing mathematics without pressure.

Maths/STEM is a great area for our students. STEM is very important to the nation’s future. We should celebrate what we do. Our students need to have role models and there are many great STEM role models.

The program: views from former students

Anna was the inspiration behind the Maths Mentor program. She graduated from Penrhos College in 2011, winning a General Exhibition. Anna went to UWA, majoring in mathematics and is now in her final year of medicine. Anna was our first university Maths Mentor and wrote the following in 2014:

In one way or another, I have been involved in the Maths department at Penrhos since 2008. Up to 2011 I was a student. I lived and breathed mathematics. I had an insatiable desire to learn more than my course allowed and I was lucky to have teachers who accommodated me and made every effort to find things for me to do. Now, I tutor Penrhos girls who have as much passion for mathematics as I did. Each year I watch Maths Mentor grow and take in more girls than it did the previous year. Each year I keep coming back! I'm so excited to see what this year holds. (Anna, 2011)

If you're in Maths Mentor, you're good at Maths, and you're allowed to say it! (Gillian, 2016)

Maths is amazing! There are so many different avenues to explore using it and it's so worth pursuing to see where it can lead you. (Ruhi, 2013)

Math Mentor isn't just maths. It challenges you and helps you develop team work and communication skills with others. These are things that a super handy in real life. I also formed some great friendships while I was in it. (Kristy, 2015)

A photo of our Maths Mentor Turns 10 celebration is shown below

Photo: Peter Chandler, Penrhos College

3.3.3 Choose Maths Outreach—Working in Australian Schools

The Choose Maths Outreach Team – Nadia Abdelal Jacinta Blencowe, Anna Bock, Helen Booth, Marcus Garrett, Vicky Kennard, Cass Lowry, Leanne McMahon, Janine McIntosh, Michael O'Connor

In this short paper some background information is provided about Choose Maths, and particularly about its Schools Outreach component.

Introduction

AMSI was established in November, 2002 with a mission to radically improve mathematical sciences capacity and capability in the Australian community by:

- supporting high-quality mathematics education for all young Australians
- improving the supply of mathematically well-prepared students entering tertiary education by direct involvement with schools
- supporting mathematical sciences research and its applications including cross-disciplinary areas and the public and private sectors
- enhancing the undergraduate and postgraduate experience of students in the mathematical sciences and related disciplines

The AMSI Schools division aims to improve the teaching of mathematics at primary and secondary levels by joining with teachers, mathematics teacher associations and government agencies to develop strategies to address issues such as teacher shortfalls and under-qualified teachers. This work has been conducted since 2005 with support from government and industry.

In 2015 AMSI began a partnership with the BHP Foundation on Choose Maths. Across four program components, with a basis in research, Choose Maths aims to:

- Increase the engagement, enthusiasm and confidence in mathematics demonstrated by girls
- Enhance teacher knowledge and confidence in mathematics and assist teachers to implement strategies known to engage and inspire girls
- Grow the understanding of the importance of mathematics in the minds of the public
- Address the tightly held public perception of gender stereotypes regarding mathematics

We achieve this through four program components:

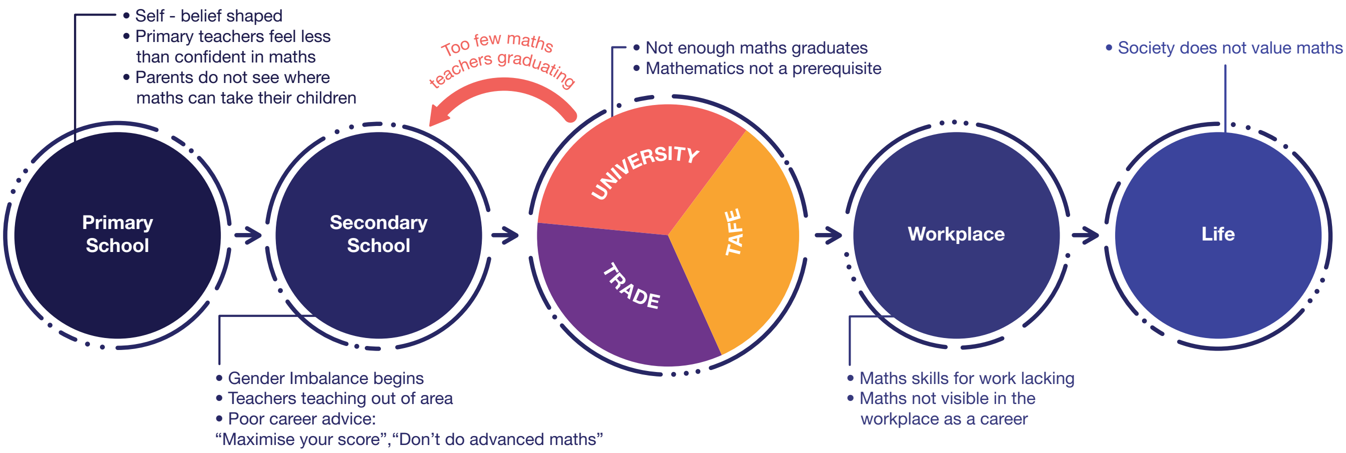
1. Choose Maths **Teacher and Student Awards**, available to all schools nationally
2. A National Mathematics **Career Awareness Campaign** to help the public understand the importance of mathematics and particularly to address the tightly held public perception of gender stereotypes in mathematics
3. **Women in Mathematics Network** with a focus on mentoring young women at a time point in their life where decisions about further studies and careers need to be made
4. **Schools Outreach** in 120 primary and secondary schools nationally. By visiting schools and working with teachers we aim to enhance teacher knowledge and confidence in mathematics and assist teachers to implement strategies known to inspire students, especially girls and young women, to continue with studies of mathematics. This outreach work is led by Michael O'Connor with a team of eight Outreach Officers who travel to schools across the country. The Schools Outreach component is the focus of this article, and will be explained in more detail in the following sections

The Need for Choose Maths

Choose Maths was developed with a specific need driving it. The mathematics pipeline from early primary school through to University and beyond is in need of interventions that will improve both the number and the calibre of mathematically capable Australians.

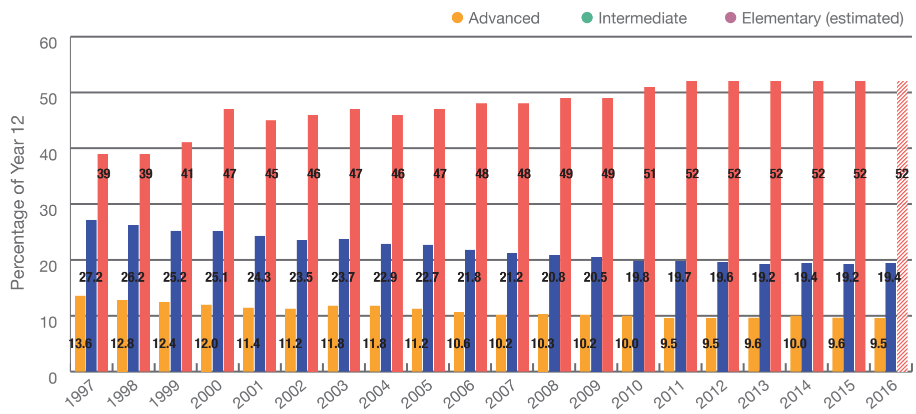
AMSI Schools programs target points of need across the pipeline, as is shown in the figure below:

Figure 3.4 The mathematics education pipeline, with points where major issues are highlighted



The proportion of students undertaking calculus-based mathematics is in decline: see the data summarised in Figure 3.5.

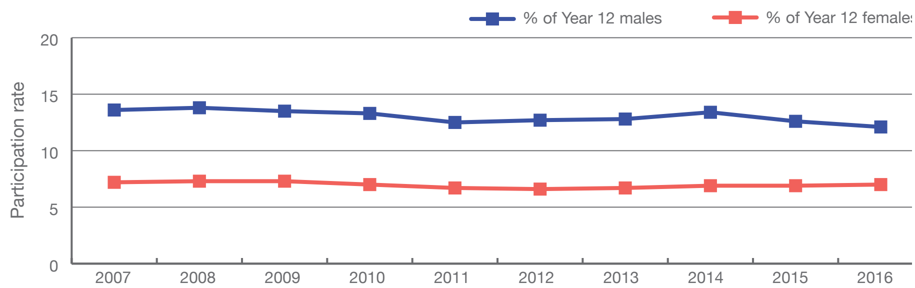
Figure 3.5 Australian Year 12 mathematics students



Source: Discipline Profile of the Mathematical Sciences, 2017, p. 21

Additionally, the number of girls choosing calculus-based mathematics in the final year of school in Australia is around half of that for boys of the same age (see Figure 3.6). Choose Maths aims to address this imbalance.

Figure 3.6 Year 12 advanced mathematics students in Australia



Source: Discipline Profile of the Mathematical Sciences, 2017, p. 22

The AMSI Way – Schools Outreach

AMSI Schools Outreach provides face to face assistance to over 120 schools around the country as part of the larger Choose Maths project. This is achieved by a team of qualified and experienced teachers, known as Outreach Officers, who visit each school on average twice in each school term.

Choose Maths Outreach plays an important role in providing teachers with research-based teaching strategies

Outreach officers travel out to regional areas a significant amount of the time. The offsite activities include: school visits, PD courses, family maths nights, Choose Maths days, State and national teacher conferences, STEM conferences and careers programs.

In addition to the work in schools, the team continually develops lessons and activities, PD material, teacher modules, career promotion material and course development advice for each jurisdiction.

Core to this work is the ability of the Outreach Team to distil essential learning from mathematics education research, and to assist teachers to implement strategies gleaned from this research into their classroom practice. It is this embedding of research from known positive strategies that gives a sound basis to the Outreach work. AMSI Outreach Officers have the time, interest and enthusiasm to explore and pass on to teachers the very best that the mathematics education research community has to offer.

One area of the research that Choose Maths has drawn from extensively is that of research into gender and mathematics. Indeed, the basis of our approach is to understand the gender disparity with regard to participation, improve community attitude and counter stereotypes that persist and work towards gender equity. We work from the position that there is no known neuropsychological difference between boys and girls with respect to ability in mathematics.

Growth Mindset

One strategy that has been consistently used across Choose Maths schools is that of Growth Mindset. Carol Dweck (2008) and Jo Boaler and Dweck (2015) encourage teachers and parents to help students develop a Growth rather than fixed mindset with respect to learning mathematics. Growth Mindset is the belief that intelligence and talent can be improved with practice, dedication and hard work.

We witness the power of adding "...yet." to our vocabulary with children on a regular basis:

"I can't do fractions." becomes "I can't do fractions... yet." and so on.

We talk with teachers and their students about how the brain works. Numerous studies have shown that struggling with a problem, trying new methods, thinking about it, discussing it and persevering actually cause brain development (increased firing of neurons and connections between neurons). This increased brain development allows greater understanding and more chance of skill mastery. But what is even more astounding is that when children are taught this, their results improve (see, for example, Boaler & Dweck, 2015).

Neurons form stronger and more long lasting connections every time a child struggles with a problem, makes a mistake or talks about the problem; the children who know this achieve higher results in all assessments.

Students at Choose Maths schools enjoy a variety of maths outreach activities from careers information sessions to maths games.

Brain conversations include information such as:

- We get 10 000 pieces of information per second
- The amygdala is the reaction filter in our brain. This is where we make the decision to fight, freeze or flee
- The pre-frontal cortex is the thinking part of the brain
- Most information is unimportant but some is seen as a threat and is sent to the amygdala. No thinking takes place here, we just react. Analogies such as - If a snake landed in your lap you don't want to waste time thinking, you would just react—can help understanding
- Something we consider difficult—such as mathematics - may be treated this way in the brain and cause us to freeze or flee
- We need to engage the prefrontal cortex so we can do some thinking. Something as simple as adding the word Yet. For example, I can't do this …. YET is enough to keep it from reacting to thinking

With regard to giving children praise, Dweck (and others) have carried out studies showing that if we praise the PROCESS rather than the person or the result, the impact is greater.

Summary

AMSI Outreach Officers work with teachers in Choose Maths Schools to assist them plan, prepare and teach mathematics across the school. We do this through school visits, professional development sessions, family nights and Choose Maths days. Teacher content knowledge is a large component of this work, and building teacher capacity in pedagogy for mathematics is key. One particular focus has been to engage with Growth Mindset, drawing on examples and processes outlined above, and to explore its implications for teaching and learning.

References

Boaler, J., & Dweck, C. S. (2015) *Mathematical mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. San Francisco, CA: John Wiley & Sons.

Dweck, C. S. (2008) *Mindset: The new psychology of success* New York: Ballantine Books.

Discipline Profile of the Mathematical Sciences (2017, September). The University of Melbourne on behalf of the Australian Mathematical Sciences Institute 2017. Melbourne, Vic.: Australian Mathematical Sciences Institute

3.4 Participants' Responses and Summary

AMSI Choose Maths' first Mathematics, Gender and Mathematics Education workshop attracted 35 workshop participants including teachers, state department of education representatives, researchers from ACER and academics from mathematics, statistics, mathematics education, psychology, engineering and, of course, the Choose Maths team.

The participants welcomed the opportunity to meet with people from outside their normal 'boundaries' with a clear indication from all participants to continue with this new network of people with similar aims. The mix of presentations and working groups—complemented by a welcome reception and dinner—led to fruitful discussions in particular on maths anxiety in students, parents and their teachers and on how to address these.

At the conclusion of the workshop, participants were asked to complete a short evaluation survey. A brief summary of the 25 sets of responses is provided below. There was much overlap in the responses of those who indicated they had attended the workshop as a Speaker and those who categorised themselves as Participant.

What do you think worked well/best at the workshop? Name up to three things starting with best

Mentioned frequently were:

- Diversity of participants ("great people—diverse and experienced")
- Mix of quality presentations (teachers and academics)
- Opportunities for formal and informal discussions and networking ("good" sized group of people)

What would you change or improve in another such workshop?

- Some changes in the venue and facilities—more collaborative setting
- More time for discussion and working groups (fewer presentations and more structured workshop time)
- Limit the workshop to two days

What would you like to see as the outcome of this workshop?

- Continued networking
- Ongoing communications between those who came, with various suggestions for the role AMSI could play to facilitate this (for example, "discussion groups on AMSI web page"; "Compile a list of valuable resources, materials, contacts, program, website to support all of us in our world—a National repository of our favourite stuff")

Would you participate in another such workshop?

All respondents replied "Yes" or "Probably".

4 Choose Maths Research Symposium at MERGA 2018: Choose Maths – an Australian Approach to Increasing Participation of Women in Mathematics

Inge Koch
Australian Mathematical Sciences Institute

Gilah Leder
Monash University and La Trobe University

4.1 Introduction

The Mathematics Education Research Group of Australasia (MERGA) held it 41st conference at Massey University Albany, in Auckland, New Zealand from 1–5 July 2018. Choose Maths contributed to this conference with a research symposium consisting of three connected research papers including a short overview, which were peer reviewed and published in MERGA's conference proceedings[1]. With the permission of the conference organisers we reproduce them here. Professor Helen Forgasz, from Monash University, agreed to be the discussant of the series of papers when they were presented at the conference.

In the following sections we present the three papers, including the short overview paper, the discussants' response to the presentations and our rejoinder.

4.2 Overview and Individual Contributions

The under-representation of women in Science, Technology, Engineering and Mathematics (STEM) in Australian is well known throughout the educational pipeline and in STEM careers. Girls have a lower average performance in mathematics, and fewer young women participate in the higher levels of mathematics in senior secondary school, in STEM degrees and in the STEM-related workforce. To address this under-representation of women in STEM and in particular in mathematics, the BHP Foundation has been funding Choose Maths, a five-year initiative, since mid-2015 in collaboration with the Australian Mathematical Sciences Institute.

The Choose Maths team has 18 staff, including eight full-time mathematics teachers, the Outreach Officers, who work with 120 schools across Australia. Choose Maths also focuses on Career Awareness, a Women in Mathematics Network which includes mentoring for young women, Teacher and Student Awards, and statistical research. An advisory committee oversees the work of the team.

In this research symposium we consider different aspects along the mathematical pipeline and into the workforce as they relate to gender:

- **Inge Koch:** *Attitude towards Mathematics and Confidence in Mathematical Ability of Students – Can it Change?* presents survey instruments and results of student interventions of Year 5 to Year 9 students that were conducted in 120 schools across Australia in 2017. The effectiveness of the interventions, which focus on growth mindset ideas and year-appropriate mathematical activities, is shown for the more than 2300 students in Year 5, and the differences between the pre- and post-survey results of boys and girls are highlighted
- **Ning Li:** *Gender Gaps in Participation and Performance in Mathematics at Australian Schools 2006 – 2016* looks at the difference of male and female students' performance in mathematics tests, and their participation in mathematics subjects in Years 11 and 12, when mathematics is no longer compulsory. In both areas female students score lower than male students. These results are complemented by teachers' opinions on factors that are most influence students in their subject choices

1 Koch, I., Li, N., and Leder, G. (2018) Symposium: Choose Maths – an Australian Approach to Increasing Participation of Women in Mathematics. *MERGA Conference Proceedings* 2018, 84-96.

- **Gilah Leder:** *Mathematics, Gender, and Careers* reviews the participation of women in the workforce and starts with potential reasons for the lower participation of women in senior mathematics classes that have been presented in psychology and related disciplines. Leder ask the question of what influences the choice of career of young men and women, relates male and female teachers' surprisingly different ratings of the level of mathematics required for different career pathways and examines the occupational pathways by gender

4.3 Symposium Presentations

4.3.1 Attitude towards Mathematics and Confidence in Mathematical Ability of Students – Can it Change?

Inge Koch
Australian Mathematical Sciences Institute

We study students' confidence in their mathematical ability and attitude to mathematics before and after an intervention in 120 schools in Australia. The 2017 Choose Maths intervention measures the effect of growth mindset ideas and targeted mathematical activities in students in Years 5 to 9. The analysis of the pre- and post-survey responses shows: boys are more confident and have a more positive attitude than girls, there is positive change in both domains, and the change for girls is much larger than that for boys.

Introduction

Australian primary and secondary students show similar performances across different national and international tests such as NAPLAN, PISA and TIMSS: on average boys outperform girls in numeracy, while girls outperform boys in literacy at every year level. Almost twice as many boys participate in Year 11 and 12 intermediate and advanced mathematics courses as girls, that is, in the years when students in Australian schools can choose different levels of mathematics including none (Li & Koch, 2017).

It is too simplistic to assume that girls' participation in Year 11 and 12 mathematics courses is lower as a consequence of their lower average performance. TIMSS and PISA results (Mullis, 2015; Thomson et al., 2017) demonstrate clearly that students' economic background has a much stronger influence on mathematics performance than gender. However, the effect of gender is not negligible, and it is important to examine the causes for the lower performance and lower participation of girls.

Based on our understanding and belief that a more positive attitude to mathematics and increased confidence in one's own ability are positively correlated with more enjoyment and engagement in the subject, and that the latter are expected to have a positive effect on performance, we focus on attitude and confidence of students with regards to mathematics.

In this paper we discuss results of surveys of more than 4800 students which we conducted as part of the Choose Maths Outreach in 120 Australian schools throughout 2017. We report students' attitudes towards mathematics, and confidence in their mathematical ability. Informed by the changes observed in the data, we comment on the potential for change. A better understanding of underlying processes affecting mathematics performance will inform if and how we can change students' confidence, attitude, engagement and ultimately performance regarding mathematics.

The Choose Maths Outreach Component

Choose Maths has eight experienced primary and secondary teachers—Outreach Officers—who work in 120 primary and secondary schools across Australia. They provide professional development for the local teachers, conduct teacher surveys and student surveys and engage with students, their parents and teachers (Koch & Li, 2017; Li & Koch, 2017). Principals of the participating schools participate in Choose Maths with the conviction that their teachers' increase in confidence and competence through involvement with Choose Maths will have a flow-on effect on students' engagement and performance.

To study attitudes and confidence of students with respect to mathematics Choose Maths developed annual intervention strategies, described in more detail below, for Year 5 to Year 9 students. We obtained ethics approval for these interventions through the University of Melbourne in late 2016 and conducted a pilot study involving about 300 Year 5 and 300 Year 8 students in Term 4, 2016. Following analysis of the pilot survey data, we modified the original intervention strategies and survey instruments, and, in 2017, collected survey data from more than 4800 students in Years 5, 6, 8 and 9.

Here we focus mostly on the Year 5 and Year 8 interventions conducted in 2017. The Year 5 cohort represents the largest sample – about 2300 students. The Year 8 data from about 1360 students are included to show that the changes observed in primary school students are also evident in the secondary students' data. The Year 5 data form a baseline for comparisons with Year 5 cohorts in 2018 and subsequent years; and assessment of the changes of the Year 5 students in their later school years.

Classroom Intervention and Survey Instruments

The Outreach Officers conducted the intervention classes with the local teacher present. Each intervention consists of a pre-survey, a presentation on growth mindset ideas (Boaler, 2015), a mathematical group activity appropriate for their year level and a post-survey. Each intervention class presents a snapshot in time. Due to time and organisational reasons, it was not possible to measure the effect of the intervention a few months later again. Interventions and surveys in 2018 and in later years will allow a follow-up. The questions for the pre- and post-survey and admissible responses are shown in Table 4.1.

Table 4.1 Survey questions 2017

	Pre-survey	Responses	Post-survey	Responses
Q1	It is okay to feel confused about maths	Agree/ Disagree	It is okay to feel confused about maths	Agree/ Disagree
Q2	Girls and boys can learn maths equally well	Agree/ Disagree	Girls and boys can learn maths equally well	Agree/ Disagree
Q3	Sharing tasks with others helps me to understand maths better	Agree/ Disagree	Working with others on the task today helped me understand this maths better	Agree/ Disagree
Q4	When I think about maths I would describe myself as	Very confident/ Confident/ Neutral/ Not Confident	After the lesson today, I feel	Very confident/ Confident/ Neutral/ Not Confident
Q5	When I think about maths I feel	Enthusiastic/ Somewhat Enthusiastic/ Neutral/ Bored	After the lesson today, I feel	Enthusiastic/ Somewhat Enthusiastic/ Neutral/ Bored
Q6	I have a maths brain	Agree/ Disagree	My brain allows me to learn new maths	Agree/ Disagree

We collect the answers in the pre- and post-survey using Plickers cards (see plickers.com). The answers are collected with the Outreach Officer's mobile phone. We record the gender of the students, and the students use the same Plickers card for the pre- and post-survey as this allows us to record and study the change in their responses as a consequence of the intervention activities.

A growth mindset presentation explains how the brain learns and introduces the 'power of YET': 'I can't do fractions yet'. The Year 5 group activity required students to create geometric shapes and use language to describe the shape, so the other members of the team could construct the identical shape without seeing it. This activity focused strongly on the interplay of language and mathematics and made students aware that the language of mathematics must be very precise. The Year 8 activity focused on discovering and generalising patterns which will ultimately lead to quadratic equations.

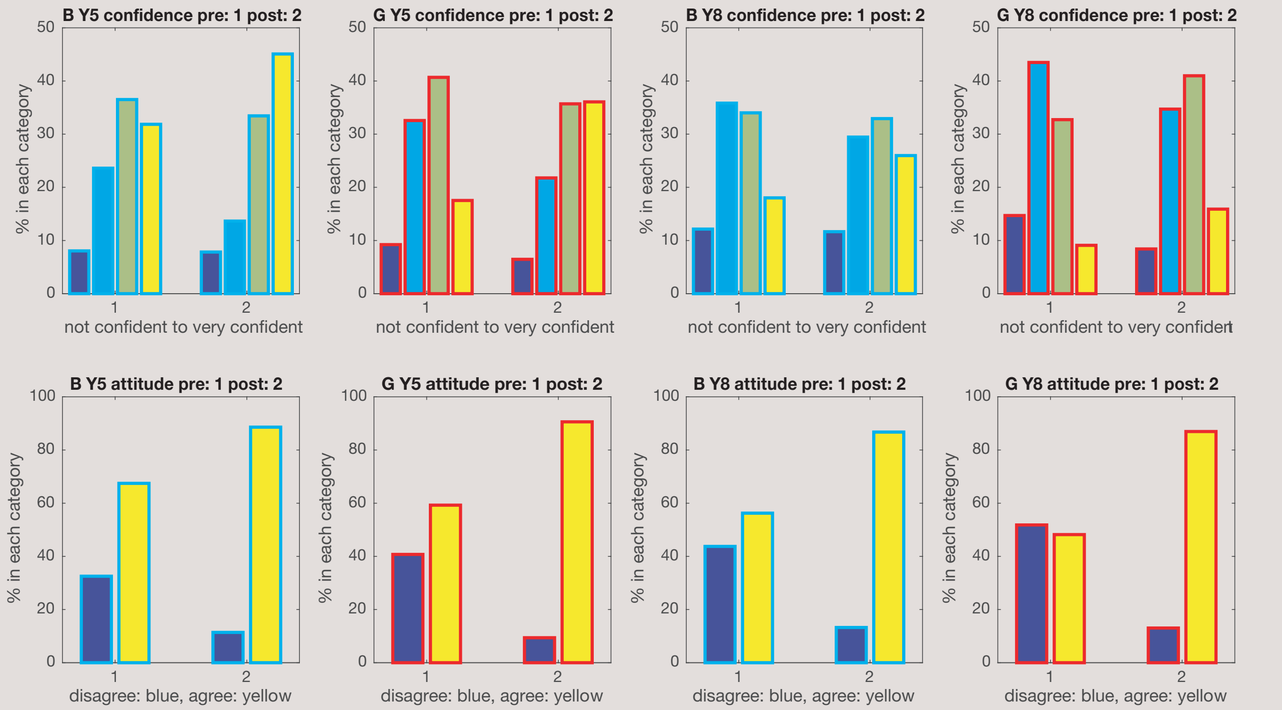
Analysis of Year 5 and Year 8 Student Surveys

Table 4.2 Percentages for each response category in Q4 for Year 5 and Year 8

	Y5 n conf	Y5 neutral	Y5 conf	Y5 v conf	Y8 n conf	Y8 neutral	Y8 conf	Y8 v conf
Boys pre	8.0	23.6	36.5	31.9	12.1	35.8	34.0	18.0
Boys post	7.8	13.7	33.3	45.0	11.7	29.5	32.9	26.0
Girls pre	9.2	32.6	40.7	17.5	14.7	43.5	32.7	9.1
Girls post	6.5	21.8	35.7	36.1	8.4	34.7	41.0	15.9

Notation used in the table: Y5 = Year 5; Y8 = Year 8; n conf = not confident; conf = confident; v conf = very confident.

Figure 4.1 Change in confidence and attitude Year 5 and Year 8



The proportion of boys in the sample is about 46 per cent across all years. There are more girls than boys in the sample, as some of our schools are single-sex girls' schools. The results for the Year 6 and Year 9 cohorts are similar to those reported below.

As can be seen in Table 4.2, the results from Q4 and, the pattern of change from pre- to post-survey, are similar for Year 5 and Year 8 students, but the percentage of confident and very confident students decreased for the higher school year. The responses to Q4 show an increase of the very confident students: 13.1 per cent (resp. 8 per cent) for boys and 18.6 per cent (resp. 8.3 per cent) for girls in Year 5—with the Year 8 results in brackets—while the other three response groups, and in particular the 'neutral' group, decrease. For girls the changes are bigger than for boys; the not confident group for girls shrinks by about one third and is smaller than that for boys in the post-survey, although the girls started with a higher not confident percentage than the boys.

Intervention based on growth mindset ideas are effective in changing, in particular, girls' attitudes to mathematics and increase their confidence

Figure 4.1 shows the change in confidence and attitude in the form of histograms, separately for boys—with blue edging—and girls—with red edging. In each panel, the first block of bars—four in the top row and two in the bottom row—refers to the pre-survey, and the second block of bars in each panel refers to the post-survey. The Year 5 data are shown in the first two panels and the Year 8 data follow in panels three and four in each row. Percentages of responses in each category are shown on the vertical axis.

The top panels in Figure 4.1 refer to the change in confidence, Q4: the four differently coloured columns are given in the same order as in Table 4.2: not confident, neutral, confident, very confident. The bottom panels refer to change in attitude, Q6. The dark blue bar shows the percentage of 'disagree' responses and yellow refers to 'agree' responses. For the changes in positive attitude, Q6, we find: boys show a 21.1 per cent increase in Year 5, and 31.5 per cent in Year 8 and girls show a 31.3 per cent increase in Year 5 and 38.8 per cent in Year 8, that is, about one third of girls changed their attitude as a result of the intervention activities.

In Q4 and Q6 we note that the change due to the intervention is particularly large for girls, and overall the results suggest that students' confidence in and attitude towards mathematics is not fixed but can be affected and changed in a positive way.

Final Words

Survey results of classroom interventions of more than 4800 students in Years 5, 6, 8 and 9, which comprised a pre-survey, mathematical activities and a post-survey during one lesson, show that students' confidence in their mathematical ability and their attitude to mathematics can change through intervention – with change occurring in a positive direction. The larger change particularly for girls is encouraging and there is hope that growth mindset approaches and appropriate teaching methods will lead to longer-lasting effects which allow students to become more confident and ultimately perform better.

References

Boaler, J. (2015). *Mathematical Mindsets: Unleashing students' potential through creative math, inspiring messages and innovative teaching*. Jossey-Bass.

Koch, I. & Li, N. (2017). *Teacher Confidence, Education and Experience: Choose Maths Teacher Survey 2016*. Melbourne: Australian Mathematical Sciences Institute.

Li, N. & Koch, I. (2017). *Choose Maths Gender report: participation, performance and attitudes towards mathematics*. Melbourne: Australian Mathematical Sciences Institute.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2015), *TIMSS 2015 International Results in Mathematics*. TIMMS and PIRLS International Study Centre

Thomson, S., Wernert, N., O'Grady, E. & Rodrigues, S. (2017). *TIMSS 2015 Reporting Australia's Results*.

4.3.2 Gender Gaps in Participation and Performance in Mathematics at Australian Schools 2006-2016

Ning Li

Australian Mathematical Sciences Institute

How do boys and girls differ in voluntary mathematical studies in Years 11 and 12? Do boys and girls perform differently in standardised mathematics exams? What factors affect students' decisions to choose or not choose mathematics? This document updates the previous literature using recent data from various sources. It is found that between 2006 and 2016 participation in Year 12 mathematics has been stable for both boys and girls, with the boys' percentage being higher than girls', both being shifted away from advanced mathematics. Students' previous achievement has been recognised by the teachers as an important influential factor for students' decisions to continue studying mathematics in senior high schools.

Introduction

Participation rate in mathematics in senior high school is a basic indicator for the progress of mathematics education, the quality of the prospective labour market, and the future economic competence. In Australia, mathematics is not compulsory in senior high school. The participation rate determines the supply pool for many university courses, which may affect gender balance in the STEM workforce (Roberts, 2014). Previous research findings show the existence of a gender gap in mathematics enrolments of Year 12 students between 1990 and 2004 (Forgasz, 2006 Sec 1.1). A few years has passed since the call for action to encourage females into STEM disciplines (Office of the Chief Scientist, 2012). What is the current situation?

Students Taking At Least One Mathematics Subject

The typical age of Year 12 students in Australia is between seventeen and eighteen years. Persons in the age group of 17-18 form the Year 12 potential population, whose size can be estimated by the average number of 17 or 18-year-olds in Australia (Li & Koch, 2017). According to Australian Bureau of Statistics (ABS data series 3101059, Table 59), between 2006 and 2016 the sizes of the Year 12 potential population, displayed as solid lines in Figure 4.2, have grown from 141344 to 151698 for boys and from 134330 to 143083 for girls. Data on Year 12 enrolments (Barrington & Evans 2017) indicate that each year, on average, one third of the boys and one fifth of the girls in the potential population did not study Year 12 between 2006 and 2016. While there were 7015 to 9128 more boys in the potential population each year, during this period 7381 to 13357 more girls enrolled in Year 12 each year. A restructuring of the secondary curriculum in Western Australia led to a half-cohort reduction in the state in that year, evident from the dips in 2014 enrolments in Figure 4.2. The extra number of boys, or the gender gap, in the Year 12 potential population has shown a decreasing trend. In contrast, the extra number of girls, or the gender gap, in the Year 12 actual population has shown an increasing trend between 2006 and 2016.

Figure 4.2 Year 12 potential, actual, and mathematics populations, 2006 – 2016

Data sources: ABS data series 3101059, Australian Demographic Statistics, Table 59 (Estimated resident population by single year of age, Australia); Year 12 enrolments data (Barrington & Evans 2017).

Mathematics subjects are offered to Year 12 students at various levels of difficulty. A student who takes any of these subjects is referred to as a mathematics student. Between 2006 and 2016 the total number of Year 12 mathematics students has been growing proportionally to the total number of Year 12 students, for both girls and boys. Each year, despite more girls enrolled in Year 12, fewer girls than boys chose mathematics, being evident from the long-dashed lines in Figure 4.2. Moreover, the difference between male and female mathematics students has been widening over time in the period.

Elementary, Intermediate, and Advanced Mathematics Students

Based on the definitions by Barrington and Evans (2016, 2017), the elementary level mathematics subjects involve little or no calculus, and are not intended to provide a foundation for any future tertiary studies involving mathematics (Forgasz, 2006). On the other hand, the intermediate and advanced mathematics subjects meet the minimum requirement for tertiary studies in which mathematics is an integral part of the discipline. By estimating the overlap of students concurrently taking elementary and non-elementary subjects, Barrington and Evans (2017) estimated the number of students taking elementary subjects only. The data reveal that the yearly increments of mathematics students between 2006 and 2016 are mainly due to increments in elementary mathematics students. Over time, students were shifting away from advanced towards elementary subjects, for both boys and girls. It is found that in Year 12 between 2006 and 2016 (Li & Koch, 2017):

- Each year, on average, at least twice as many boys and girls enrolled in elementary mathematics as in intermediate mathematics; four times as many boys and seven times as many girls enrolled in elementary mathematics as in advanced mathematics
- The percentage of elementary mathematics students has increased by 15 per cent for boys and by 6 per cent for girls in the period
- In contrast, the percentage of intermediate mathematics students has decreased by 12 per cent for boys and by 10 per cent for girls
- The percentage of advanced mathematics students has decreased by 12 per cent for boys and by 10 per cent for girls
- Girls were, on average, at least 43 per cent less likely than boys to study advanced mathematics
- The percentage of Year 12 advanced mathematics girls appears to have a mild increase from 6.6 per cent to 7.0 per cent monotonically over the period between 2012 and 2016
- The girl to boy ratio within advanced mathematics students has decreased from 2006 to 2014, but has increased since, and reached 6:10, the highest in the last decade

Table 4.3 Average scores of students' mathematics tests in NAPLAN, PISA, TIMSS, by gender

			1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NAPLAN	Year 3	Boy										401	398	398	403	400	399	405	402	407
		Girl										393	390	393	394	391	395	398	394	397
	Year 5	Boy										482	493	494	493	492	492	493	497	497
		Girl										470	481	483	482	485	479	482	488	489
	Year 7	Boy										552	549	553	550	544	547	550	546	552
		Girl										537	538	543	539	532	537	541	539	547
	Year 9	Boy										587	592	591	589	590	590	593	596	593
		Girl										578	586	579	577	578	577	582	587	585
PISA		Boy		540			527			527			519			510			494	
		Girl		527			522			513			509			498			486	
TIMSS	Year 4	Boy	496				500				519				519				522	
		Girl	493				497				513				513				513	
	Year 8	Boy	507				511				504				509				506	
		Girl	511				499				488				500				504	

Source: NAPLAN National Report 2008 – 2016. Mullis et al. (2015), TIMSS 2015 International Results in Mathematics. Thomson et al. (2017), PISA 2015: Reporting Australia's results.

Teachers' Views about Factors influencing Students' Decisions to Choose or Not Choose Mathematics in Years 11 & 12

Factors that may potentially affect students' decisions to continue studying mathematics in Years 11 and 12 are obtained from a survey of mathematics teachers (Li & Koch, 2017), and are displayed along the horizontal axis in Figures 4.3. The teachers expressed their opinions by selecting one box from five choices 'Strongly Disagree', 'Disagree', 'Neither Agree Nor Disagree', 'Agree', and 'Strongly Agree' for each factor. The percentage of 'Strongly Agree' responses is displayed along the vertical axis in Figure 4.3.

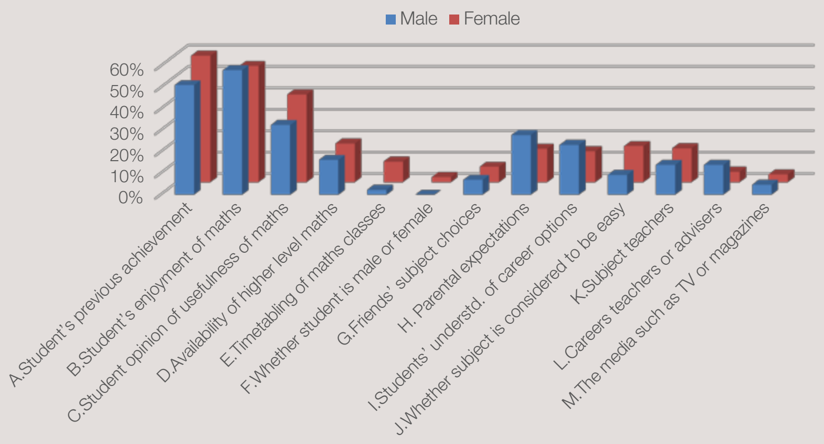
The teachers reported that students' previous achievements in mathematics and students' enjoyment of mathematics are the most influential factors to students' decisions in the subject selection. The next most influential factors, as reported by the teachers, are students' perceptions of the usefulness of mathematics, followed by parental expectations, students' views of career options with mathematics, whether the subject is regarded to be easy, the subject teachers, and the media.

Previous mathematics achievements, according to teachers, are the most influential factors in students choosing mathematics

Final Words

Girls are less likely to choose mathematics when they have the option not to, and girls on average perform less well than boys on standardised tests. According to teachers' opinions, students' previous achievements and enjoyment in mathematics are important factors regarding whether students choose mathematics in Years 11 and 12. There seems to be little data of Australian students on their thoughts in the process of subject selection. Nonetheless, effective teaching practices must be identified and used in classrooms to encourage students', particularly girls' participation in mathematics. It is also important to show students career opportunities involving mathematics. It is crucial for teachers to show the fun and wonder of mathematics to motivate and maintain students' intrinsic interest in mathematics.

Figure 4.3 Teachers' opinion about factors influencing students' decisions to continue studying mathematics



Data source: Choose Maths Teacher Survey 2016

References

Barrington, F. & Evans, M. (2016). *Year 12 mathematics participation in Australia - The last ten years*. AMSI Publication, Research and Data Melbourne, Vic.: Australian Mathematical Sciences Institute

Barrington, F. & Evans, M. (2017) *Discussion paper for the AMSI EAC meeting on 21 February 2017.* AMSI Documentation.

Forgasz, H. (2006). *Australian year 12 mathematics enrolments: patterns and trends*, International Centre of Excellence for Education in Mathematics and the Australian Mathematical Sciences Institute

Li, N. & Koch, I. (2017). *Choose Maths Gender report: participation, performance and attitudes towards mathematics*. Melbourne: Australian Mathematical Sciences Institute.

Office of the Chief Scientist (2012). *Mathematics, engineering & science in the national interest*. Australian government.

Roberts, K. (2014). *Engaging more women and girls in mathematics and STEM fields: The international evidence*. Report prepared for the Australian Mathematical Sciences Institute.

Wilson & Mack (2014). Declines in High School Mathematics and Science Participation: Evidence of Students' and Future Teachers' Disengagement with Maths. *International Journal of Innovation in Science and Mathematics Education*, 22(7), 3

4.3.3 Mathematics, Gender, and Careers

Gilah Leder
Monash University

Gender differences in mathematics learning continue to attract attention – from educators, researchers, and stakeholders. The genesis of this topic and early research findings are outlined briefly. Contemporary occupational participation data are provided, generally and for those with a sound mathematics background. Teachers' beliefs about the mathematical pre-requisites for selected occupations are also presented.

Introduction

Mathematics is generally recognised as a critical component of the school curriculum and as a gatekeeper to many tertiary pathways and career opportunities. Historically, mathematics has been considered to be a male domain, that is, an area more suitable for males than for females. "There are perhaps only three or four women until the nineteenth century who have left behind a name in mathematics. Women were lucky to receive any education at all" (Mckinnon, 1990, p. 347). Over time, and as schooling became more widely accessible, it was recognised that females, particularly those in a sympathetic social environment and from a financially comfortable milieu, could cope adequately with the mathematical curriculum demands imposed on males (Clements, 1979). Yet small but persistent gender differences in mathematics achievement, typically in favour of males have continued to be reported.

Gender and mathematics learning – a snapshot of research

A number of findings emerged from the early research work. On average, females' achievement levels were found to be lower than males', particularly when it came to solving challenging mathematics problems. When mathematics was no longer compulsory, females' participation rates were lower than males'. Females' views were found to be less functional regarding future success than those of males, on a range of affective/attitudinal measures about mathematics and about themselves as mathematics learners. At the same time it was regularly emphasised that, when observed, gender differences were small compared to much larger within-group variations.

Recurring differences in mathematics learning in favour of males have continued to be reported including: achievement in post-compulsory mathematics courses, on certain content domains and topic areas, and among high-achieving students (e.g., Li & Koch, 2017; Andreescu, Gallian, Kane, & Mertz, 2012; Leder 2011, 2009).

Multiple models and explanations have been put forward to account for the small yet persistent gender differences in mathematics achievement. Different theoretical and value-driven perspectives have been used to shape and guide research on gender and mathematics learning, Most of the models proposed contain a range of interacting factors, both personal and environmental. Included among the latter are the school culture, social mores, and the values and expectations of peers, parents, and teachers. "It is important to note", wrote Eccles (1986, p. 15) "that any discussion of sex differences in achievement must acknowledge the problems of societal influence". Else-Quest, Hyde, and Linn (2010) argued that "considerable cross-national variability in the gender gap can be explained by important national characteristics reflecting the status and welfare of women" (p. 125). Leder (2017) reported that for mathematically able females, more than able males, societal expectations might serve as a barrier to continued participation in mathematics and eventual career intentions.

Why not do mathematics?

It must of course be recognised that not all students, whether male or female, necessarily aim for intensive study or proficiency in mathematics. Damarin (2000)'s evocative explanation why some choose other options is worth noting:

Mathematics teachers and researchers have observed that mathematics is unique among school subjects in that, for many students, failure in mathematics is not an *occasion of embarrassment; these students (often with the support of parents, peers, and sometimes guidance counselors and other teachers) refer to the inability to do mathematics with a certain pride. Thus, from leading journals of public intellectual discussion, from the analyses of sociologists of science, from the work of (genetic) scientists themselves, from the pages of daily papers, and from practices of students and adults within the wall of our schools, there emerges and coalesces a discourse of mathematics ability as marking a form of deviance and the mathematically able as a category marked by the signs of this deviance. (Damarin, 2000, p. 78)*

Congruent explanations for turning away from mathematics are found in different theoretical frameworks. Francis (2010, p. 31) talked of the need by some female students in particular to achieve a "'balance' between sociability and high achievement to avoid being 'othered' as a 'boffin' or swat". Within the psychological literature, and more specifically within the framework of the expectancy-value theory of achievement motivation, the fear of success or motive to avoid success construct has been used to highlight a dilemma considered relevant to high-ability, high-achievement oriented females – those who are capable of, and aspire to success, but are at the same time concerned about the negative consequences that may accompany this success. Success in a male-dominated employment area could be such a situation (see e.g., Leder, 2017).

What influences the choice of occupations which are pursued by males and females in the Australian workforce? Of the myriad of issues that could be examined several are considered here: the gender profiles of different occupations, the occupational choices of mathematical science graduates, and the views of mathematics teachers about the level of mathematics required for different occupations.

Composition of the Australian workforce

Using the Australian and New Zealand Standard Classification of Occupations [ANZSCO], jobs can be clustered into eight major occupational codes, with each further divided into five hierarchical levels bundled together on the basis of the similarities of occupations with respect to skill level and skill specialisation. The major groups are: Managers, Professionals, Technicians and Trades Workers, Community and Personal Service Workers, Clerical and Administrative Workers, Sales Workers, Machinery Operators and Drivers, and Labourers. Of these, Professionals is the largest group, followed by Clerical and Administrative Workers, and Technicians and Trades Workers. Educational qualifications vary within and across the groups. In the most highly skilled groups, Managers, Professionals, and Technicians and Trade Workers, more than 70 per cent of workers have post-school qualifications. In contrast, less than half of the workers categorised as Labourers, Machinery Operators and Drivers, and Sales Workers hold any post school qualification (Australian Government, 2017).

Gender composition of the Australian workforce

More detailed inspections of recent collections of occupational data reveal different gender profiles for different occupations. "The Australian labour market is highly gender-segregated by industry and occupation, a pattern that has persisted over the past two decades" (Workplace Gender Equality Agency [WGEA], 2016, p. 2). For males, the three most common occupational codes, technicians and trade workers, professionals, and managers, are the same as those listed for the full workforce. For females, however, professionals, clerical and administrative workers, and community and personal service workers are the largest categories. Examples of starkly different levels of male/female participation in different industries, based on 2016 census data, include Health Care and Social Assistance (F: 78 per cent; M: 22 per cent), Education and Training (F: 71 per cent; M: 29 per cent), Mining (F: 14 per cent; M: 86 per cent); Construction (F: 12 per cent; M: 88 per cent) (WGEA, 2016). The career directions of those drawn to mathematical studies, that is, those who have completed a mathematical science degree are the focus of the next section.

Mathematical science graduates, pathways by gender

For many years Graduate Careers Australia [GCA] surveyed newly qualified higher education graduates. In 2015, well over 100,000 graduates responded. Of these, 38 per cent were males and 62 per cent were females. Among the respondents there were 750 graduates in the field of mathematics. Of these, two-thirds were males. The Office of the Chief Scientist (2016) also reported somewhat older, but still relevant gender related data. In 2011 there were more than 25,000 individuals in Australia with a degree in mathematical science. The majority of these (61 per cent) were males. The employment pathways of the graduates were described as follows:

The top three industry divisions that employed Mathematical Sciences graduates were Education and Training, Professional, Scientific and Technical Services, and Financial Services (24, 20 and 15 per cent, respectively)…. There were more males compared to females employed in all industries of employment except Health Care and Social Assistance. (Office of the Chief Scientist, 2016, p. 150)

Thus it seems that gender differences in participation in more advanced levels of mathematics education continue, with more males than females engaged in such courses. Furthermore, the occupational fields in which females were found to outnumber males mirrored those reported for the larger workforce. What those involved in the teaching of pre-university mathematics think about the mathematical demands of selected occupations is described next.

Teachers' beliefs about the mathematical pre-requisites for selected occupations?

As part of a larger survey, administered to 620 mathematics teaching staff in 85 schools, Li and Koch (2017) collected information for 14 occupations about the level of mathematics thought to be needed: university mathematics, year 12 mathematics, year 10 mathematics, and basic mathematics skills. For six of the occupations at least 70 per cent of both the male and female teachers considered university mathematics to be necessary. For each of these a higher percentage of females than males believed this to be the necessary pre-requisite – see Table 4.4.

A higher proportion of female than male teachers regard university mathematics as necessary for occupations including biologist, pilot and secondary school teacher

Table 4.4 Occupations requiring university mathematics – teachers' ratings

Occupation	% males	% females
Biologist	72	81
Computer scientist	89	97
Economist	94	94
Finance advisor	78	83
Pilot	83	89
Secondary school teacher	78	83

Adapted from Li and Koch (2017)

A small number of the occupations listed were thought to require only basic mathematics. Again gender differences were found. As a group, the females identified five such areas: chef (6 per cent thought this); farmer (6 per cent); lawyer (3 per cent); retail sales worker (8 per cent), and health worker (3 per cent). Among the males only one of the occupations was assumed to need only basic mathematics: retail sales worker (11 per cent considered this). It is not easy to determine whose judgements about the level of mathematics required in the different occupations are the more accurate, nor the extent to which the students are aware of, or are influenced, by these views.

Final words

As noted at the outset, mathematics is widely thought to be a gatekeeper to tertiary pathways and career opportunities. That a sound knowledge of mathematics can open many occupational doors is persuasively illustrated by the diversity of occupations listed in Sterrett's (2014) popular 101 careers in mathematics. Covered are areas traditionally linked with mathematics as well as less predictable areas - including the arts, music, and the law.

Data presented in this paper serve as examples of the persistence and extent of gender linked occupational participation, for the workforce at large and for those in mathematics related areas. Gender differences in post school mathematics courses enrolments, and in teachers' assessment of the mathematical requirement for different occupations have also been presented. Options to counter the flow-on effects of the gender differences highlighted here, as well as those found more broadly, certainly warrant further exploration.

References

Andreescu, T., Gallian, J. A., Kane, J. M., & Mertz, J. E. (2008). Cross-cultural analysis of students with exceptional talent in mathematical problem solving. *Notices of the American Mathematical Society*, 55(10), 1248-1260.

Australian Government, Department of Employment (2017). *Australian jobs*. Retrieved from (docs.jobs.gov.au/system/files/doc/other/australianjobs2017.pdf)

Clements, M.A. (1979). Sex differences in mathematical performance: An historical perspective. *Educational Studies in Mathematics*, 10, 305-32.

Damarin, S. K. (2000). The mathematically able as a marked category. *Gender and Education*, 12(1), 69-85.

Eccles, J. S. (1986). Gender-roles and women's achievement. *Educational Researcher*, *15*(6), 15-19.

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin*, *136*(1), 103-127.

Francis, B. 2010. Girls' achievement: Contesting the positioning of girls as the relational 'achievers' to 'boys' underachievement'. In *Girls and Education 3-16: Continuing concerns, new agendas*, eds. C. Jackson, C.F. Paechter, and E. Renold, 21-37. Maidenhead: Open University Press.

Graduate Careers Australia (2017). *Graduate Opportunities.* Retrieved from (graduateopportunities.com/graduate-salaries/mathematics/mathematics-all-degree-levels/)

Leder, G. C. (2017). Mathematics Performance and Future Occupation: Are They (Still) Related? In A. Downton, S. Livy, & J. Hall (Eds.), 40 years on: We are still learning! *Proceedings of the 40th Annual conference of the Mathematics Education Research Group of Australasia* (pp. 51-54). MERGA: Adelaide.

Leder, G. C. (2011). Mathematics taught me Einstein's old cocktail of inspiration and perspiration: Mathematically talented teenagers as adults. *Canadian Journal of Science, Mathematics and technology Education, 11*(1), 29-38.

Leder, G. C. (2009). High achieving females in mathematics: here today and gone tomorrow? In M. Tzekaki, M. Kaldrimidou, & H. Sakonidis (Eds.), In search for theories in mathematics education. *Proceedings of the 33rd Conference of the International Group for the Psychology of Mathematics Education Vol.3* (pp. 497-504). Thessaloniki, Greece: PME.

Li, N. & Koch, I. (2017). *Choose Maths Gender Report: Participation, Performance, and Attitudes Towards Mathematics*. Melbourne: Australian Mathematical Sciences Institute. Retrieved from (amsi.org.au/publications/gender-report-2017-participation-performance-attitudes-towards-mathematics/)

Mackinnon, N. (1990). Sophie Germain: or was Gauss a feminist? *Mathematical Gazette*, 74(470), 346-351. Doi:10.2307/3618130

Sterrett, A. (Ed.) 2014. *101 careers in mathematics*. New York: The Mathematical Association of America.

Workplace Gender Equality Agency (2016, August). *Gender segregation in Australia's workforce.* Retrieved from (wgea.gov.au/sites/default/files/20160801_Industry_occupational_segregation_factsheet.pdf)

4.4 Response

4.4.1 Discussant Reaction to: Choose Maths – an Australian Approach to Increasing Participation of Women in Mathematics

Helen Forgasz
Monash University

From the overview of the symposium, it was evident that Choose Maths is a very large project: 18 staff; 8 full-time mathematics teachers (Outreach Officers), and 120 schools participating.

The symposium papers were ordered by the "pipeline effect": primary (Inge Koch), secondary (Ning Li), post-school (Gilah Leder). There is another way to consider the symposium papers as suggested below.

First the context for increasing women's participation rates in mathematics was presented: the under-representation of girls/women in senior secondary mathematics (Ning Li) and in related careers (Gilah Leder). In setting the scene with these data, the need for a project to identify ways to increase women's participation in mathematics was made clear. The direction of the gender differences in achievement, attitudes, and participation in related careers has been known for some time. But continued monitoring to draw attention to the currency of the gaps challenges any complacency that the problem has been solved.

The Australian government is focusing on trying to address the shortage of women in STEM fields. In my view, this focus is driven more by the economic imperative than by a genuine desire to foster gender equity. For many years, the OECD has drawn attention to the economic benefits of educating women and bringing them into the workforce. Allowing women to drive in the post-oil trajectory of Saudi Arabia's economy is recent evidence of an economically-motivated change. Women, however, still need a man's permission to drive; gender equality was not, in my view, the prime stimulus for this development!

The second important aspect covered by the symposium papers was a summary of some of the project's field research: Inge Koch (students' confidence/attitudes), Ning Li (teachers' views on factors affecting decisions to continue with mathematics), and Gilah Leder (teachers' beliefs about mathematics pre-requisites for particular occupations).

Overall impression of the symposium papers

The fieldwork focus on teachers is a big plus – I will come back to the reasons for seeing this as a positive later.

Some specific reactions to the presentations

1. Student's confidence/attitudes – Inge Koch's presentation

There were indications of the potential that the (single lesson) intervention positively affected attitudes. However, I was not totally convinced for several methodological reasons:

- Pre- and post-survey designs normally call for the use of very similar questions; this was not the case here. The pre-items presented targeted students' general views of mathematics; the post-items focused on the mathematics encountered in "this lesson". The domains of the two sets of questions were different and drawing inferences based on these data may not be appropriate
- While using four categories of response is acceptable, it is questionable to use two positive choices ('very confident', and 'confident') but only one negative choice ('not confident'); the fourth option being 'neutral'. The respondents may be swayed to respond in the direction they view as expected, in this case the positive (confident) direction
- Perhaps, in the responses being gathered immediately after the lesson, the "Hawthorn effect", defined as "the tendency, particularly in social experiments, for people to modify their behaviour because they know they are being studied, and so to distort (usually unwittingly) their research findings" (Payne & Payne, 2004) may also have been at play. After all, it was an Outreach teacher, and not the classroom teacher, who taught the lesson

2. Teachers' views on factors affecting decisions to continue with mathematics – Ning Li's presentation

The "strongly agree" data on the various factors presented to the teachers in the survey and illustrated in Figure 2 were very interesting. The data fit with previous, quite early, explanatory models for gender differences in mathematics learning outcomes (e.g., Eccles et al., 1985, Leder, 1993). Prior achievement, enjoyment, perceived usefulness of mathematics – the top three found in the study – are found in the models. Parental expectations, and the peer group (but to a lesser extent here than in previous research) also feature in the explanatory models.

Of concern is the relatively low impact of subject teachers and career teachers. In a study of adult women from single-sex schools, Gilah Leder and I (Forgasz & Leder, 2017) also found that these two school-based factors had little impact on STEM career decisions.

In the paper, it is suggested that drawing students' attention to careers involving mathematics and for teachers to motivate and maintain students' interests are needed. But, the main factor identified by teachers, "student's prior achievement", is a greater challenge, particularly for girls. As demonstrated, on average, girls' achievements are generally lower than boys' – how can the gender gap be addressed? We know that girls' and boys' achievement levels are impacted by the form of assessment (e.g., class testing versus exams; multiple choice versus open-ended items, etc.), the content balance in "tests" (gender differences vary depending on content domains tested, e.g., arithmetical versus geometrical). Depending on the 'statistic' cited, the direction of gender differences can vary. For example, with NAPLAN, boys do better than girls when mean scores are used, but a higher proportion of girls than boys reach the pre-set benchmark levels.

3. Teachers' beliefs about pre-requisite mathematics requirements for various careers – Gilah Leder's presentation

The differences by teacher gender in their beliefs about the levels of mathematics serving as pre-requisites for the group of professions listed in Table 4.4 (and in the text) was surprising, particularly that higher proportions of female than male teachers believed some levels of mathematics were needed. These are new data – I have not seen any similar data reported. I certainly concur with Gilah Leder that further research is needed to find out why this difference by teacher gender exists. Are females more accurate than males in their beliefs about the pre-requisites, or do they have higher expectations of the mathematics needed? Alternatively, are the males more accurate, or do they undervalue the need for mathematics for particular occupations?

Implications of and issues associated with the outcomes of the Choose Maths project

As noted earlier, I believe that the focus on teachers in the Choose Maths project has the potential to make a difference in the long run. Students are transient, but teachers stay around to teach large numbers of students over the years. Teachers can also share knowledge and skills with colleagues, both now and in the future. There is the potential in this project for this to happen, that is, the "train the trainer" model in operation. Of course this is dependent on the teachers accepting that what they are learning in this project is, in fact, value-adding to their students' mathematics learning.

However, I am curious how the project will be able to demonstrate that there has been an impact on the students, girls in particular, and that the impact is long-term.

What I am not so certain about is the focus on "growth mindsets" (Boaler, 2016). This is not the mathematics learning theory underpinning the Australian mathematics curriculum or the mathematics teacher education programs that I am familiar with. Certainly classroom factors, including teaching approaches, are critical. In my PhD (many years ago) I examined the relationship between classroom factors and attitudes towards mathematics. What emerged as the most salient classroom factor identified by the students (both male and female) was "personalisation", that is, that the teacher is perceived as being interested in students (and their progress) as individuals.

There have been many interventions to promote mathematics (and for that matter, computing) for females in the past. Leder, Forgasz and Solar (1996) summarised many of the early interventions to promote mathematics participation in a handbook chapter. We found that a major failing of the projects was that once the monies ran out, so too did any impact on students that the projects might have had.

In the late 1990s, it was the Victorian Department of Labour (today called Employment) that, having identified the economic benefits of having more women in the (what we now call) STEM workforce, embarked on an advertising campaign targeting parents. The "Maths Multiplies Your Choices" (with the slogan, "Don't pigeon hole your daughters") campaign had measurable impact (see McAnally, 1991) – there was an increase in the number of girls enrolling in Year 11 mathematics subjects in the following year. [A copy of an advertisement screened on TV can be downloaded from amsi.org.au/publications/maths-multiplies-choices/]. So successful was that campaign that there was no further funding in the following year. Predictably, enrolment numbers quickly reverted to previous patterns. Not dropping the ball is paramount, and targeting parents, not just teachers or students, appears to be important.

Final words

People involved in the Choose Maths project are to be congratulated on the project's achievements to date. I've heard accounts of some of the excellent work that the teachers in the project have done in stimulating their students' interest in mathematics. Long may it last!

References

Boaler, J. (2016). *Mathematical mindsets*. San Francisco, CA: Jossey-Bass.

Eccles, J., Adler, T. F., Futterman, R., Goff, S. B. Kaczala, C. M., Meece, J. L., & Midgley, C. (1985). Self-perceptions, task perceptions, socializing influences, and the decision to enroll in mathematics. In S. F. Chipman, L. R. Brush, & D. M. Wilson (Eds.), *Women and mathematics: Balancing the equation* (pp.95-121). Hillsdale, NJ: Lawrence Erlbaum.

Forgasz, H., & Leder, G. (2017). *Single-sex versus co-educational schooling and STEM pathways: Final report*. Report to the Alliance of Girls' Schools Australasia. Retrieved from (agsa.org.au/wp-content/uploads/2018/03/Alliance-final-report.pdf)

Leder, G. C. (1993). Gender differences in mathematics: An overview. In E. Fennema & G. C. Leder (Eds.), *Mathematics and gender* (pp.10-26). St. Lucia, Queensland: Queensland University Press.

McAnally, K. (1991). Encouraging parents to stop pigeon-holing their daughters: The "Maths Multiplies Your Choices," campaign. *VIER Bulletin* (66), 29-38.

4.3.2 Rejoinder

Inge Koch
Australian Mathematical Sciences Institute

The authors would like to thank the discussant, Helen Forgasz, for her critical appraisal of the three contributions and her very positive opinion about Choose Maths. This type of critical feedback is very valuable.

Forgasz' alternative way of looking at the problem we address, namely 'the context for increasing women's participation rates in mathematics and the under-representation of girls/women in senior secondary mathematics and in related careers' is the motivation for the multilevel approach of Choose Maths (see Figure – 1.1 of Section 1 on p.), and we believe it is one of the reasons why the project will have an impact even in the relatively short time we currently have funding for. Some of our data and field work support this claim – see for example Figure 3.1 of Koch, Section 3 of the Gender Report which shows the effect of the professional development on teachers' confidence and decrease in feeling tense when teaching mathematics.

Regarding the effectiveness of the student intervention, a four or five year study can only be the beginning but is required partly to examine and determine directions that will be successful. A continuation of the current project combined with longitudinal student data collection is required to achieve and demonstrate longer-term effects on an increase of confidence in and a change of attitude towards mathematics.

In the current project, we measure the 'point-in-time' effect of the intervention and the specific mathematical activities, so pre- and post-survey questions need to be slightly different in order to capture this. The potential bias Forgasz mentions as a consequence of asymmetric responses to the survey questions is cancelled out by the fact that the responses in the pre- and post-survey are the same. We are primarily interested in the movement or transition of students as a consequence of the intervention and less so in their starting points. This movement or transition is showcased in Tables 3.3 – 3.5 of Koch, Section 3. We thank Helen Forgasz for pointing out that the title of Figure 4.2, in Li's contribution is incorrect and have fixed this.

Finally we appreciate Forgasz raising that further research into the effect of teachers' gender on the level of mathematics required for different career pathways is needed. We hope to shed more light on this question during the remaining two teacher surveys in 2018 and 2019.

5 Choose Maths Days for Year 9 and 10 Students in Australian Universities and Schools in 2018

Julia Collins
Australian Mathematical Sciences Institute

Choose Maths Days are conducted at universities and Choose Maths schools around Australia, aiming to raise mathematical aspirations and enjoyment of girls in Year 9 and 10. Surveys conducted at these events provide information about students' prior engagement with mathematics, their career ambitions, their expectations around Year 11/12 subject selections and their opinions of the impact of the day.

A total of 762 students attended Choose Maths Days in 2018 and this report analyses the data from 392 female students attending events at universities. Around 60 per cent of the students said that the Choose Maths Days had influenced the level of mathematics they wished to take in Year 11/12, with a quarter of students explicitly stating that they now want to take a higher level of mathematics than they had previously decided upon.

The activities or talks which had the biggest impact on students' reported levels of mathematics enjoyment were those which targeted students with lower levels of mathematics enjoyment and future aspirations. Year 9 students were also more influenced than Year 10 students.

5.1 Introduction

As detailed in Section 5.2, Choose Maths Days are part of a range of activities run by AMSI's Choose Maths project to encourage the uptake of higher levels of mathematics among young women beyond Year 10. They are part of the "Women in Maths Network" component of the project, which also encompasses Choose Maths Mentoring.

These events bring together different aspects of the Choose Maths project: the AMSI careers ambassadors who are part of the nationwide careers campaign are also invited as speakers to Choose Maths Days, as are the mentors involved with Choose Maths Mentoring. AMSI's research into student and teacher attitudes towards mathematics and teaching of mathematics (Li & Koch, 2017) will help to inform the format of Choose Maths Days, while the surveys of students at Choose Maths Days will themselves form part of the body of research about student attitudes to mathematics and STEM careers.

This report details the results from student surveys at the 2018 Choose Maths Days around Australia, focusing in particular on events held at universities for Year 9 and 10 girls. It then uses these results to make recommendations for modifications to this survey in the future, and will be used to inform the direction and content of 2019 Choose Maths Days. For a longer version of this report see Collins and Koch (2018).

5.2 Choose Maths Days

Choose Maths Days are events aimed primarily at girls in Years 9 and 10, before they make their subject selections for Year 11. Similar events for Year 12 female students have run successfully at UNSW and the University of Adelaide for a number of years.

Choose Maths have two formats:

- University Choose Maths Days: AMSI Choose Maths works with one or more of its member universities to host each event, and multiple schools from the university feeder schools are invited to attend. Each school is offered up to 20 student places and we recommend that students be selected on the basis of their potential for increased engagement with maths, rather than school grades. The schedule typically comprises short talks by industry and academic speakers and Choose Maths careers ambassadors, hands-on activities, and a Q&A session with the speakers and current university students

- School Choose Maths Days: AMSI works with its Choose Maths secondary schools to host events. Nearby schools are invited to attend. The schedule typically comprises talks by industry speakers and Choose Maths careers ambassadors, hands-on activities, and a 'speed-dating' session with speakers and other local mathematics champions

University events in 2018 have been held in state capital cities, while school events have been in regional or remote locations.

The aim of these events is to encourage students to choose a higher level of mathematics in Year 11 than they were currently considering. That is, if a student was not planning to take any mathematics, to encourage them to choose *some* mathematics; if they were planning to do an elementary mathematics subject, to encourage them to choose the intermediate subject, and so on. To this end, the events focus on the range of careers that are accessible to those with a mathematics background, personal stories from people who are using mathematics in their jobs or studies, and activities that broaden students' conceptions of what mathematics is and why it is important. The hands-on activities nurture the teamwork and problem-solving aspects of mathematics, and aim to build students' confidence in their own abilities.

As a secondary aim, the events are intended to provide professional development to those teachers who attend. These teachers may be mathematics classroom teachers, either in-field or out-of-field, or they may be careers teachers.

The data in this report comes from the surveys done at the beginning and end of each event. The surveys were designed by the Choose Maths team. All surveys are anonymous, asking for no identifying details apart from gender and year group. It is made clear to the students that completion of the surveys, and thus participation in this research, is voluntary.

In total we have data from six university events and two school events, with a total of 762 attendees and 519 student surveys returned (see Table 5.1). This is an overall response rate of 68 per cent. The analysis in this report will focus on the university data excluding boys (392 surveys; a response rate of 76 per cent), since the event format and audience is more consistent across these events. The school-based events only make up 39 surveys in total from girls across Years 9 and 10.

We hope to expand the Choose Maths Days in 2019 and future reports are expected to include data from school events, since it will be interesting to compare the demographics attending the two kinds of events and the slightly different formats of each.

Table 5.1 List of Choose Maths Days 2018

University or School event	Date	Location	Number of attendees	Number of surveys returned
U	25 May	University of Sydney (jointly organised with UNSW & UTS)	180	140
U	4 June	La Trobe University	92	74
U	6 June	QUT	80	61 (11 boys)
U	8 June	Murdoch University	70	45
U	13 June	University of Melbourne	50	31
U	3 July	University of Adelaide	60	52
S	31 May	Hedland Senior High School	90	38 (21 boys)
S	16 August	Roxby Downs Area School	140	78 (31 boys; 8 undisclosed)

5.3 Surveys at Choose Maths Days

All students attending Choose Maths Days receive their surveys upon arrival at the venue. They are asked to complete the pre-survey before the main activities of the day begin, and the post-survey (on the back of the same paper) at the end of the day after the last activity has finished but before they leave the venue. Each survey has a unique identifying number; no personal details are asked for apart from gender and school year. Ethics approval for these surveys has been obtained from the Human Ethics Committee of the University of Melbourne in 2018.

The questions in the survey are given below in Table 5.2.

Table 5.2 Choose Maths Day survey questions

Pre-survey questions	Post-survey questions
1. *What grade are you in?*	1. *Which activity or presentation did you like best?*
2. *What gender do you identify with?*	2. *Circle the number [from 1 to 5] that best describes your enjoyment of today's mathematical activities.*
3. *Circle the number [from 1 to 5] that best describes your enjoyment of mathematics.*	3. *To what extent did the Choose Maths Day cause you to think positively about mathematics in a way you haven't thought about before?*
4. *What level of mathematics subjects (if any) are you planning to take in Years 11 and 12?*	4. *Has the Choose Maths Day influenced the level of maths you want to take in Years 11 and 12? If so, how?*
5. *What do you intend to study/train for after school and what career(s) are you interested in?*	5. *Did today's activities change your mind about the type of career you want to pursue?*
6. *What are your two favourite subjects at school?*	
7. *What do you hope to get out of attending the Choose Maths Day today?*	

The pair of questions (Q3 pre, Q2 post) allow us to compare each student's general enjoyment of mathematics with their enjoyment of the mathematics activities at the Choose Maths Day. Both questions ask students to rate their enjoyment of mathematics on a scale from 1 to 5, where 1 is "I don't like maths", 3 is "I sometimes like maths", and 5 is "I enjoy maths very much". A follow-up question on the post-survey asks explicitly whether the Choose Maths Day has caused the student to think positively about mathematics in a way they hadn't thought of before (Q3 post).

The next pair of matched questions (Q4 pre, Q4 post) concerns the student's subject selections in Year 11. The pre-survey asks the student to tick which level of mathematics they are planning to study in Years 11 and 12, choosing from Elementary, Intermediate and Advanced (using the corresponding names for those courses in each state), with an option for 'Undecided'. The post-survey contains a free text box where students are asked to write about whether the Choose Maths Day has influenced the level of mathematics they want to take in Years 11 and 12.

The final pair of matched questions (Q5 pre, Q5 post) concerns the student's intentions about careers. On the pre-survey is a free text box which asks the student what they intend to study/train for after school and what careers they are interested in. The post-survey contains a free text box asking whether the day's activities have changed their mind about the type of career they want to pursue.

The pre-survey asks students to name their two favourite school subjects (Q6). This will form a point of comparison between subjects they are engaged with at school and their choice of career path.

Finally, there are two questions which ask about the Choose Maths Day itself (Q7 pre, Q1 post). The pre-survey asks what the student hopes to get out of attending the event while the post-survey asks which activity or presentation they liked best. These are designed to help us improve the marketing and experiences of future Choose Maths Days.

5.3.1 Participation in Choose Maths Days and Surveys

A total of 532 students attended the university Choose Maths Days. Of these, 403 students returned surveys, which is 76 per cent of the total. Eleven of the surveys returned (2.7 per cent) were from boys; all other surveys were from girls. The university events were female-only, with the exception of the event at QUT.

Of the female surveys returned at the university events, 190 (48 per cent) were from Year 9 students, and 202 (52 per cent) were from Year 10 students. All of the university events had students from both year groups, apart from the event at Murdoch University, which was Year 10 only.

In total, 27 schools attended university Choose Maths Days in 2018. These were a mixture of government (21), private (1), Catholic (4) and selective (1) schools. Seven of the schools were girls-only and twenty were co-educational.

A total of 230 students attended the school Choose Maths Days. Of these, 116 students returned surveys, which is 50 per cent. However, 51 of these surveys (44 per cent) were from boys, with a further 8 of undisclosed gender (7 per cent), leaving 57 surveys from girls. These include 16 from students in Years 6-8, 13 from Year 9s, and 26 from Year 10s.

In this report we analyse the 392 surveys done by female students at university events.

5.4 Analysis of Survey Data

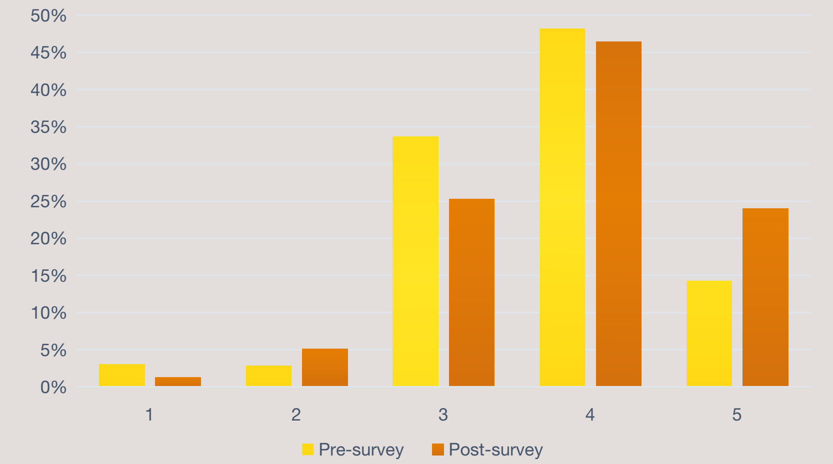
5.4.1 Enjoyment of Mathematics

One of the aims of the Choose Maths Days was to increase students' engagement with mathematics, by doing hands-on activities to show that mathematics is a subject which is interesting and important, emphasising team-work and problem solving. It is therefore instructive to compare the students' answer to Q3 on the pre-survey with their answer to Q2 on the post-survey. In these questions the students rated their enjoyment of mathematics on a scale of 1 to 5, with the options being (pre / post):

1. *I don't like maths / I did not like today's maths*
2. *I am not sure if I like maths / I am not sure if I liked today's maths*
3. *I sometimes like maths / I quite liked the maths*
4. *I enjoy maths / I enjoyed the maths*
5. *I enjoy maths very much / I enjoyed the maths very much*

In Figure 5.1 we compare the percentages of students in each response group. This graph shows us that the largest shifts are for option 3 – decreasing from 34 per cent to 25 per cent – and for answer 5 – increasing from 14 per cent to 24 per cent. Overall the proportion of students saying they "enjoyed mathematics" (answer 4) or "enjoyed mathematics very much" (answer 5) increased from 62 per cent to 70 per cent.

Figure 5.1 Student ratings of mathematics enjoyment pre- and post-survey



Note: *Data from pre-survey Q3 yellow and post-survey Q2 orange, with 1 low and 5 high.*

In Figure 5.2 we take a closer look at how the students' answers changed between the pre- and post-surveys. The darker the colour of the square, the higher the proportion of the students who chose that pair of answers. For example, 11 per cent of students chose 4 in the pre-survey and 5 in the post-survey (shown in row 2 and fourth percentage column). The grey cells give the total percentages for the rows and columns.

The largest positive shift was from those who chose 3 in the pre-survey: 43 per cent of these students changed to a 4 in the post-survey (14 per cent of all students) and 23 per cent changed from a 3 to a 5 in the post-survey (8 per cent of all students). Although the numbers are small, all of the students who chose 1 or 2 in the pre-survey increased their answer in the post-survey, with 87 per cent changing their choice to a 3 or more.

Figure 5.2 Pairings of pre- and post-survey mathematics enjoyment ratings

		3%	3%	33%	47%	14%	100%
Post-survey	5	1%	1%	8%	11%	3%	24%
	4	1%	1%	14%	23%	6%	46%
	3	0.5%	1%	9%	10%	4%	25%
	2	0.5%	0%	1.5%	2%	1%	5%
	1	0%	0%	0.4%	0%	0.5%	1%
		1	2	3	4	5	
		Pre-survey					

Note: *Data from pre-survey Q3 and post-survey Q2, with 1 low and 5 high. Darker squares indicate higher percentages. Grey cells at top of each column and end of each row give total percentages.*

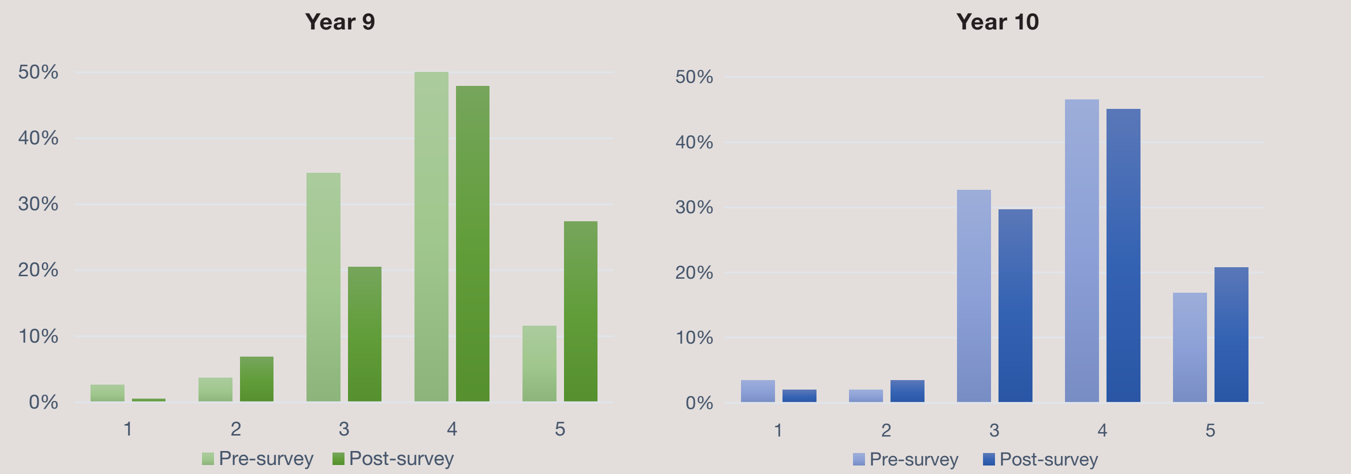
The 47 per cent of students who chose 4 in the pre-survey were equally likely to move down to a 3 or up to a 5, while just under half of the initial 5 voters dropped to a 4 in the post-survey.

From this analysis we see that the Choose Maths Days had the greatest positive effect on those who only sometimes enjoy mathematics. This is encouraging, as this is the demographic we most wish to target – those students who are considering taking *some* mathematics in Year 11 but who may not have the confidence or interest to do as high a level as they are capable.

Choose Maths Days had the strongest positive effect on students with lower enjoyment of mathematics

In Figure 5.3 we look at the breakdown of results by year group, with Year 9 in green (left) and Year 10 in blue (right). The change in opinion on mathematics enjoyment is more pronounced among the Year 9 students, who have the greatest increase in the number saying they "enjoy mathematics very much", from 11 per cent in the pre-survey to 27 per cent in the post-survey. By Year 10 it seems that student opinions about mathematics are more fixed, with positive change still possible but not to the same extent as the younger students.

Figure 5.3 Student ratings by year group of mathematics enjoyment pre- and post-survey



Note: *Data from pre-survey Q3 and post-survey Q2 separated by responses from Year 9 (green) and Year 10 (blue), with 1 low and 5 high.*

The conclusion that Year 9 students were more influenced in their views on mathematics than the Year 10 students is also borne out by Figure 5.4, which shows that the Year 9 students were more likely to select 'Very' or 'Extremely' than Year 10s, about whether the Choose Maths Day caused them to think more positively about mathematics. However, the results are encouraging for both year groups, with over 90 per cent in both cases saying that the event had given them a more positive view of mathematics than before.

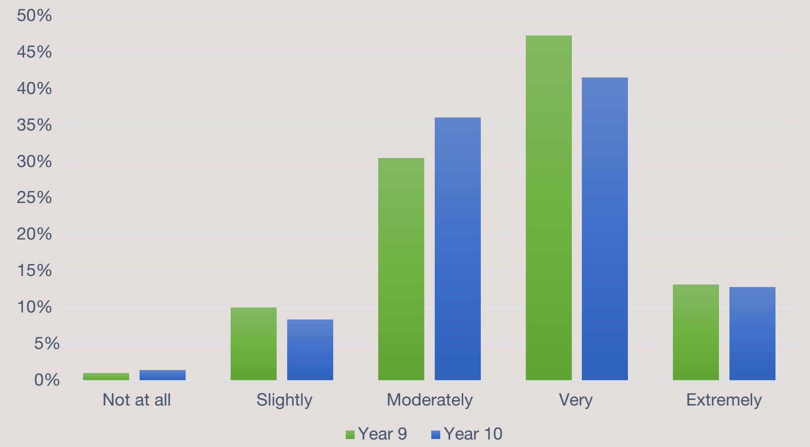
5.4.2 Year 11/12 Subject Selections

The main aim of Choose Maths Days is to encourage students to choose as high a level of mathematics in Year 11/12 as they are capable of and, where possible, to increase the level they are thinking of taking. Here we analyse responses to Q4 on the pre-survey and Q4 on the post-survey (see Table 5.2) to understand which subjects students were aspiring to take in Year 11/12 and whether the Choose Maths Days changed their opinion on this.

Figure 5.5 shows the percentages of students selecting each of the three categories of Year 11/12 mathematics in the pre-survey, as well as those who are undecided. The 'elementary' category contains those students expecting to take non-ATAR courses as well as the lowest level of ATAR mathematics. The names of the different courses in each state and their ascribed category can be found in Appendix 1 of the AMSI Gender Report 2017, see Li and Koch (2017).

Note that no student indicated that they did not want to do mathematics in Year 11. However, it is unclear among those who were undecided whether they were undecided about taking mathematics, or undecided about the level of mathematics. This ambiguity is something that will be addressed in the 2019 surveys.

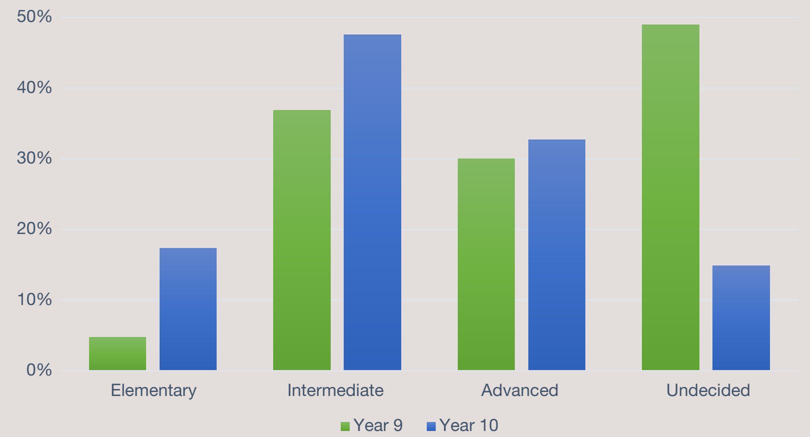
Figure 5.4 Student responses on whether the Choose Maths Day caused them to think more positively about mathematics



Note: *Data from post-survey Q3: "To what extent did the Choose Maths Day cause you to think positively about mathematics in a way you haven't thought about before?".*

Year 9 students' attitudes to mathematics can be more positively influenced than attitudes of Year 10 students

Figure 5.5 Expected mathematics subject choices in Year 11/12



Note: *Data from pre-survey Q4: "What level of mathematics subjects (if any) are you planning to take in Years 11 and 12?".*

There is a clear difference in the answers given by the Year 9 students and the Year 10 students. Namely, nearly half (49 per cent) of the Year 9 students are undecided about their subject selections, while only 14 per cent of Year 10 students are undecided. Of the students who have made a decision, the majority in both year groups is for the intermediate level of mathematics, followed by advanced, and then elementary.

Figure 5.5 shows us that the distribution of students attending the university Choose Maths Days differs from that of the general female population. Of the students in our cohort, 17 per cent expect to choose elementary mathematics and 32 per cent to choose advanced mathematics. In contrast, in the general population of Year 12 students, 53 per cent of girls chose elementary mathematics and 7 per cent chose advanced mathematics in 2016 (Li & Koch, 2017). Since Choose Maths Days are voluntary, those students already interested in mathematics are more likely to attend than those who are not planning to continue with mathematics.

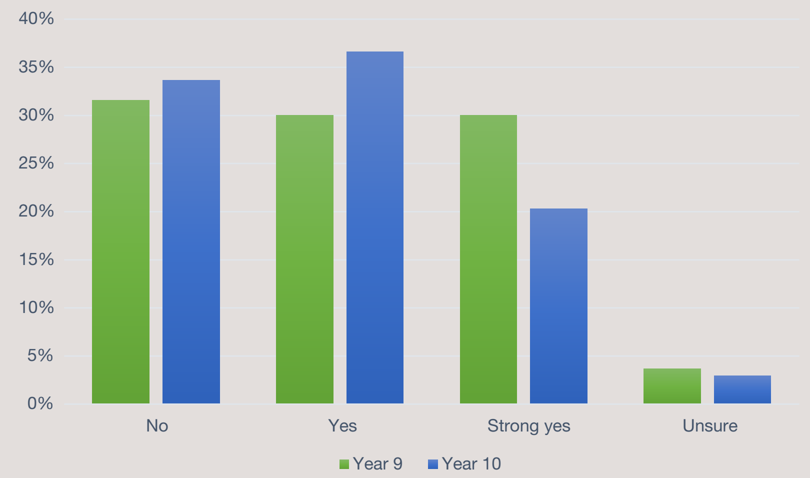
In the post-survey (Q4), students were asked whether the Choose Maths Day had influenced the level of mathematics they wanted to take in Year 11/12. The results are given in Figure 5.6 below. Here a 'strong yes' means that the student has indicated that they would now like to take a higher level of mathematics than the one they had suggested in the pre-survey. A 'yes' means that the student gave a positive response to the question but without being specific on the action they would take. (Some sample responses are given at the end of this section.) In total, 60 per cent of Year 9 students and 57 per cent of Year 10 students wrote 'yes' or 'strong yes' to this question, and about a third of each year group wrote 'no'. The Year 9 students were once again more positively influenced than the Year 10 students, as measured by the choices for the 'strong yes' category.

In Figure 5.7 we look at which students were most likely to be influenced by the Choose Maths Days, by comparing their answers about subject selection from the pre-survey with their answer about subject selection influence in the post-survey. Out of those students who chose 'yes' or 'strong yes' in the post-survey, the majority (99 students out of 267, or 37 per cent) were those who had said they would do intermediate mathematics, with a further 26 per cent coming from those who were undecided about subject selections in the pre-survey. This was more pronounced among the Year 9 students, where 39 per cent of the 'yes' and 'strong yes' choices were from students who were undecided.

A further encouraging result from these data is that 72 per cent of the students who said they wanted to do elementary mathematics indicated that the Choose Maths Day had influenced their subject selections ('yes' or 'strong yes').

Note that total numbers in Figure 5.7 are greater than the number of surveys, since students could choose more than one option in pre-survey Q4.

Figure 5.6 Student responses on whether the Choose Maths Day influenced the level of mathematics they wanted to take in Year 11/12



Note: *Data from post-survey Q4 with responses categorised by 'No' (negative response), 'Yes' (positive but vague response), 'Strong yes' (positive response indicating student will take a higher level of mathematics), and 'Unsure'.*

Figure 5.7 Numbers of student responses on whether the Choose Maths Day influenced subject selections, separated by their pre-survey expected level of Year 11/12 mathematics

Level (pre-survey)	No	Yes	Strong yes	Unsure	
	147	157	110	15	
Undecided	38	33	36	7	114
Advanced	42	44	26	3	115
Intermediate	57	63	36	4	160
Elementary	10	17	12	1	40

Influenced level of mathematics (post-survey)

Note: *Data from pairings of pre-survey Q4 and post-survey Q4. Darker cells indicate higher numbers. Grey cells at top of each column and end of each row give total numbers.*

Choose Maths Days are effective in changing students' thinking and plans regarding mathematics participation in Year 11 and 12: More than 25 per cent of students who attended are planning to take higher-level mathematics courses in Year 11 and Year 12 than originally planned

Comments by students who say they were influenced in their subject selection:

- *I found out maths was necessary for a lot of careers*
- *I want to challenge myself now*
- *I feel more confident in taking a higher level of maths, especially [after] hearing the presentations*
- *Now I know most people find maths a challenging subject*
- *I definitely want to take up maths because I have found out that it can open so many more doors than I thought*
- *I haven't decided what level of maths I would like to do but it encouraged me to give it a go*
- *It has made me want to try harder and achieve larger goals*
- *[I've realised] that maths isn't always boring*
- *Before today I was ok with accepting General maths, now I want to strive for Advanced*

5.4.3 STEM Careers

One of the ways that Choose Maths Days seek to influence students' opinions of mathematics is to showcase the range of careers that mathematics can lead to, with the message that the more mathematics we study, the more careers are open to us. This is done through specialised careers talks by Choose Maths outreach officers and by personal stories from people in industry and research who are using mathematics in their work. In this section we will look at the types of careers that students were initially interested in (pre-survey Q5) and the question of whether the Choose Maths Days influenced these ideas (post-survey Q5).

The answers to the pre-survey Q5 about careers were coded into two categories: STEM and non-STEM. We used the list of STEM degrees given in Appendix A of [4]. This includes traditional science subjects, mathematics, computing and engineering, as well as medicine, dentistry, forensic science, veterinary science and conservation science. Careers classified as non-STEM include architecture, physiotherapy, business and commerce, criminology, interior design, nursing, and trades such as electrician, mechanic or carpenter.

Figure 5.8 gives the results of the pre-survey Q5, separated by year group. Notice that percentages add up to slightly less than 100 per cent since there were missing responses. The 'both' column counts students who listed both STEM and Non-STEM careers. Students who listed more than one possible STEM career (e.g. medicine and engineering) were only listed once in the STEM column (and similarly for non-STEM).

Figure 5.8 Pre-survey career intentions of students

Note: *Data from pre-survey Q5: "What do you intend to study/train for after school and what career(s) are you interested in?". Reponses are classified as 'STEM' and 'Non-STEM' based on subjects listed in Appendix A of Australia's STEM Workforce: Science, Technology, Engineering and Mathematics (Office of the Chief Scientist, 2016). .*

About 51 per cent of the Year 9s and 45 per cent of the Year 10s named a STEM subject or career that they were interested in. The Year 9 students also seem slightly more open to a broad range of careers, with 21 per cent (compared with 17 per cent for the Year 10s) saying they were interested in both STEM and non-STEM careers. Around 10 per cent of students in both year groups were undecided.

It is interesting to look at the relationship between those students who named mathematics or science as a favourite subject, and those who are interested in STEM careers. In Figure 5.9 we look at the numbers of each, broken down by year group. Here 'Not-STEM' means that the student did not list a STEM career in the answer to Q5 on the pre-survey.

There is quite a change between the Year 9 and Year 10 students. More students in Year 10 consider mathematics or science to be a favourite subject than those in Year 9: 70 per cent compared with 60 per cent respectively. Out of those students who consider mathematics or science a favourite subject at school, 64 per cent of Year 9s but only 52 per cent of Year 10s are considering a STEM-based career. This is an interesting finding that would benefit from further research in order to address it before the students make their Year 11/12 subject selections.

Figure 5.9 Numbers of students choosing STEM careers compared with their favourite school subjects

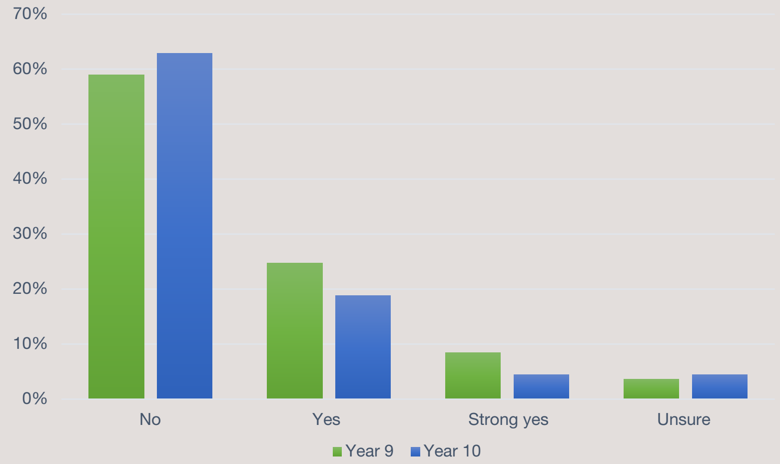
			Favourite subjects: Mathematics or Science	Favourite subjects: Not Mathematics or Science	
Year 9	Careers	Not-STEM	41	52	93
		STEM	74	23	97
			115	75	190
Year 10	Careers	Not-STEM	69	42	111
		STEM	76	15	91
			145	57	202

Note: *Data from pre-survey Q5 and Q6. Grey cells in each row and column give total numbers.*

It is perhaps heartening that even among those students who did not list mathematics or science as a favourite subject, 31 per cent of Year 9s and 26 per cent of Year 10s *are still considering careers in STEM.*

Figure 5.10 gives the results of the answers to post-survey Q5 about whether the Choose Maths Day had influenced their choice of career. (Specific comments are provided on the next page.) In total, 61 per cent said 'no', and 28 per cent said 'yes' or 'strong yes'. (Here, 'strong yes' means that the student indicated that they would now like to pursue a STEM career.) The Year 9 students were more positively influenced than the Year 10s (33 per cent compared with 23 per cent). One possible reason for this difference is that younger students have a less rigid view of their future and are more likely to be interested by a range of options. Coming into the event with a more open-minded view would make them more receptive to the messages of our speakers and workshop providers. However, further research is needed to explore this question.

Figure 5.10 Student responses on whether the Choose Maths Day influenced their choice of career



Note: *Data from post-survey Q5: "Did today's activities change your mind about the type of career you want to pursue?". Responses are categorised by 'No' (negative response), 'Yes' (positive but vague response), 'Strong yes' (positive response indicating student is now considering a STEM career), and 'Unsure'*

Comments by students who say they were influenced in their career choices:

- It made me think about pursuing a career more involving maths
- It made me consider doing a maths course in uni along with my other course (environmental science)
- It gave me ideas about alternative jobs I could do that I didn't already know about
- I will think of maths in a different light from now on when doing my maths homework or in maths class
- It has taught me that maths is required for the career I want to pursue
- I now feel that I have a wider range of options
- The activities today changed my mind about my selections, as I was thinking about going into an art-only-related career. It broadened my perspective
- I gained a lot of knowledge that can help me choosing the right career path

5.4.4 The Choose Maths Days

For the purposes of improving the format and content of Choose Maths Days, it is instructive to look at the answers to Q7 of the pre-survey, about what students hoped to get from the event, and Q1 of the post-survey, which asks what students liked most about the day.

The responses to Q7 of the pre-survey were divided into five main categories:

- Careers: responses regarding gaining information about career choices or about learning how mathematics is needed in different careers
- Y11 course info: responses indicating that the student wants help in making subject selections in Year 11
- Enjoy mathematics: responses indicating that the student enjoys mathematics and/or would like to learn more about mathematics
- Increase motivation for mathematics: responses indicating that the student is looking for motivation to continue with mathematics, to gain confidence in mathematics, or to develop strategies for improving at mathematics
- Day off: responses indicating that the student is only at the event as a way to take a day off school

There was also a general category of 'other', which included responses such as finding out more about courses at university, meeting other people who enjoyed mathematics, getting free food, and learning about the Choose Maths project. This category also included responses such as 'knowledge' and 'learning new skills'.

In Figure 5.11 we see that more than 40 per cent of students in both year groups chose 'careers' as their response. For the Year 10 students, increased motivation in mathematics was also a strong response (21 per cent).

Figure 5.12 shows the post-survey responses about what students enjoyed the most about the Choose Maths Days. (Percentages in this figure add up to more than 100 per cent since students were able to choose more than one option.) It is clear that the hands-on workshops/activities were the favourite part of the day for most students, with very little variation between the year groups. However, it is also worth noting that events typically included 3 or 4 workshops and 3 or 4 speakers, but only one Q&A, so we would expect fewer votes for this activity.

5.4.5 Variations between universities

Although the conclusions reached above are broadly similar between all the university Choose Maths Day events, there was some variation between the survey results for the different host venues.

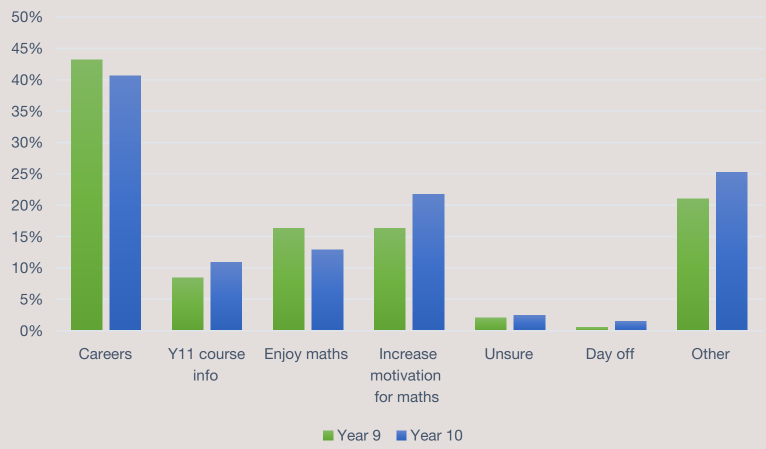
Mathematics enjoyment

Figure 5.13 shows averages for the pre-survey Q3 compared with the post-survey Q2, which ask for the students' level of enjoyment of mathematics. The orange line is the line of 'no change', so universities above the line had a positive effect on mathematics enjoyment and those below had a negative effect.

The university with the biggest impact on their attendees was A, whose average increased from 3.36 to 4.04 (+0.69). University E also had a strong positive effect, going from 3.62 to 4.11 (+0.49). These were also the two universities that started with the lowest levels of reported mathematics enjoyment. University F event started with the strongest reported mathematics engagement (4.19) but this was not changed by the Choose Maths Day.

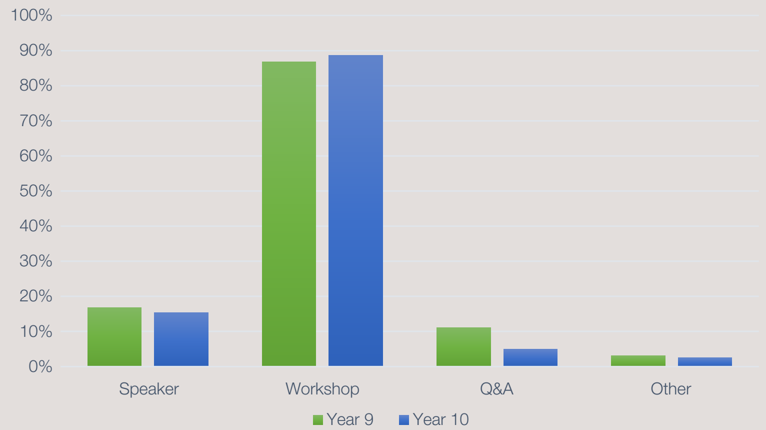
It is surprising that students at event A had such a low average in their pre-survey reported mathematics enjoyment, since they had the

Figure 5.11 Reasons given for students attending Choose Maths Days



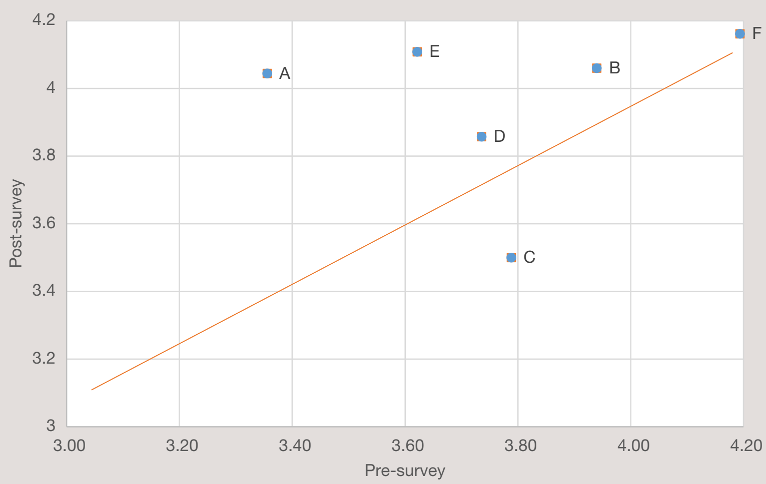
Note: *Data from pre-survey Q7: "What do you hope to get out of attending the Choose Maths Day today?".*

Figure 5.12 Students' favourite elements of Choose Maths Days



Note: *Data from post-survey Q1: "Which activity or presentation did you like best?".*

Figure 5.13 Comparison of pre- and post-survey mean scores for mathematics enjoyment for each university event



Note: *Data from pre-survey Q3 and post-survey Q2, separated by the six university events. These have been anonymised and given letters A-F.*

highest percentage of students reporting mathematics as a favourite subject (64 per cent; the next best was event D with 50 per cent). University E had the lowest percentage of students with mathematics as a favourite subject, with 31 per cent.

Year 11/12 subject selections

In Figure 5.14 we compare answers to Q4 (pre and post) about subject selections in Year 11/12 across the different events.

Despite event C seeming to have a negative effect on mathematics enjoyment among attendees (from Figure 5.13), they were the university with the strongest reported positive effect on students' Year 11/12 subject selections, with 65 per cent of students saying 'yes' or 'strong yes' to Q4 on the post-survey. Students at event D were also enthusiastic about taking a higher level of mathematics in Year 11/12 (64 per cent), but their pre-survey answers showed that most were already planning on choosing the highest level of mathematics in Year 11/12.

The results from event A are interesting: almost none of the students considered advanced mathematics. Out of those event A students thinking of taking elementary mathematics, 56 per cent of them say that they were influenced by the event, compared with 42 per cent overall.

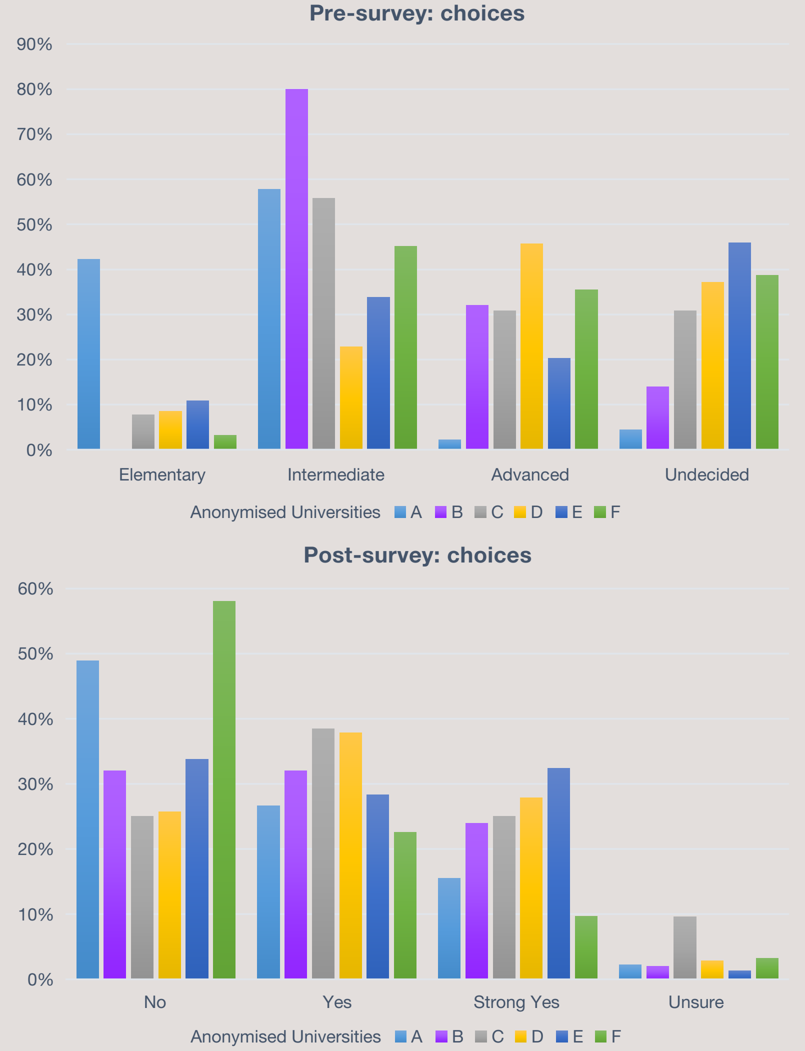
Out of all the universities, the event A students are those with the highest percentage saying the event had an 'extremely high' effect on how positively they thought about mathematics (post-survey Q3).

The analysis in the last two sections show that the different metrics for assessing the success of the day are largely independent. Students may enjoy the mathematics presented and yet not be swayed in their subject selections, and vice versa. They may consider mathematics their favourite subject and yet have low aspirations for the level of mathematics they wish to do in Year 11. It is therefore important to consider answers to all the pre- and post-survey questions in order to measure the success of any given event.

Careers

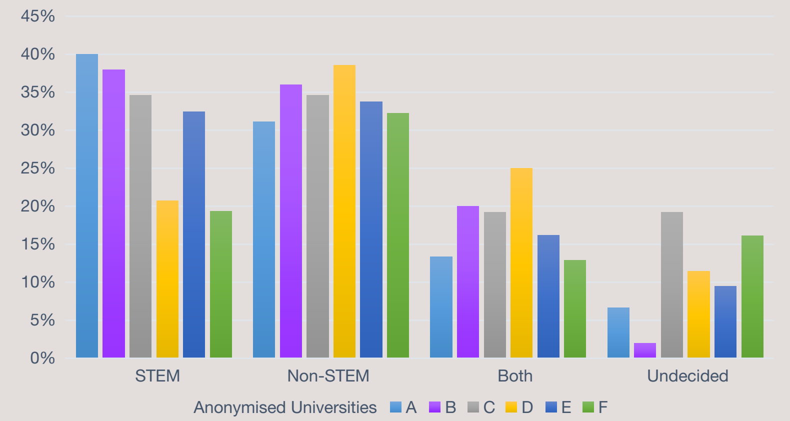
In Figure 5.15 we see that most universities recorded broadly similar percentages of students interested in STEM and non-STEM careers, with two notable exceptions. The events at universities D and F had the lowest

Figure 5.14 Expected mathematics subject choices in Year 11/12 and responses about whether the Choose Maths Day has influenced this, separated by each university event



Note: from pre-survey Q4 and post-survey Q4, separated by the six university events A-F. A response of 'strong yes' in the post-survey indicates that the student will now choose a higher-level mathematics subject in Year 11/12 than they initially expected.

Figure 5.15 Pre-survey career intentions of students, separated by each university event



***Note:** Data from pre-survey Q5, separated by the six university events A-F.*

proportions of students saying they were interested in STEM degrees and/or careers. It is interesting to contrast this with the pre-survey data for subject selections (Figure 5.14), where universities D and F were the two events with the highest recorded percentages of students saying they wanted to take advanced mathematics in Year 11/12. It is important to find out why students are choosing the highest levels of mathematics in high school if they are not interested in STEM-based careers after school.

5.5 Summary and Recommendations

Choose Maths Days are events which very positively influence students' perceptions and enjoyment of mathematics, and their aspirations for choosing mathematics in Years 11 and 12. The analysis of this survey data shows that the events are more beneficial for some categories of students than others. We will use our analysis to make recommendations for future Choose Maths Days and for further potential research into the attitudes of female attitudes towards mathematics in school.

5.5.1 The Target Audience for Choose Maths Days

In 2018 the Choose Maths Days were targeted equally at Years 9 and 10, with a view to the current Year 9 students potentially being able to attend two such events before their subject selections towards the end of Year 10. Although Choose Maths Days had a positive effect on both year groups – both in terms of improving enjoyment of mathematics and in influencing subject selections – the Year 9 students were more influenced in both aspects. Where there is a question of deciding who to invite for future events, therefore, we suggest Year 9 students should be prioritised over Year 10s.

The Choose Maths Days had a greater positive effect on those students who began the day with a low-to-medium level of mathematics engagement, and with those with lower aspirations for their level of Year 11 mathematics. When marketing the event to schools in the future, emphasis should be put on inviting those students who are less engaged with mathematics but who have the potential to engage and achieve, and/or those who are planning to select an elementary level of mathematics in Year 11.

We intend to increase the number of events in 2019, including holding more events in regional and rural schools to complement those held in cities at universities. Events held in schools are more likely to include a broad range of students and to include those who are not already interested in mathematical study or STEM careers.

5.5.2 Changes to the Choose Maths Day Format

The university Choose Maths Days in 2018 apparently did not have a very strong influence on students' career choices. It is important to assess how we can improve the Choose Maths Days for 2019 in this respect.

It would be instructive to look at the selection of careers suggested by the students, inviting speakers who can talk about the most common non-STEM ones and the ways that mathematics is needed for them. For example:

- Art and design careers, such as architecture, interior design, game design, and fashion design
- Medical and veterinary sciences and caring professions, such as optometry, nursing, physiotherapy, midwifery, dermatology, and paramedics
- Law-related careers, such as criminology, forensic science, barrister;
- Finance and business careers

While mathematics and science were the most common 'favourite subjects' of the attending students (across both year groups), the students also named art, English and sport as common favourites. This should be taken into account when designing workshops, showing not only that mathematics is interesting and important, but also how it can be embedded within other disciplines. This would help to emphasise the message that students do not need to label themselves as either a 'mathematics person' or a 'humanities person', but that mathematics is an important skill no matter the choice of career.

The survey responses will inform changes to the survey design in 2019 in order to capture ambiguities and to decrease missing responses.

5.5.3 Proposals for Further Research

The analysis of the responses at the different universities has revealed some interesting results which would benefit from further surveys and analysis. For example, at event A, the pre-surveys showed that the students had simultaneously the highest proportion of those who listed mathematics as a favourite subject, the lowest average enjoyment of mathematics and the lowest proportion of those considering taking advanced mathematics in Year 11. What does it mean for a student to list a subject as their favourite, and what relationship does this have towards their plans for further study and careers after school?

The other interesting anomaly in the university data was that the two events where the students had the highest aspirations in their Year 11 mathematics level were also the two events where the students were least likely to want to go into STEM careers. We recommend further research into the reasons behind students' subject selections in Year 11 in order to investigate this finding.

References

Collins, J and Koch, I. (2018). *AMSI Choose Maths Research No 3.* Melbourne, Vic.: Australian Mathematical Sciences Institute

Koch, I. and Li, N (2017). *AMSI Choose Maths Research No 1*. Melbourne, Vic.: Australian Mathematical Sciences Institute

Li, N. and Koch, I. (2017). *AMSI Choose Maths Research No 2*. Melbourne, Vic.: Australian Mathematical Sciences Institute

Office of the Chief Scientist (2016). *Australia's STEM Workforce: Science, Technology, Engineering and Mathematics,* Australian Government.

6 Conclusions and Recommendations

The under-representation of girls and women in the more advanced mathematics courses in senior secondary school, in university degree programs that require mathematics and in mathematics-related careers is of concern for economic and gender-equity reasons. To meet industry demand for highly capable graduates with adequate mathematics and STEM skills in Australia, collaboration and partnerships between education institutions, government and industry are necessary.

Analysis of PISA data shows that the mathematics performance of boys and girls has decreased over the last 15 years, while maths anxiety of these students increased over the same period. Maths anxiety is known to be an impediment to achievement, and its increase is therefore of real concern. Girls are more affected by maths anxiety than boys, and the gender gap in maths anxiety and in students' confidence in their mathematical abilities is much larger than that in performance.

It is possible that the higher incidence and higher level of maths anxiety and the lower confidence of girls is a major cause which leads to the under-representation of girls and women in senior school mathematics and beyond. Reducing maths anxiety, increasing confidence and improving students' attitudes towards mathematics is urgent, since:

- Maths anxiety starts early in primary school and increases through the primary school years and into secondary school
- Maths anxiety has increased in school students over time
- Maths anxiety has a measurable effect on directing brain activity away from regions involved in mathematical reasoning, and thereby resulting in a 'performance deficit' and lower achievement
- Maths anxiety is an impediment to students' achievements relative to their abilities
- Maths anxiety of parents and teachers encourages traditional gender stereotypes and contributes to students' negative attitudes about mathematics
- Maths anxiety and low confidence reinforce each other and impact negatively on performance, which, in turn, increases maths anxiety and decreases confidence

Recent research on twins and maths anxiety has shown that environmental non-genetic factors contribute more to the development of maths anxiety than genetic risk factors. These findings suggest that maths anxiety can be reduced through the design and use of appropriate methods and strategies.

Policy makers and curriculum designers need to understand the recent advances in maths anxiety research. They also need to be aware of the increase in maths anxiety in students, and, in particular, in girls, and its negative effect on students' beliefs and performance. These facts require urgent actions to be taken such as forming partnerships of different stakeholders to design and implement strategies and programs which stop the increase of maths anxiety and reduce it and its negative effects on performance.

Crucial for the success of partnerships to combat maths anxiety is that they focus on maths anxiety in pre- and in-service teachers as well as students. To reduce maths anxiety in pre-service teachers, a solid knowledge of mathematics and effective mathematics teaching methods need to be integrated with strategies which enable pre-service teachers to reduce their own as well as their students' maths anxiety and simultaneously increase their own and their students' confidence. Unless pre-service teachers receive adequate training and knowledge in these areas, their own maths anxiety and potentially low confidence can undermine their teaching and impact negatively on students' enjoyment of, engagement with and performance in mathematics.

Changes in attitude and improvements in confidence and skill level are possible, as evidenced in the Choose Maths teacher and student survey data which show that the following can be achieved with well-designed programs:

- Improving teachers' mathematical skill base and reducing their maths anxieties through strategic Choose Maths Schools Outreach
- Increasing students', and particularly girls' confidence in their abilities and impacting on their attitudes towards and engagement in mathematics through appropriate intervention
- Increasing students' and particularly girls' interest and engagement in mathematics and careers requiring mathematics through targeted mentoring sessions and well-structured Choose Maths Days

Networking and stakeholder liaison at different levels are required to bring about and foster change and improvements. Events such as AMSI's Choose Maths workshop: *Mathematics, Gender and Mathematics Education* in June 2018 enable the communication, exchange and integration of ideas and research findings from psychology, mathematics education, statistics and educational practice while aiming towards informing policy development, teacher education and teaching practice. Outcomes of such workshops provide insight and directions to pursue for partnerships between education institutions, government and industry.

We conclude with recommendations for students, teachers and parents based on the findings in this report.

Supporting our Students

Strengthen students' beliefs in their mathematical abilities and increase their enjoyment of mathematics through:

- Improving access to learning resources with a focus on aptitude and engagement to decrease maths anxiety
- Increasing access to positive role models
- Disconfirming traditional gender stereotypes and strengthening girls' interest in STEM through career awareness
- Increasing access to Choose Maths Days and Choose Maths Mentoring, particularly for girls, to increase students' confidence and interest in mathematics

By providing students, and in particular girls, with good access to these support measures, there is an expectation and growing evidence that students' fear and avoidance of mathematical tasks and challenges, and hence also their maths anxiety, will be reduced. Such a reduction in maths anxiety may lead to students engaging more with mathematics and deciding to participate longer in the learning of mathematics.

Supporting our Teachers

Support pre-service and in-service teachers by:

- Ensuring pre-service teachers can gain a solid knowledge of mathematics and access to effective teaching methods and practices to meet students' needs
- Providing all teachers with better information about the effects of maths anxiety, stereotype threat and low self-confidence on student achievement
- Increasing access to information and strategies to support teachers in reducing their own maths anxiety and that of their students
- Providing common training to primary and secondary pre-service and in-service teachers to support transition of their students from primary to secondary school
- Improving access to positive reappraisal and growth mindset resources to support mathematics learning, and to increase the enjoyment and engagement of students

For these support measures to become effective and to result in more knowledgeable and more engaging mathematics teachers, it is crucial that pre-service and in-service teachers have good and regular access to support, to new research and to research-based teaching strategies.

Providing more common training for primary and secondary teachers across the transition period from primary to secondary school will have the added effect of reducing maths anxiety and increasing the confidence of students at this critical step.

Measures for teachers could include access to further education in mathematics or mathematics education or teaching, as additional training and education has proved to be effective in improving knowledge and simultaneously decreasing maths anxiety and increasing confidence of teachers.

Supporting our Parents

Promote parents supporting their children in learning mathematics by

- Providing better information regarding the effect of maths anxiety, traditional gender stereotypes and low self-confidence on student achievement, especially for girls
- Contributing to positive home learning environments through the development of resources to support parents in fostering positive appraisal and growth mindset learning
- Encouraging stronger communication between teachers and parents to affect change in attitude and behaviour towards mathematics
- Empowering parents to support learning through access to mathematical activities that encourage engagement and interest of their children in mathematics

Parents form a vital part in the education of their children and contribute to their subject selection in Year 10 and their career choices. Parents' understanding of the effect of positive appraisal, of non-traditional role models and their attitude towards mathematics are crucial in the home learning environment. Improving such understanding and developing stronger links with teachers and other parents will impact on their children's attitudes and behaviour towards mathematics.

List of Figures

List of Tables

AMSI Mission

The radical improvement of mathematical sciences capacity and capability in the Australian community by:

- supporting high-quality mathematics education for all young Australians
- improving the supply of mathematically well-prepared students entering tertiary education by direct involvement with schools
- supporting mathematical sciences research and its applications including cross-disciplinary areas and the public and private sectors
- enhancing the undergraduate and postgraduate experience of students in the mathematical sciences and related disciplines

CHOOSE
MATHS

AN **AMSI** SCHOOLS PROJECT

DELIVERED BY AMSI

SUPPORTED BY BHP Foundation

ISBN: 978-0-7340-5555-2 (PRINT)
ISBN: 978-0-7340-5556-9 (DIGITAL)

AMSI.ORG.AU
t: +61 3 8344 1777
e: enquiries@amsi.org.au
Australian Mathematical Sciences Institute
Building 161, c/- The University of Melbourne
Victoria 3010 Australia