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Maths Anxiety

Students, Pre- and In-Service Teachers

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Executive Summary

The under-representation of young women in advanced mathematics courses in school, in university mathematics degree programs and in mathematics-related careers in many western countries is of concern for economic and gender-equity reasons. Effective strategies for increasing engagement and participation of girls and young women in mathematics and STEM require an understanding of the forces and factors contributing to the current disengagement. Potential causes include maths anxiety and low confidence in one's mathematical abilities.

The partnership between the Australian Mathematical Sciences Institute and the BHP Foundation, which began in 2015, is aiming to increase participation of girls and young women across Science, Technology, Engineering and Mathematics (STEM) through the Choose Maths project in a multilevel approach.

Maths anxiety, which starts in early primary school, has been shown to be an impediment to achievement, and female primary teachers with maths anxiety are likely 'causes' affecting behaviour and attitudes especially of female primary students. Though no evidence exists of a gender gap in mathematical ability, gender disparity in mathematics performance is evident from early primary school, and the gender gap in self-confidence and maths anxiety develop around the same time and are accompanied by a decrease in positive attitudes and engagement in mathematics of girls.

This report reviews and examines likely causes of the lower interest, participation and achievement of girls and young women in mathematics: maths anxiety and lower confidence in the mathematical abilities of female students and primary teachers. The report includes approaches that have been employed in addressing maths anxiety in students and pre-service teachers. The main findings are:

- Maths anxiety affects brain activity, and results in a 'performance deficit' which can lead to achievements below actual abilities (Section 2);
- Girls are more maths anxious and less confident in their mathematical ability than boys although there is no evidence of a gender difference in mathematical ability (Section 4.3);
- 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 3.4);

- Environmental non-genetic factors contribute more to the development of maths anxiety than genetic risk factors (Section 3.1);
- Teachers are one of the most influential factors impacting on student achievements (Section 3.5);
- Higher levels of maths anxiety in teachers are related to lower mathematics achievements of their students (Section 3.5);
- Teachers with more knowledge of mathematics are more confident and less anxious in their teaching practices and better able to encourage mathematical learning (Section 6);
- Pre-service teachers require solid knowledge of mathematics, good teaching practices and methods for reducing maths anxiety (Section 5.4).

An analysis of survey data from primary teachers in Australia's Choose Maths schools shows evidence of maths anxiety and perceived inadequate pre-service training among primary teachers, as well as evidence that change in improving teachers' mathematical skill base and reducing their maths anxiety is possible through suitable intervention.

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

Contents

1 Introduction

For more than 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% 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 body of knowledge and research findings relating to evidence of the effect of maths anxiety on teachers and students are causes for concern.

Women and young girls are more often and more severely 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 percent 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, reviews and reports have dealt with the phenomenon of maths anxiety, 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 complement the literature with findings from the analyses of Australian teacher and student survey data we collected in 90 Choose Maths primary schools in 2017, and
C. to make recommendations for addressing maths anxiety of teachers, teacher education and degree programs, students and their parents within the Australian framework.

Maths anxiety starts in at the primary school level but its effects carry over into secondary school. At the secondary school level, the percentage of out-of-field mathematics teachers is of serious concern; see Koch and Li (2017) and Prince and O'Connor (2018) and references therein. The lack of adequately qualified mathematics teachers especially during Years 7 to 10 has a potential negative impact on students with maths anxiety and low confidences as well as potentially affecting students' subject selection choice for mathematics in Year 11 and 12.

In line with the aims of the Choose Maths program of the Australian Mathematical Sciences Institute, namely to increase participation of girls and young women in mathematics and mathematics-related areas, our interest and goals will focus on addressing and reducing maths anxiety in female students and teachers. Reducing maths anxiety in teachers and in particular in female students will have the potential of increasing students' confidence in their abilities, their interest and hence also their engagement with mathematics. We provide an outline of the Choose Maths project at the beginning of Section 6. For more details see Koch and Li (2017) and Koch (2019).

For the reader's convenience we summarise relevant terms in the way we use them in this report, as they are not always uniquely defined or used in the literature. Unless otherwise stated we will use these terms in the context of mathematics and mathematics education. The term maths anxiety is defined at the beginning of Section 2.

- ***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 synonymous 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. Often used as synonym for an individual's ability.
- ***Aptitude*** refers to an individual's potential and innate ability to acquire knowledge and skills.

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.

In 1957 the term 'number anxiety' was coined, but in the following decades it has been replaced by the term 'maths anxiety'. Different definitions of maths anxiety have emerged and have variously been in use 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 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. In this report we use Hembree's definition which is well established and general enough to cover the spectrum of maths anxiety ranging from feeling of uneasiness to very severe cases.

Maths anxiety presents in different ways which have been characterised by fear and avoidance of mathematics as shown in the diagram in Figure 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 or challenge. The level of anxiety or fear can range from a feeling of not being comfortable to paralysing fear in the worst case. 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.

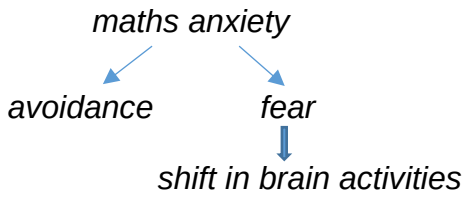


Figure 1: Expressions of maths anxiety

Maloney and Beilock (2012) report that maths anxiety affects a person's cognitive resources. Their hypothesis is supported by research in neuroscience and functional magnetic resonance imaging (fMRI). This research demonstrates 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 away from the mathematical reasoning regions and into the regions that deal with negative emotions appears to be specific to maths anxiety. In their study of 7 to 9-year old children regarding general anxiety, Young et al did not observe this shift. Lyons and Beilock (2011) found similar results for adults, again based on fMRI data.

The findings of Young et al (2012) show that 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 notion 'working memory resources' has been adopted in the context of maths anxiety 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 '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. Based on a study of 900 participants from 9 to 22 years, the researchers found that there is some evidence that male brains show more connectivity within lobes of the brain and within each hemisphere, while female brains show more connectivity between the hemispheres, see Buckley (2016) and references therein. These findings have been questioned by other researchers, and more research is required to arrive at valid and repeatable conclusions. 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. The presence of maths anxiety in an individual is expressed in their fears and emotions which

- negatively impact on their brain activities and reduce activities in regions related to mathematics; and
- lead to avoidance of mathematical activities and increase fear.

As a consequence, by avoiding mathematical challenges or learning new 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.

3 Developing Maths Anxiety

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 and reaches a peak around Years 9 or 10, then plateaus out but 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).

Some researchers argue that maths anxiety in young children arises from difficulties in numerical or spatial processing with 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 the way they appraise, perceive and interpret previous mathematical experiences and outcomes, teachers and themselves. Ramirez et al refer to this approach as 'interpretational account'. The ideas are founded on appraisal theory and integrate emotional outcomes and attitudes based on interpretation of events. 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. Renewed interest in appraisal theory and its potential for directing appraisal in a positive-adaptive way could lead to overcoming the negative responses associated with maths anxiety.

In an empirical study on 514 twins aged 12, Wang et al (2014) found that maths anxiety develops as a combination of nature and nurture: genetic risk factors contribute about 40% 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% contribution from non-genetic factors suggests that large reductions in maths anxiety can be achieved through appropriate methods which should start in the early school years.

Maths anxiety is most commonly identified through self-reporting surveys or questionnaires in which individuals 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.

3.2 Parental influences on maths anxiety

Children of parents with high levels of maths anxiety who frequently help their children with mathematics homework become more maths anxious and learn less mathematics compared to their peers whose parents are either maths anxious but do not help with mathematics homework or who are less maths anxious. The findings suggest that during those homework-helping situations, high 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) and references therein.

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 point of view of mathematics as 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.

3.3 Developmental trajectory of maths anxiety

Teachers' and parents' attitudes towards mathematics – whether positive or negative -- influence young students' behaviour and attitudes and lay the foundation for later behaviour.

The increase in maths anxiety with increasing age is typically accompanied by a decrease in positive attitude towards mathematics. Factors that contribute to an increase in maths anxiety include negative attitudes of teachers, parents and other students, social and gender stereotypes, low self-esteem, difficulty in doing and learning mathematics and 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 and Beilock, 2016).

Some researchers suggest 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). The findings of different research groups do not always agree on this issue as Dowker et al (2016) discuss in their review of 60 years of maths anxiety, indicating that more research is required to gain better insight into the causes and the transmission of maths anxiety.

Two time periods are special with regard to the development and increase in maths anxiety:

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

We consider both here.

In a study of elementary teachers and their students in the US, 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 produces maths anxiety in their female students; rather, as shown in the diagram in Figure 2, maths anxiety of teachers encourages and endorses traditional

gender stereotypes in their young female students (Maloney, 2019). This endorsement of gender stereotypes impacts on girls' achievements, and a lower achievement typically impacts on and increases maths anxiety.

The findings of Beilock et al (2010) are based on 17 elementary teachers, 52 boys and 65 girls in their elementary classes. Their study leads the way in examining how maths anxiety of female teachers is passed on to female students and it provides important insight, though based on a moderate sample of teachers and students. It would be valuable to confirm and reproduce the findings on a larger scale and in different locations including Australia.

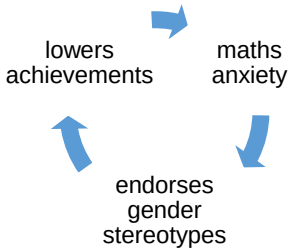


Figure 2: Passing on and increasing maths anxiety

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

Regarding the transition from primary to secondary school, O'Keeffe et al (2018) focus on this period as it is a time when students are particularly vulnerable (Hanewald, 2013; Maguire and Yu, 2015). The student surveys of O'Keeffe et al 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).

O'Keeffe et al (2018) collected online surveys of 618 Year 7 and 622 Year 8 students in South Australia yielding a 70% response rate. The surveys are based on 13 items relating to mathematical self-efficacy, self-concept and maths anxiety. Although the survey are similar for the two year, some questions differ for primary and secondary students. Their findings include that

- the belief in their mathematical capabilities has decreased at a similar rate for boys and girls from Year 7 to Year 8;
- female Year 7 and Year 8 students are more likely to find mathematics difficult than the boys;
- the greatest difference between boys and girls is 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 with students aged around 11 or 12. In South Australia students attend primary school until the end of Year 7. This discrepancy in the transition in South Australia and the other Australian states is not likely to affect the results of O'Keeffe et al (2018) in any material way, however it would be of value to conduct surveys similar to theirs for Year 6 and Year 7 students in other states and compare the results.

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. Li (2019) describes the survey instruments she developed for Choose Maths in order to determine the motivation and factors that govern students' subject choices and to establish whether the factors are the same for boys and girls. Better insight into the factors that influence students' subject selection for Years 11 and 12 will allow us to develop methods that address the lack of engagement and participation of girls in higher levels of mathematics.

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. Five of the questions related to maths anxiety and their findings 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 similarly 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 PISA index of maths anxiety, based on standardised student responses, allows comparisons between different cohorts.

The analysis also shows that

- Australian female students reported a level of intrinsic motivation to learn mathematics that was below the OECD average;
- Australian and New Zealand students have the largest gender gap in the maths anxiety index among comparable OECD countries; and
- Male students tended to believe that they were more competent in mathematics than female students.

In Australia the largest gap of the index – of size 0.34 – occurs between boys and girls, and this gap is almost twice as large as the next largest gap of the index 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 percentage 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% 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 shows that the higher maths anxiety of girls that O'Keeffe et al (2018) observed for Year 7 and 8 students persisted in the 15-year old cohort. Another factor that influences students' beliefs of their competency includes the degree of control students feel they have over their ability, performance and future career choices and directions.

3.5 From pre-service education to in-service teaching

At the beginning of Section 3.1 we noted that 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. A proportion of primary teachers in Choose Maths schools have not been exposed to or trained in mathematics content or teaching methodology according to their responses in the teacher surveys conducted by the Australian Council for Educational Research (ACER) for Choose Maths in 2017. 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% 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 6 and Table 1 provide details.

Consistent with the general population, female students majoring in primary education exhibit a higher level of maths anxiety than their male fellow students, 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 will 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 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 affect their mathematics teaching and student learning. Such teachers are not likely to enjoy teaching mathematics. Their maths anxiety, lack of confidence and inadequate preparation and training during their 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 mathematics, to improve their factual knowledge, their enjoyment of mathematics and 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 of their students. Their findings are similar to those of Beilock et al (2010) who considered second grade students -- see Section 3.3. Unlike Beilock et al who made the link to lower performance via stereotype threat, this more recent study of older students focusses on students' perception of a teacher's integration of growth mindset ideas (Boaler, 2015) – or lack thereof -- and the relationship with mathematics performance.

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 pre-service teachers with solid knowledge of mathematics, good teaching practices on teaching mathematics and how to influence student learning. Current and future teachers 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 available for in-service teachers on a regular basis and needs to include access to more mathematical knowledge through professional development or appropriate further qualifications.

Studies in the US have shown that among pre-service primary teachers in a first mathematics content course maths anxiety decreases during the semester and simultaneously there is a decrease in the accuracy of the students' self-assessed mark compared to the 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 reduction in maths anxiety of their pre-service teachers 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.

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 in 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 that 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 may indicate that a change in perception regarding mathematics and gender occurred over the 20-30 years to 2004. It would be interesting to repeat these surveys in order to determine whether the differences in beliefs have decreased since 2004.

Dowker et al (2016) review a range of publications with 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 while others including Beilock et al (2010) observe that maths anxiety exhibited by young female students is fostered by the teachers' gender beliefs and anxieties regarding mathematics and 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 and 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. 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 gender 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.

4 Maths Anxiety, Confidence, Performance and Capability

In this section we review relationships between maths anxiety, stereotype threat, confidence constructs such as self-concept and self-efficacy, attitude, performance, achievement and capability. A literature search shows that these terms are not always defined or used in the same way by different researchers. The summary at the end of Section 1 gives the definitions we will be using here.

We will typically only distinguish between confidence, self-confidence, self-efficacy and self-concept when research has shown different relationships of these constructs with other maths anxiety related concepts. In a seminal paper Bandura (1986) defines and discusses the different confidence-related terms and includes subtle distinctions between different terms. Since its publication, the work has been cited more than 75000 times. For more recent accounts of confidence-related ideas we refer the reader to Pajares and Miller (1994) and Bong and Skaalvik (2003).

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. In Section 3.2 we looked at the negative influence on children of maths anxious parents. 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 3.3 relates findings of Beilock et al (2010) that maths anxiety in parents and teachers may not directly cause maths anxiety in children but that the path leads 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 and can result in avoidance and a growing fear of

mathematics. As we have seen in Section 2, fear and avoidance of mathematics 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 which question the evidence of

- the relationship between maths anxiety and stereotype threat; and
- 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 which repeats and extends the respective studies. However, meanwhile 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, its effect in school students of different ages and on their performance. Their findings point to inconsistencies in the effect of stereotype threat on girls' mathematical performance and the clear need for more research.

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.

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 gender confidence gap widens at a time when maths anxiety begins to develop. Self-concept and self-efficacy are closely linked with maths anxiety, and it is often not possible to determine which comes first – 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. It seems undisputed that low confidence and maths anxiety negatively impact each other (Dowker et al, 2016) and both affect students' enjoyment of mathematics negatively.

Poor or low self-concept of one's own 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 abilities 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 does not only affect students but applies equally to pre-service and to in-service teachers. Because of the effect female primary teachers have on female students and the negative impact arising from teachers' negative attitudes, gender stereotypes or teaching practices, it is vital that maths anxiety and confidence building are addressed repeatedly during the pre-service training of teachers and in school children from early primary school onwards.

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. The level of self-efficacy influences the effort the individual expends and the level of perseverance in the face of challenge. Further, 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.

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. Devine et al quote some authors who claim that mathematical performance is the highest single contribution to children's maths anxiety.

Figure 2 shows the spiral of maths anxiety, stereotype threat and lower performance. Not included in this figure is the powerful effect 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 discussed in Section 2 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.

Reports offer conflicting opinions regarding gender differences in mathematical performance and achievement. Unlike the results of Devine et al (2012), which we described at the beginning of this section, 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. Identifying and understanding maths anxiety as well as finding ways to reduce and avoid maths anxiety are therefore crucial for successful mathematics learning.

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.

5 Addressing and Remediating Maths Anxiety

In this section we consider different aspects and beliefs that are related to maths anxiety and consider approaches or methods that have proved to be valuable in alleviating or remediating specific phenomena. These are detailed in the next few paragraphs.

At present there are no known interventions which prevent the onset of maths anxiety.

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 and those children are most likely to develop maths anxiety (Maloney and Beilock, 2012). A focus on improving basic numerical or mathematical skills of young students could strengthen students' beliefs in their own abilities at an early age before they lose 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 evidences by fMRI scans, see Ramirez et al (2018) and references therein.

Presenting mathematical problems in 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 rule-focussed 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.

Some researchers successfully use expressive writing as a form of interventions. See Maloney (2019). For secondary students who are advanced enough to write essays, such interventions can provide an opportunity to re-think their 'narrative' and appraisal processes and to learn to adopt a 'failure-as-enhancing' mindset rather than a 'failure-as-debilitating' mindset. The effect of such interventions can be enhanced by teachers and students adopting the growth mindset approach of Boaler (2015) which values making mistakes and learning from mistakes by reappraising mistakes and failure.

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 avoidance of mathematics and to increase the engagement of their children as well as growth mindset ideas. The latter build on the importance of learning from mistakes, by treating mistakes as enhancing the understanding rather than regarding mistakes as failure which can lead to a debilitating mindset (Boaler, 2015).

5.2 Approaches to dealing with stereotype threat

Maths anxiety of teachers, parents or other role models can communicate negative attitudes and beliefs about mathematics and this can lead to stereotype threat especially in young female students which then often results in a negative spiral toward lower achievement and increased maths anxiety of the students.

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 reappraisal in a positive way which can overcome the negative responses associated with maths anxiety. Adaptive appraisal can reduce stress and increase self-efficacy which could constitute an important factor in directing students away from perceived negative prior mathematical experiences (Ramirez et al, 2018). Students with negative mathematical experiences may need to be taught and learn how to successfully reappraise their experiences towards more positive directions.

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 and maths anxiety in women and female students using professional learning and teaching to understand the phenomena including strategies to manage and alleviate maths anxiety. Timing is important: the chosen strategies and approaches need to be employed from the early years of primary school and reinforced through repetition in subsequent years in order to be effectively and to eliminate a potential stereotype threat before students endorse it. Addressing stereotype threat in young children can decrease maths anxiety and its consequences on engagement and performance.

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.

Section 4.2 emphasises the strong effect of low self-concept on maths anxiety. Further, students' beliefs about their ability affects their cognitive functioning and their learning.

Improving female students' confidence and beliefs in their mathematical abilities is therefore incumbent. Interventions especially for 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 and programs that Choose Maths employs with students from Year 5 onwards are described in Koch (2019).

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

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 which focuses on trial and error, on finding patterns and seeing connections and similarities. Making mistakes and learning from mistakes is an intrinsic part of mathematics. Section 4 of Koch (2019) illustrates the effectiveness of interventions and growth mindset-based teaching on improving confidence particularly of girls. Successful teaching 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, to make mistakes and become creative in their thinking about mathematics as well as increase students' enjoyment of mathematics.

Building and improving self-confidence of female students needs to include parents and should not be restricted to the school environment. Parents may need to be provided with access and information regarding mathematics-related activities that they can engage in with their children and that increase the enjoyment aspect of mathematics.

5.4 Improving pre-service and in-service mathematics education

Maths anxiety affects how teachers assess their own mathematical ability. The more mathematics teachers know, the more confident they are in their mathematical ability and, as a consequence of increased self-assessed mathematical ability, teachers rate the importance of the teaching of mathematics to young children highly (Geist, 2015).

Findings about teachers' impact on students' achievements are of concern and demonstrate the need for action by teacher educators and governments: Pre-service teachers require a solid knowledge of mathematics, a variety of good and effective mathematics teaching methods and practices to be able to influence student learning and to meet students' needs. Pre-service teacher education must address improving classroom performance with respect to strategies for alleviating maths anxiety and improving mathematical self-concept. The planning and development stage must include research into which institutional practices and curricula will achieve best results in mathematics learning and eliminate the cycle of maths anxiety. The implementation stage is expected to increase students' enjoyment of mathematics and limit their own maths anxieties as well as avoid transmitting their maths anxiety to the classroom.

As 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 available and accessible. It could take the form of professional development, enrolling in courses, or through interventions – see Buckley

(2019). The latter approach in particular aims 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.

Other options could include financial support or time off for enrolling in a postgraduate degree, such as a Masters degree in mathematics education. Such post-graduate degrees seem to contribute considerably to a teachers' overall improvement and increase their confidence in their mathematical knowledge (Gresham, 2018).

6 Maths Anxiety in Choose Maths Primary School Teachers

The Choose Maths program of the Australian Mathematical Sciences Institute (AMSI) addresses the under-representation of women by aiming to increase participation of girls and young women in mathematics and disciplines requiring mathematics throughout the school and university education and into the workforce. The project is funded by the BHP Foundation from 2015 to 2019 and has a staff of 18 including eight experienced primary and secondary teachers. Choose Maths comprises the four components

A. Mathematics-Ready Teacher Professional Development;
B. Women in Mathematics Career Awareness Campaign;
C. Inspiring Women in Mathematics Network; and
D. The Annual BHP Billiton Awards for Excellence in the Teaching and Learning of Mathematics.

The design of survey instruments for teachers and students in the 120 schools associated with component A, and the annual collection and analysis of teacher and student data relating to the four components shows the effectiveness of the multilevel approach and informs the direction of the program. For details see Koch and Li (2017) and Koch (2019).

Wave 1 Choose Maths of the survey of teachers 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 in 2016, and this number increased to 120 schools by the end of 2016 and remained constant since then, see Koch and Li (2017).

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

We focus on survey questions related to maths anxiety, confidence and competence of the 764 primary teachers who responded to the 2017 survey. This number corresponds to a response rate of about 62%. Survey questions relating to the effectiveness of the Choose Maths professional development in the 120 schools are described in Section 3.2 of Koch (2019).

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 how confident and competent they feel on issues ranging from their enjoyment of

and confidence in teaching via teaching specific subject content to integrating new technologies into their teaching. Table 1 shows numbers and percentages of teachers and their assessment of being adequately or not adequately trained to teach mathematics.

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

Table 1: Teachers with adequate/not adequate pre-service training

In Table 1 and in the following '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 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 level, and 61 who did not respond to this question. Table 1 and Figures 1 to 3 focus on those teachers who *were* trained to teach primary mathematics as part of their university education.

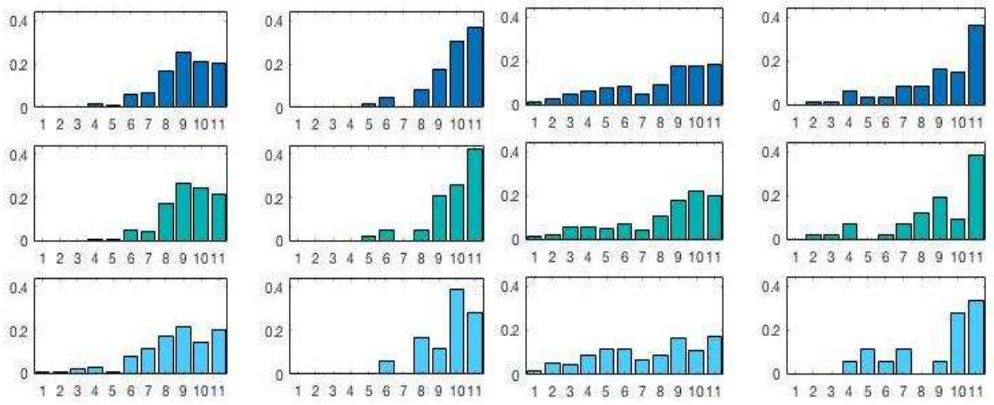
It is of concern that only 61% of teachers who have been trained to teach primary level mathematics feel they are adequately trained. How is this reflected in their confidence or competence? Figure 3 shows responses to the following survey items

(a) Enjoy teaching mathematics;
(b) Do not feel tense when teaching mathematics;
(c) Teach mathematics well; and
(d) Feel knowledgeable about and on top of the mathematics content you teach.

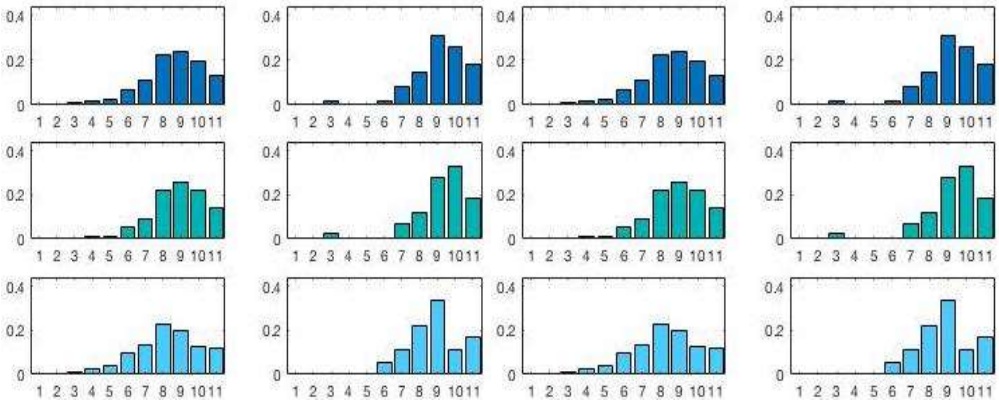
For each survey item (a) –(d) above teachers indicated their level of agreement by choosing a number out of 11, where 1 indicates lowest agreement and 11 highest agreement. Figure 3 shows the results for each survey item in the 6 panels above the survey item label. In each panel the height of the bars 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 with different training.

The different colours 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.

A comparison between the primary trained and the primary and secondary (both) trained teachers shows that the 'both' teachers consistently result in larger proportions for the higher levels of agreement. This pattern persists for the two subgroups adequately and not adequately trained. A comparison between the adequately and not adequately trained subgroups within each cohort and each question (a) – (d) shows that teachers who feel adequately trained do better in all four aspects of teaching.



(a) Enjoy teaching mathematics (b) Not feeling tense when teaching



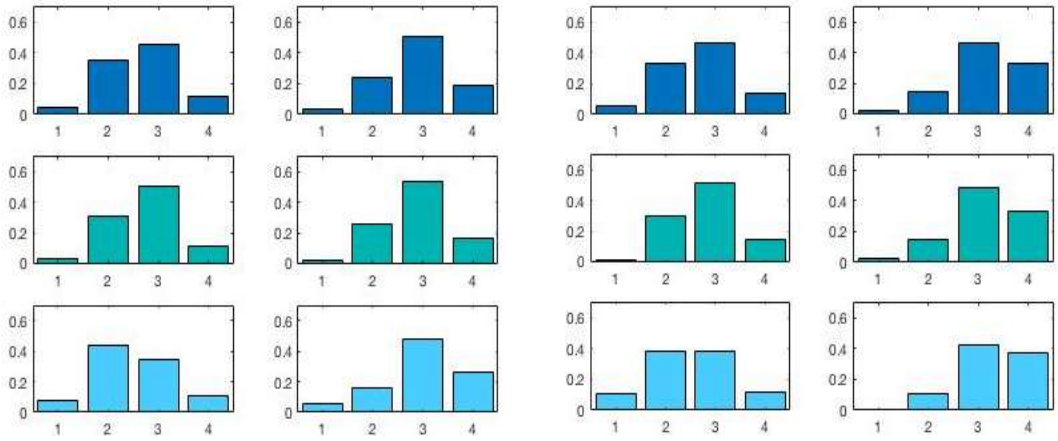
(c) Teach mathematics well (d) Feel knowledgeable about mathematics

Figure 3 Teachers' assessment about teaching aspects; primary trained (left) and both primary and secondary trained (right) in panels (a) to (d). Green row: scores of teachers who feel adequately trained; light blue row: scores of teachers who do not feel adequately trained. Level of agreement from 1 (low) to 11 (high).

A possible interpretation is that teachers with more knowledge of mathematics – here knowledge of primary and secondary school mathematics – are more confident in their knowledge, and hence less anxious about their teaching. This is further illustrated in Figure 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 are 1 – not confident, 2 – somewhat confident, 3 – confident and 4 – very confident. Figure 4 shows proportions of teachers at each of the four responses to panels (e) and (f). Figure 4 is based on 'primary trained' and 'trained in both'. We use the cohorts 'primary' and 'both' in the columns and the same colour scheme in the rows as in Figure 3: adequately trained (green) and not adequately trained (light blue).



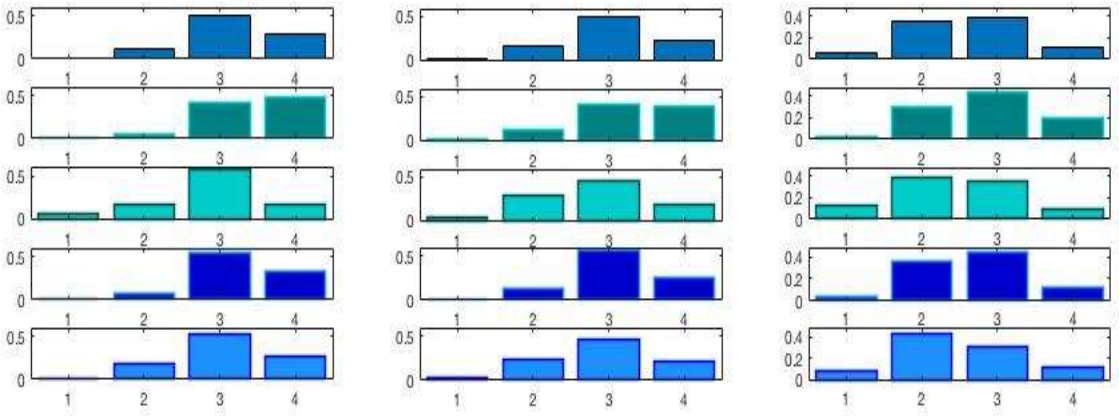
(e) Confidence with mathematics curriculum (f) developing assessment tasks

Figure 4 Teachers' assessment about broader issues; primary trained (left) and both primary and secondary trained (right) in panels (a) and (b). Green row: scores of teachers who feel adequately trained, light blue row: scores of teachers who do not feel adequately trained. Level of agreement from 1 (low) to 4 (high).

The higher bars for responses 2-- 'somewhat confident' of the 'primary trained' teachers who do not think they are adequately trained and shown in the third row is particularly noticeable in Figure 4 (e) in the form of a mode occurring at 2, 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 3 the difference appears to be the additional knowledge of mathematics.

The effect of teachers' beliefs of a lack of knowledge or training and associated maths anxiety can also be seen in the panels of Figure 5 which shows responses of teachers to the questions

(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.



(g) Number and algebra (h) Statistics and probability (i) Problem solving in content areas

Figure 5 Teachers' assessment about content areas (g) to (i). First row: all teachers, second row: 'trained in both' teachers, third row: teachers trained neither for primary nor secondary mathematics, forth row: teacher who believe they are adequately trained, and last row: teacher who belief they are not adequately trained. Responses 1 (not competent) to 4 (very competent).

The four possible answers are 1 – 'not competent', 2 – 'somewhat competent', 3 – 'competent' and 4 – 'very competent'. The rows in Figure 5 show the responses of the following cohorts: top row all teachers, second row 'trained in both' teachers, third row: teachers trained neither for primary nor secondary mathematics, forth row: teacher who believe they are adequately trained, and last row: teacher who believe they are not adequately trained.

As in Figures 3 and 4, teachers who are trained in primary and secondary are regard themselves more competent in all three areas than any other group. But even for these teachers, the mode occurs at 3 – 'competent' for the last survey item – integrating proficiencies and problem solving. The difference between the responses of these teachers to the 'neither trained' in the following row is particularly strong. The latter feel slightly less competent than those who have primary training but regard themselves as not adequately trained and shown in the last row.

The overall clear message is that teachers need access to more training and support to increase their confidence and competence as well as their enjoyment of mathematics and of teaching mathematics.

7 Conclusion 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 of 15-year old boys and girls has increased since around 2000 and the gender gap has widened during those years.

The maths anxiety of pre-service teachers typically increases when they become in-service teachers. Further, negative attitudes of maths anxious teachers have a strong influence on same-gender students, and with a very high percentage of female primary teacher -- over 90% in Australian primary schools -- teachers have a powerful impact on young female students, including reinforcing 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 are performing below their mathematical ability levels.
- Low self-concept of one's own mathematical ability has a strong effect on increasing maths anxiety. Avoidance combined with low levels of confidence negatively impact on an individual's effort to 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 during the mathematics education of teachers can lead to poor teaching practices which then contribute more to maths anxiety of students than the actual content of the subject.

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:

- Pre-service teachers with a solid knowledge of mathematics, good teaching practices on mathematics teaching and strategies on how to influence student learning; and

- Current and future teachers with adequate access to methods for reducing 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 teachers and needs to include access to more mathematical knowledge through professional development or appropriate further qualifications. These avenues of support also need to extend to out-of-field mathematics teachers in secondary schools.

Reducing maths anxiety in pre-service, in-service and out-of-field teachers and in female students will have the potential of increasing students' confidence in their abilities, their interest and hence also their enjoyment and engagement with mathematics.

The higher incidence and higher level of maths anxiety and the lower confidence of girls could be major causes leading to the under-representation of girls and women in senior school mathematics and beyond. More research is required to establish the validity of this hypothesis and to inform practical approaches and strategies.

Although at present there are no known interventions which prevent the onset of maths anxiety, recent research on twins and maths anxiety found that non-genetic environmental factors contribute more to maths anxiety than genetic risk factors. These results are promising in that maths anxiety can be effectively addressed from its onset in the early years of primary school.

Gender differences in mathematical confidence and maths anxiety are much larger than the gender gap in interest or achievement of primary school students, demonstrating a need for interventions which increase girls' confidence. Such interventions should start early and be repeated in order to create a positive and lasting effect on confidence, attitude, interest, achievement and career decisions. Such interventions should include:

- A focus on positive role models which includes addressing and disconfirming of stereotype threats;

- Efforts on building and improving confidence and, simultaneously, decreasing maths anxiety;

- A focus in teaching on emphasising aptitude, engagement, and building of confidence instead of achievement and performance; and

- 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.

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