

# Maths Anxious Pre-Service Teachers' Perspectives of "Doing" Mathematics in a Whiteboard Room

Sarah Sanders  
*Villawood East Primary School*

Wendy Nielsen  
*University of Wollongong*

Caz Sandison  
*University of Wollongong*

Tricia Forrester  
*University of Wollongong*

Received: January 26 2018 Accepted: March 22 2019  
© Mathematics Education Research Group of Australasia, Inc.

Mathematics anxiety is common among pre-service primary teachers and many experience higher levels of maths anxiety than other university students. This study asks: What are maths anxious pre-service teachers' perspectives of "doing" mathematics in a whiteboard room? The Abbreviated Mathematics Anxiety Rating Scale (A-MARS) was used to identify high, medium and low levels of maths anxiety in a cohort of first-year pre-service teachers (n=196). Semi-structured interviews (n=6) explored perspectives that were analysed through Vygotsky's sociocultural dimensions of the intrapersonal and the interpersonal, as well as the physical environment of the whiteboard room. Results show that doing maths in a whiteboard room was positive and engaging for participants because the room afforded positive interpersonal interactions and fostered an engaging learning environment that served to ease their maths anxiety. The whiteboard pedagogy is thus recommended in pre-service teacher education.

**Keywords:** preservice teachers · maths anxiety · A-MARS · primary teachers · whiteboard room

## Introduction

The need for quality mathematics educators is a growing concern in Australia (Teacher Education Ministerial Advisory Group [TEMAG], 2014) and elsewhere (see for example, Hiebert, Miller, & Berk, 2017; Ingvarson & Rowley, 2017). Program Standards in Initial Teacher Education courses in Australia now require pre-service teachers to be in the top 30% of the general population in numeracy and literacy prior to their university graduation (Australian Institute for Teaching and School Leadership [AITSL], 2011). However, pre-service primary teachers commonly experience higher levels of mathematics anxiety as compared to other university students (Bekdemir, 2010; Brown, Westenskow, & Moyer-Packenham, 2011; Vinson, 2001) and often have negative attitudes or ambivalence toward mathematics (Itter & Myers, 2017). Thus, maths anxiety may contribute to many pre-service primary teachers [PST] lacking adequate confidence and mathematical understanding to be effective teachers of mathematics (Cooke & Hurst, 2013; Gleason, 2013; Rayner, Pitsolantis, & Osana, 2009).

Maths anxiety is a state of discomfort or fear experienced by primary pre-service teachers [PST] in response to situations involving mathematics and develops from personal, intellectual and environmental factors in their educational pasts (Hadfield & McNeil, 1994; Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004). Maths anxious PST may also suffer from 'maths teaching anxiety' which limits their ability to be effective teachers (Brown et al., 2011). Brown et al. note that being maths anxious does not necessarily make one maths teaching anxious; however, maths anxiety interferes with mathematics learning and has origins in earlier schooling and pre-service math methods subjects are a key location for easing maths anxiety (Gresham, 2018).

Teacher education students, like other university students, may feel overwhelmed because university programs must cover a wide range of content in a short space of time (Núñez-Peña, Bono, & Suárez-Pellicioni, 2015). As a result, universities typically provide additional voluntary mathematics centres to assist any struggling students (Woodard, 2004). However, O'Sullivan, Mac an Bhaird, Fitzmaurice and Ni Fhlionn (2014) estimate that 33% of first-year university students who require assistance avoid mathematics and do not seek help or attend support centres, and these avoidance behaviours are common among students with high levels of maths anxiety. Strategies to reduce maths anxiety among university students (Anderson, Conrad, & Corbett, 1989) or high school students (Lavasani & Khandan, 2011) also work for pre-service teachers (Barrett, 2013; Bekdemir, 2010). Strategies include cooperative learning, one-to-one feedback, hands-on concrete experiences and use of manipulative tools.

In the current study, we test a new strategy that uses a whiteboard room to potentially help maths anxious pre-service teachers think differently and possibly feel more confident in doing mathematics. A whiteboard room has standard whiteboards that line all four walls of the classroom (Sandison, Forrester, & Denny, 2015) and has been used successfully for many years in tertiary mathematics programs (Seaton, King, & Sandison, 2014). Research with high school students and whiteboard rooms has been growing (Liljedahl, 2016a; Pruner, 2016; Sandison et al., 2015; Towers, Martin, & Heater, 2013) Most of these studies focused on interaction, collaboration and engagement rather than maths anxiety. Whiteboard room use in pre-service primary teacher education is relatively new and we propose that the strategy may help pre-service teachers with maths anxiety.

### *Mathematics Anxiety*

Maths anxiety has been an area of research concern since the late 1950s when Dreger and Aiken (1957) identified number anxiety among college maths students as an emotional syndrome and disturbance in the presence of mathematics that includes feelings of tension and apprehension impeding the ability to complete mathematical problems. To study this, Richardson and Suinn (1972) developed a college-level maths anxiety measurement. Tobias (1978) described maths anxiety as a state of fear, paralysis and mental disorganisation that interferes with the manipulation of mathematical problems. These feelings were present for adults who were otherwise competent and confident. Maths anxiety can also take the form of mathematics test anxiety, which is a state of panic aroused before, during or after a test or examination (Beilock & Willingham, 2014).

Maths anxiety includes emotional reactions to mathematics as a school subject, but it also has physiological and cognitive dimensions (Adeyemi, 2015; Beilock & Willingham, 2014; Ho,

Senturk, Lam, Zimmer, Hong, Okamoto et al., 2000). Physiological dimensions such as sweating, heart palpitations and tightening of muscles can manifest during mathematics activity for maths anxious persons (Perry, 2004; Wilder, 2012). Cognitive abilities such as attention, interpretation, concentration and working memory capacity can also be disrupted by the cognitive dimensions of maths anxiety (Ashcraft, 2002; Ashcraft & Kirk, 2001), which may, in part, account for the relationship illustrated by Peker (2009) between maths anxiety and learning styles among pre-service primary and secondary teachers. Ashcraft and colleagues (Ashcraft, 2002; Ashcraft & Kirk, 2001; Ashcraft & Moore, 2009) argued that individual cognitive processes respond to negative emotions and impact operational and numerical processing capability with consequences that may include mental blanks, negative self-talk, self-doubt and increased error in solving mathematics problems, making an important link between maths anxiety and achievement. While this work was with university students in psychology, high school students with maths anxiety took longer to perform mathematics tasks (Beilock & Willingham, 2014; Ho et al., 2000) and thus, when maths anxiety is aroused, there is a likely decline in mathematics performance obscuring the learner's true ability (Adeyemi, 2015; Ashcraft & Moore, 2009).

Causes for maths anxiety among PST were proposed by Hadfield and others (Hadfield & McNeil, 1994; Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004). Personal, intellectual and environmental factors are implicated in PST' maths anxiety (Cohen & Rubinsten, 2017). Personal factors include character attributes such as low self-esteem or shyness (Hadfield & McNeil, 1994; Trujillo & Hadfield, 1999), low self-efficacy (Thiel & Jenssen, 2018), low motivation and incorrect judgment of mathematics ability, all of which influence the level of motivation when university students were faced with mathematical challenges (Akin & Kurbanoglu, 2011). For pre-service teachers, there is an important relationship between low self-esteem about their abilities and effective teaching (Beswick, Ashman, Callingham, & McBain, 2011; Gresham, 2008; Haciomeroglu, 2013), making an important connection with maths teaching that Ren and Smith (2018) linked to mathematics knowledge for teaching. Low levels of content knowledge contribute to PST maths anxiety (Cooke & Hurst, 2013; Gleason, 2013; Rayner et al., 2009). Such personal factors can result in pre-service teachers demonstrating mathematics avoidance behaviours such as disengagement with the content (Ashcraft, 2002; Cook & Hurst, 2012; Haciomeroglu, 2013). These further influence intellectual factors.

Intellectual factors contributing to primary pre-service teacher maths anxiety include attitudes, beliefs, content knowledge and learning style preference towards mathematics (Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004). Maths anxious pre-service teachers are likely to hold negative attitudes and beliefs about mathematics (Cooke & Hurst, 2012), poor mathematical understandings; poor reasoning ability in mathematics, poor spatial reasoning skills (Novak & Tassell, 2017) and low confidence in their own ability to teach mathematics (Haciomeroglu, 2013; Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004). Maths anxiety in PST also influences their expectations for students (Mizala, Martínez, & Martínez, 2015). Importantly, there is a strong relationship between teachers' negative attitudes to mathematics and their students' mathematics achievement (Mensah, Okyere, & Kuranchi, 2013): maths anxious teachers can pass maths anxiety on to their students (Bekdemir, 2010; Cooke & Hurst, 2012; Vinson, 2001). Mathematics teachers can contribute to maths anxiety if children perceive their teachers as stark or evaluative and focus on getting the correct answer rather than creating a supportive and cooperative environment for learning (see for example, Confrey, 1994; Geist,

2010). There are also environmental factors influencing maths anxiety and by extension, maths teaching anxiety.

Environmental influences are implicated in the origins of maths anxiety, both for children (Geist, 2010) and pre-service teachers (Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004). Influences include parents' beliefs, expectations and attitudes and negative experiences in the classroom, including experiences with teachers and different pedagogies (Gresham, 2007; Suarez-Pellicioni, Núñez-Peña, & Colomé, 2016). Parents may endorse negative gender stereotypes by suggesting males are more capable in mathematics and females more innately suited to reading (Suarez-Pellicioni et al., 2016; Tobias, 1978) or by treating activities for males and females differentially (Gunderson, Ramirez, Levine, & Beilock, 2012). This may account for the higher incidence of maths anxiety among women generally. Parents' negative attitudes and beliefs about mathematics may also transfer to their children, which may impact children's self-efficacy and maths anxiety (Suarez-Pellicioni et al., 2016; Tobias, 1978). However, parents can also positively influence children's maths anxiety (McLeod, Weisz, & Wood, 2007; Vukovic, Roberts, & Green Wright, 2013) through involvement with mathematics-related school activities and supportive conversations about mathematics.

Classroom experiences are the strongest environmental influence on maths anxiety beginning in the early years of school, although maths anxiety can also be carried into high school and beyond (Bekdemir, 2010; Geist, 2010; Gresham, 2018; Hadfield & McNeil, 1994). Powerful negative emotions arise from school experiences of failure or public embarrassment in mathematics (Bekdemir, 2010; Hadfield & McNeil, 1994). Further, mathematics knowledge plays an important role in maths teaching (Ren & Smith, 2018) due to teachers' perceptions and behaviours towards the subject of mathematics, which can heighten students' maths anxiety if students internalise negative perceptions of mathematics based on the teacher's portrayal of mathematics (Geist, 2010; Uusimaki & Nason, 2004). Teachers with negative perceptions of mathematics may lack confidence in their own ability to teach mathematics and may be maths anxious themselves, which could lead to maths teaching anxiety where these tensions are felt when teaching (Brown et al., 2011; Peker, 2009). As a result, these teachers may employ traditional teaching practices that emphasise correct answers, speed computation or drilled rote learning (Choppin, 2011; Geist, 2010; Hadley & Dorward, 2011). Mathematics classrooms that focus on getting the correct answer through drill and practice can be stark and rigid learning environments (Confrey, 1994) that challenge students' feelings of competence and prevent them from help-seeking behaviours (Geist, 2010; Stipek, Salmon, Givvin, Kazemi, Saxe, & MacGyvers, 1998). Such teacher-driven practices can foster maths anxiety in students (Bekdemir, 2010; Geist, 2010; Hadley & Dorward, 2011). Bekdemir (2010) linked pre-service teachers' experiences of a teacher's hostile behaviour (toward mathematics), whole-class instruction and rote memorisation of algorithms as influences on their attitudes towards mathematics and their own maths anxiety. Bekdemir concluded that teachers with maths anxiety have the potential to pass on negative attitudes and fears of mathematics to their own students and therefore pre-service teacher education programs need to address maths anxiety during mathematics subjects (see also Gresham, 2018 and Hadley & Dorward, 2011).

Maths anxiety is mostly a learned condition, so it can be unlearned (Whyte & Anthony, 2012). Teacher educators, as university instructors, thus need sufficient awareness and understanding of possible causes, consequences and interventions in order to identify pre-service teachers at risk of maths anxiety (Ashcraft, 2002). Mathematics subjects for pre-service

teachers must create a positive learning environment in order to relieve pre-service teachers' feelings of tension and anxiety (Bekdemir, 2010). Maloney and Beilock (2012) argue that a positive learning environment lowers the risk of negative mathematics experiences for students (Bekdemir, 2010; Tobias, 1990) but also supports individual learning needs to build basic maths competencies so that mathematics teaching practices prevent maths anxiety in the first place (Bekdemir, 2010; Brown et al., 2011; Vinson, 2001).

Classroom practices such as cooperative learning, one-to-one support and concrete materials also help to prevent or reduce maths anxiety for pre-service teachers (Barrett, 2013; Bekdemir, 2010; Vinson, 2001). Cooperative learning is beneficial when it enables social interactions, peer-mediated teaching and discussions in the teacher education program (Bekdemir, 2010; Vinson, 2001) and can help maths anxious high school students (Hellum-Alexander, 2010) and pre-service teachers (Vinson, 2001) develop positive attitudes towards mathematics. A mechanism for relieving maths anxiety appears to be that high school girls were more willing to ask for assistance during cooperative learning activities as compared to more traditional classroom methods (Lavasani & Khandan, 2011). This suggests implications for pre-service teacher education too.

Immediate feedback is an additional strategy to help relieve university students' maths anxiety (Anderson et al., 1989; Nunez-Pena et al., 2015). Anderson et al. showed that when university students received immediate feedback, they required less time to develop understanding. Nunez-Pena et al. found a positive link between university students' class attendance and the type of feedback received in different kinds of sessions, for example, attendance was much better in classes where more immediate feedback was given. This had additional benefits for students who developed better content understanding but also reduced the negative impact of maths anxiety.

Teachers thus have an important role in interrupting the cycle of maths anxiety (Bekdemir, 2010; Brown et al., 2011). Pre-service teachers in their pre-service programs may have experienced some of the dimensions of maths anxiety as school children, similar to those in the review above and pre-service mathematics programs must take care not to reinforce PST' feelings of discomfort or fear in attempting mathematics tasks, but work to reduce maths anxiety. A positive and collaborative classroom culture in pre-service teacher education and pedagogical approaches including cooperative learning, immediate feedback and hands-on concrete learning experiences are beneficial for reducing PST' maths anxiety. However, maths anxiety remains an important issue for mathematics learners who will become classroom teachers and thus the current study examines a new strategy to deal with pre-service teacher maths anxiety.

### *A Whiteboard Room*

Since the mid-nineteenth century, chalk and blackboards have been used to teach and record thinking (Greiffenhagen, 2014). Such practices continue with dry-erase markers and standard whiteboards that Liljedahl (2016a) calls 'vertical, non-permanent surfaces' (VNPS). Standard whiteboards<sup>1</sup> are common artefacts in Australian primary and secondary classrooms and may take the form of a teacher's board or mini-whiteboards (Beauchamp & Kennewell, 2008; Wake &

---

<sup>1</sup> Standard VNPS whiteboards are not to be confused with electronic, interactive or 'smart' whiteboards.

Pampaka, 2008). Teachers in New South Wales commonly use one large whiteboard for teacher-directed instructions and activities. However, mini-whiteboards can be used individually for student-centred activities such as deconstructing mathematical problems or recording 'in-the-moment' thinking. Students can respond by holding up their whiteboards in a public display during class discussion (Preciado-Babb, Metz, Sabbaghan, & Davis, 2015; Swan, 2006; Wake & Pampaka, 2008). The practice of public display allows the teacher to make formative assessments, continually monitor individual student progress and help students to explore problem solving strategies and sharing solutions. However, the small size of mini-whiteboards limits their utility for group work or collaboration. An extension of this concept that better enables group work is a room with wall-size whiteboards, called a 'whiteboard room' (Sandison et al., 2015).

A whiteboard room is a room lined with large, wall-mounted, standard whiteboards on all four walls of the classroom. Typically, desks and chairs are removed, however, stools may be provided for students while working on the whiteboard. In mathematics teacher education subjects, pre-service teachers arrive to the whiteboard room and receive a set of mathematical problems to complete on the whiteboard walls. The students choose to work in groups, pairs or individually on the boards, which gives them ownership (Hudson & Morris, 1995; Seaton et al., 2014). The whiteboard room models how mathematicians 'do' mathematics: they rarely sit in silence and 'think' about doing mathematics; they often use erasable boards 'in action' to investigate, pose and solve mathematical problems (Barany & Mackenzie, 2014; Greiffenhagen, 2014). The act of "doing" mathematics on whiteboards thus lets learners adopt similar practices to mathematicians, that is, to actively explore, annotate, erase and redraw mathematical concepts in an easily visible format (Sandison et al., 2015; Seaton et al., 2014). These also indicate high levels of engagement, active learning and peer learning, as well as offering opportunity for student feedback (Liljedahl, 2016a; Towers et al., 2013) because mathematics becomes a shared and visible representation of students' mathematical thinking that is critical for the development of reasoning (Barany & Mackenzie, 2014; Greiffenhagen, 2014).

In the whiteboard room, mathematics learners experience mathematics as a social and collective investigation (Pietsch, 2005; Romberg & Kaput, 1999) drawing on the interplay of oral interaction and written symbol representations, which are essential modes for doing mathematics and thinking mathematically (Arzarello, Paola, Robutti, & Sabena, 2009; Radford, 2009). These are also important 'Working Mathematically' processes in the New South Wales K-10 curriculum (NSW Board of Studies, 2012). Unfortunately, mathematics classrooms are commonly organised for students to sit quietly and do mathematics on their own (Pietsch, 2005; Sandison et al., 2015).

Sounding a note of caution, however, the act of doing mathematics in the view of others has the potential to be anxiety-producing, even though the whiteboard pedagogy has demonstrated positive effects for mathematical problem-solving and thinking mathematically. We wonder if maths anxious pre-service primary teachers could benefit from the use of the whiteboard pedagogy in similar ways to learners in high school or other university mathematics courses. The current study asks the following question: *What are maths anxious pre-service primary teachers' perspectives of "doing" mathematics in a Whiteboard Room?*

## Methods

The whiteboard room enables “doing” mathematics and often includes conversation and interactions in collaborative groups, hence our proposition that the physical environment of the whiteboard room may enable productive interactions among pre-service teachers as learners of mathematics and help to mitigate feelings of maths anxiety. The whiteboard room is also a social space and following Vygotsky (1978), we consider social interactions among peers and teachers as possible social influences on individual learning. This interpersonal dimension to maths learning complements Vygotsky’s intrapersonal dimension that includes individual knowledge, attitudes and beliefs, among these, maths anxiety.

### *Study Context and Participants*

Primary Bachelor of Education students take a compulsory maths methods subject and may participate in guided workshops held in whiteboard rooms as part of their subject activities. Subject content includes problem-solving, numeration, number theory, geometry, measurement, probability, statistics and graphical representation of data and the subject aims to develop pre-service teachers’ deep understanding of fundamental mathematics and essential numeracy skills needed to become confident and effective teachers of mathematics.

As a part of the subject, the pre-service teachers complete a Diagnostic Skills Test in Week 1 to formally assess their numeracy skills. If they fail to achieve a result of 80% (20/25) or higher, they must attend weekly mathematics workshops that are held in a whiteboard room. Attendance at these workshops is optional for those achieving 80% or higher on the Diagnostic Skills Test. Workshop attendees arrive to their weekly one-hour whiteboard workshops and get a sheet of mathematical problems and work in groups of two or three to solve the problems together. All participants are primary pre-service teachers.

### *Procedures*

The study used case methods (Creswell, 2014; Stake, 1995) and included two phases: Phase 1 identified potential study participants and Phase 2 explored pre-service teachers’ perspectives of “doing” mathematics in a whiteboard room. In Phase 1, all students in the subject (n=196) completed the Abbreviated Mathematics Anxiety Rating Scale (A-MARS) (Alexander & Martray, 1989) as a pre-measure in Week 1 and then again on the last day of class. Similar to Trujillo and Hadfield (1999), we used the pre-measure to identify potential participants for Phase 2 of the research. Our interest in the possible influence of the whiteboard room led us to seek participants with different levels of maths anxiety. The A-MARS was again administered at the conclusion of the subject.

Phase 2 of the research involved semi-structured interviews in the middle of the semester with volunteering PST who exhibited high (n=2), medium (n=2) or low (n=2) levels of maths anxiety. Interviews explored participants’ attitudes towards mathematics, prior experiences with mathematics and maths anxiety, the implications of the physical environment of the whiteboard room and comparisons to other experiences in learning mathematics. The interviews were audio recorded, lasted about 30 minutes and were transcribed verbatim. The research protocols were reviewed by the University of Wollongong Social Sciences Human Ethics Committee. Pseudonyms are used throughout.

### *Instrument: Abbreviated Mathematics Anxiety Rating Scale (A-MARS)*

The *Abbreviated Mathematics Anxiety Rating Scale* (A-MARS) is a 25-item, five-point Likert scale self-report survey comprised of three subscales (i.e., Mathematics Test Anxiety, Numerical Task Anxiety and Mathematics Course Anxiety) (Alexander & Martray, 1989). Participants report on the intensity of their feelings about each item from the response choices: "not at all", "a little", "a fair amount", "much" and "very much", which are converted to a numerical score (1-5) for each item. A-MARS reliability and validity have been demonstrated with university undergraduates (Alexander & Martray, 1989). The subscales also have acceptable reliabilities for college students with maths anxiety (Baloglu & Koçak, 2006). In the current study, the A-MARS was used as a pre-measure to identify PST across a range of levels of maths anxiety among the cohort. We adopted Suinn and Edwards' (1982) cut-point values of low (<30<sup>th</sup>) and high (>75<sup>th</sup>) percentiles of maths anxiety. This was the only mention of cut-points we could find in the research literature, so used these as guidelines.

The sum of the item scores for the A-MARS items provides a total score for each student and the possible score range is 25 to 125. Because we wanted to identify a range of maths anxiety in the cohort and to establish a pool of possible participants for Phase 2 interviews, we added a "medium" category to include the range between the 30<sup>th</sup> and 75<sup>th</sup> percentile as shown in Table 1.

*Table 1. Cut-point values of maths anxiety (adapted from Suinn & Edwards, 1982)*

Category of Anxiety	Percentile Range	Raw Score Distribution	Frequency in Cohort (n=196)	Frequency in Subset (n=72)
Low	<30	32-52	56	21
Medium	30-75	52-75.5	100	34
High	>75	75.5-105	40	17

### *Phase 1 Analysis*

Figure 2 shows the distribution of pre-test A-MARS raw scores, sorted by gender, for the cohort (n=196) of pre-service teachers. Raw scores ranged from 32 to 105 and frequencies of the three categories in the cohort are shown in Table 1. From the whole-class cohort, a sub-set of pre-service teachers (n=72) initially expressed interest in participating in Phase 2 of the research. Their A-MARS raw score distributions across the levels of anxiety are also included in Table 1. In selecting a sample of possible students for Phase 2 interviews, we sought maximum variation across the three levels of maths anxiety and chose two individuals from each band (one female and one male) as participants for Phase 2. It is interesting to note that five females in the highest anxiety range of 95–100+ expressed interest in the research by responding to the initial invitation to attend an interview, however ultimately declined to participate. They noted time constraints or withdrawal from the subject as reasons. It is difficult to draw inferences from this, but it is likely that a high level of maths anxiety is somehow implicated.



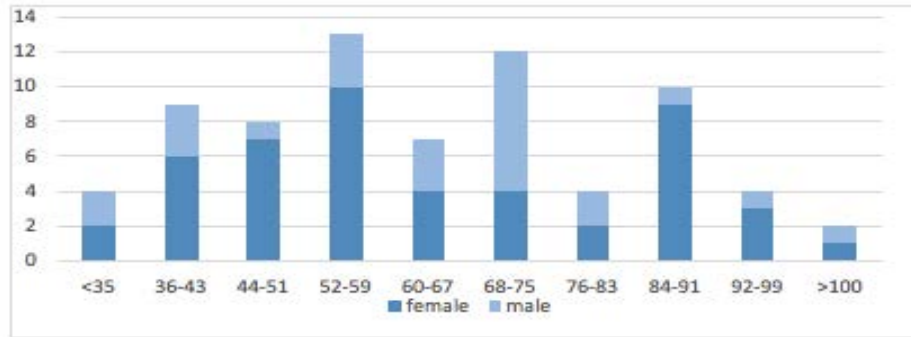


Figure 2. Phase 1 A-MARS raw scores distribution.

### Phase 2 Analysis

Interviews were analysed using an interpretive process that employed three *a priori* analytic categories as shown in Table 2: Vygotsky's (1978) (1) interpersonal and (2) intrapersonal dimensions, and (3) the physical environment of the whiteboard room. The interpersonal dimension focused on social interactions and two sub-codes were developed according to who was involved: (a) the teacher and a pre-service teacher (PST); or (b) two (or more) pre-service teachers. Because there is a theorised relationship between content knowledge and maths anxiety, (c) maths anxiety and (d) content knowledge are considered sub-codes in the intrapersonal dimension. Based on literature describing the nature of the whiteboard room (Liljedahl, 2016a; Sandison et al., 2015; Seaton et al., 2014), the environment category includes aspects of the physical space of the whiteboard room as sub-codes: (e) actively doing; (f) standing up; (g) space on the board; and, (h) non-permanent surface. Table 2 also includes sample quotes from the data set to illustrate each sub-code.

Table 2.  
*A priori codes, with Examples*

Code	Sub-code	Example from Data
Interpersonal	Teacher-to-PST (a)	"She gives me strategies about how to work out questions."
Interpersonal	PST-to-PST (b)	"You're with other people that you are talking to and sharing solutions."
Intrapersonal	maths anxiety (c)	"I know I can't change what happened. I beat myself up."
Intrapersonal	content knowledge (d)	"I have learnt something, accomplished something."
Environment	actively doing (e)	"It's good because everyone is actually doing the work and not pretending to work."
Environment	standing up (f)	"It's good to be up and moving around, it kind of wakes you up."
Environment	space on the board (g)	"Seeing things big is better."
Environment	non-permanent surface (h)	"You can just rub things out and easily fix it up."

## Results and Discussion

We briefly introduce the participants and then develop themes from this research where we explored pre-service teachers' perspectives on doing mathematics in the whiteboard room and possible relationships to maths anxiety. We interpret pre-service teachers' perceptions of learning activity in the whiteboard room through our analytic perspectives of sociocultural theory and the physical environment.

### *The Pre-Service Teacher Participants*

Table 3 introduces the participating students, who were all volunteers from the cohort of primary pre-service teachers. Pseudonyms were assigned using the first letter as reference to the participants' level of anxiety. For example, participants with "low" anxiety were given a pseudonym beginning with the letter L, as in "low-anxiety-Laura." Based on the exploratory purpose of the research, the six participants were selected for maximum variation across the cohort for A-MARS scores rather than being representative of the gender distribution or incidence of maths anxiety in the wider sample. The participants were not all in the same workshop; however, the workshops were centrally coordinated and all were run in a similar manner.

Table 3.  
*Phase 2 Participants and Pre/Post A-MARS Raw Scores*

Participant	A-MARS			Comments
	Pre	Post	Change	
Laura	42 (low)	43 (low)	+1%	First year out of high school
Luke*	44 (low)	n/a	n/a	Second year out of high school; elected to attend workshops
Mary	75 (med)	69 (med)	-5%	Mature aged student; prior maths class 6 years ago
Mark	77 (med)	25 (med)	-42%	First year out of high school
Hannah	88 (hi)	39 (med)	-39%	Mature aged student; prior maths class, 10 years ago
Harry	105 (hi)	92 (hi)	-10%	First year out of high school
Cohort	57 (med)	58 (med)	+1%	N=196

\* Because Luke's attendance at whiteboard workshops was optional, he was not present on the day that the post-measure was administered.

### *Improvement to Measured Maths Anxiety*

Several medium and high -level anxiety participants showed marked improvements on the pre and post A-MARS even as the average change for the cohort was only about 1% and negligible in these analyses. The sections that follow offer possible explanations for the noted improvements in maths anxiety levels, in particular, PST build confidence through feeling safe in the environment due to positive interactions with peers and the instructor.

### *Safe Interactions in the Whiteboard Room*

Both activity within the social space of the classroom and perceptions of safety are shaped by interpersonal relations among students. The physical environment of the vertical whiteboard space fosters face-to-face interactions even though some participants (3 of 6) reported initial feelings of fear because they did not know their classmates and the active learning style of writing on the boards was unfamiliar:

I had no idea what a workshop was going to be. I was a bit worried because I didn't know anyone and then they were like, 'You are going to work on the boards together'. It's a bit daunting when you don't know anyone. But after a few weeks, you all get to know each other. (Laura)

The unfamiliar feelings eased over time according to medium-anxiety-Mark:

Initially I was a bit weird about it. I wasn't too worried. It was good that everyone else was doing the same thing. So that made it better. Maybe after one lesson [then] I was sweet. It wasn't too bad or anything. If everyone does it, it's fine.

When "everyone else was doing the same thing," there is a safety in the collective. These comments illustrate that pre-service teacher perceptions of the whiteboard room changed over a period of time as they gained familiarity with the environment and each other, similar to the university learners described in Seaton et al. (2014).

The physical arrangement of the whiteboard room allowed the pre-service teachers to visibly explore mathematics as a shared experience. High-anxiety-Harry explained his comfort in working with peers of the same ability level:

Doing [mathematics] on the board it is ok. You are all on the whiteboards together, so you are pretty much the same ability level ... we are all the same level. It's not like a few people are miles above and we are trying to work to their ability.

Through this shared experience, participants felt a sense of belonging because they were on a similar footing to each other and felt less intimidated in exploring mathematical problems together, either with their peers or the instructor. All participants (6 of 6) valued the interaction and collaboration of doing mathematics with peers, as noted by Laura:

You can speak and you can be loud. Talking to everyone in the room but more like on the same walls. Just whoever is there, we might say, 'Have you done this question? How did you do it?' ... I definitely like being able to talk freely and interact with everyone.

Importantly, she felt free to discuss mathematical ideas in a shared, collective experience. High-anxiety-Hannah also considered the physical arrangement of the vertical whiteboards to be conducive for group work, fostering interactions between peers in their own group as well as across the whiteboard room:

I remember there is one girl who I haven't really spoken to - you just smile and say hi to. She passed the last test and she was still [working] on the board. I just said to myself, 'I am a little stuck with this' and she heard me and she said 'Oh, all you have to do is add this to that, and this and that'. It was so good. I feel like everyone is interacting.

The physical space of the whiteboard room made others' work visible and even for highly-anxious-Hannah, her work became a prompt for discussion because another student noticed that she needed help. It is significant that peers felt confident to move around the room and lend assistance to others they did not know very well. This level of mobility among people and ideas in the whiteboard room is consistent with Liljedahl (2016a) who found that the whiteboard surfaces fostered high school students' interaction and knowledge mobility between groups. The whiteboards in the current study appeared to support knowledge mobility as they formed relationships with each other whilst cooperating and collaborating on the boards (Seaton et al., 2014).

While the physical space of the whiteboard room afforded positive interactions between students, interactions between PST and the instructor were possible because the instructor could observe students' thinking as expressed on the whiteboards and offer individualised feedback, as noted by low-anxiety-Luke:

[The tutor] is pretty on the ball about walking around the room and seeing when people need help .... If we have problems we can just call her over for help and because it is on the whiteboards she can see if we have errors. So, she will often come over because she can see if you are struggling.

Medium-anxiety Mary also noted that she felt comfortable asking for help in this environment, which as Seaton et al. (2014) noted, helps to break down barriers between instructor and students:

I know that we are actually doing the questions and can ask for help ... I find it [the whiteboard room] a lot more relaxed and at our pace and a lot [easier] to ask questions and to work with other people, so yeah. I find it is a lot more relaxed environment.

Similar views were expressed by 5 of 6 interviewees, but high-anxiety-Harry had a different perspective of his interactions with the teacher. He did not feel confident in the whiteboard room:

We are half way through something and our tutor will be like, 'That's not right' and we are like, 'Well, we haven't finished yet' .... And then for that you go into fight mode and say, 'Well, don't judge me' ... I think that is one of the biggest things, like being afraid of that - poking holes in it. I guess writing down while people can see it [on the board] maybe gives the chance [for someone else] to poke holes in what you are doing.

Harry seemed sensitive to the instructor as an authority figure who was 'poking holes' or critiquing his work. As a highly maths anxious student, it was significant that Harry felt uncomfortable and judged when the instructor offered feedback, suggesting that instructors need to take care in how they interact with highly anxious mathematics students who may feel vulnerable.

While Harry may have felt intimidated by the instructor, the majority of participants (4 of 6) felt that the busy-ness of the whiteboard room helped them feel comfortable sharing their thinking in view of others, as illustrated by Hannah, another highly anxious student: "I really don't think anyone in the class would feel anxious. I know myself, I don't. It is not a judgmental environment at all. Everyone seems to help each other, everyone respects each other." She also made an interesting point about making an error on the board:

That's when you start waiting for help or start helping each other. If you don't get [the question correct] - that's probably the only time I don't rub it out, if I have gotten it wrong ... I just leave it on the board and go on to the next [question].

Leaving her mathematical thinking in the view of others even when she knew there was an error was an important aspect of feeling safe in the environment. Part of this was the busy environment, but also because they all worked on their own whiteboards, and according to Mary, "it is not as if I am doing a question and they are watching me directly. They're busy, they're focused on what they are doing." In a way, the participating students seemed to lose track of what others were doing, even as the same problems were being explored. Unsurprisingly perhaps, highly-anxious-Harry preferred to work on paper at a desk:

I think it is [that] you're doing your own thing [on paper], rather than someone watching you [on the whiteboard]. Not that it is not like a massive thing to not do it on the whiteboard compared to doing it on paper. I think just everyone would just prefer to have their own little thing that they work on and are doing, and then compare when they are happy with what they have done.

Harry seemed to be projecting his own preference for solving problems in private and this points to a possible drawback for some students: possibly being watched by others and feeling uncomfortable in making errors on the board are clear manifestations of high levels of maths anxiety. However, for most participating pre-service teachers, the whiteboard room fostered positive feelings of safety and comfort to do mathematics in public.

### *Physical Space Fosters Engagement*

The whiteboard room cultivated conditions for behavioural, cognitive and affective engagement and most importantly, actively doing mathematics. After their initial nervous feelings, most pre-service teachers became comfortable with this style of learning activity. As Luke noted, "Once you get used to writing on the boards and feel confident about the questions you are doing, it mixes up the type of study." While doing mathematics on the boards was a new and possibly confronting experience, these pre-service teachers' nervousness is interesting because writing on the board is a common activity for teachers. Behaviours in the whiteboard room do become routine, however, as illustrated by Hannah:

We all walk in there like we are ready to work. Literally, I have noticed everyone without even thinking - we are all classically conditioned to walk in there, grab a whiteboard marker, a sheet and start working...we don't even sit down ... Everyone walks into the room like, 'Go get the [whiteboard] markers.'

Hannah's comment reflected on-task behaviour and high-level engagement, participation and a positive perception of mathematics, feeling ready and attentive to explore, which is notable for a highly maths anxious person. Medium-anxiety-Mark expressed a similar attitude:

[Whiteboard] workshops are a lot more productive for doing uni work, instead of watching someone in a lecture. I probably enjoy the work better [in the whiteboard room] just because you're actually doing the work and practising the questions.

Mark made an interesting comparison between his behaviour in the whiteboard room and the lecture hall and noted the value of the whiteboard room as a productive and enjoyable space to do mathematics. High school students in Sandison et al.'s (2015) study were similarly engaged in on-task mathematics activity in a whiteboard room as compared to a traditional paper and desk classroom.

The high level of involvement and engagement in doing mathematics in the whiteboard room also influenced participants' perceptions of time; they became so absorbed as to lose a sense of time. For example, Mary commented, "I find the workshops go very fast. Lectures go forever and tutorials are really slow. I find the whiteboards to go the fastest." Hannah likewise reported, "It is the fastest hour of everyone's time and we would probably try to stay on, but we have a lecture straight afterwards." It is notable that these maths anxious pre-service teachers became so absorbed and engaged in the process of doing mathematics in the whiteboard room that they lost track of time and even wanted to continue working. The positive results of participants' behavioural engagement, high levels of involvement and losing track of time are

reminiscent of Csikszentmihalyi's (1975) concept of 'flow,' where an individual experiences a state of complete immersion and involvement in a task, which is a very positive outcome for maths anxious students.

The pre-service teachers' willingness to invest time and effort in doing mathematics in the whiteboard room also reflected their sustained concentration and investment in their learning, including a strong task focus, direct effort towards understanding the task and desire to go beyond subject requirements. A majority of the participants (4 of 6) perceived their own high levels of concentration in the whiteboard room. Harry's comment is representative:

It [whiteboard room] is a space where you are not as distracted and you just focus on [mathematics]. During individual study, it is easy to procrastinate. In the workshops, you are there to do it ... it creates a space for just focusing on maths for that hour. It gives you a distraction-free environment to smash it out.

Participants experienced a directed effort, investment and concentration towards understanding the mathematics content, as noted by Luke:

Yeah, standing up and the novelty of writing on the board makes it easier to remember what has happened...you are remembering [mathematics content] in a different way [and] it is easier to recall in tests .... It is more the process of getting to the answer, rather than the answer, that I am finding more effective.

Doing mathematics in the whiteboard room goes beyond the behaviour of standing up and writing on the board and suggests a deeper cognitive investment in the doing of mathematics. Participants even preferred the whiteboard room to their regular tutorials, as noted by Mary:

Personally, I would find it more beneficial to not do the tutorial but go to two [whiteboard] workshops ... just for that extra practice doing the questions because I feel that is where I learn the most maths over the week.

Mary suggested a willingness to make cognitive investment in doing mathematics and directing effort to learn and understand the mathematics content. There is also link here to affective engagement.

Many participants expressed positive emotions, indicating that doing mathematics in the whiteboard room was a valuable and enjoyable experience. Mary was one of the participants who purchased her own whiteboard for use at home:

I went and bought a big whiteboard in the second week of uni...So, I thought, 'Well, [doing mathematics] works on the big whiteboard, I might use a whiteboard at home,' and I've done it ever since.

The whiteboard room thus extended Mary's interest, reflecting strong affective engagement. Most participants (5 of 6) identified positive emotional reactions to doing mathematics on the vertical whiteboards, for example, writing on the board, having space on the board, using a non-permanent surface and standing up to do mathematics. As a representative example, Laura explained:

I like working on the whiteboards ... seeing things bigger is better, and you can just rub things out really easily and fix it up. You have room to write up the steps on the side if you want to.

Laura described a number of advantages in doing mathematics on the whiteboard that created interest and enjoyment that apparently supported and eased her process of doing mathematics.

This positive affective engagement came with the large working space and the act of writing on the whiteboards (see also Sandison et al., 2015). Thus, the physical space allowed mathematics to become positive and affectively engaging.

Some participants commented that standing up for an hour (in the whiteboard room) could be tiring, however, Luke offered a different perspective:

Yeah, I like it [whiteboard workshop]. I go to an 8:30am workshop on [a] Friday morning. It's good to be up and moving around, it kind of wakes you up a bit. I have a two-hour tutorial after it and I have to sit down the entire time. I would much prefer the workshop because it is not as tiring, you get in there and you're awake. You do the work.

In summary, the physical space of the whiteboard room provides conditions conducive to participants' behavioural engagement to actively do mathematics; cognitive engagement in terms of the focus and investment in learning; and affective engagement in the form of the positive emotional responses of enjoyment, value and interest in doing mathematics.

### *Perceptions of Learning Activity in the Whiteboard Room*

This section explores the relationship between the physical space of the room and the interactional space where peers and the teacher influence perceptions of maths anxiety. All participants (6 of 6) felt a degree of maths anxiety if they lacked a strong understanding of mathematics content. Unsurprisingly, those participants with a low level of anxiety felt more confident in their abilities, whereas participants with medium and high levels of anxiety expressed feelings of worry and distress if they did not understand the content. For example, medium-anxiety-Mary reported: "I do have a lot of anxiety if I don't understand the concept. I do need a lot of one-on-one help with that and once I get that help then I'm fine." This finding is consistent with literature that associates PST' maths anxiety with perceived level of content knowledge (Trujillo & Hadfield, 1999; Uusimaki & Nason, 2004).

A majority of the participants (5 of 6) affirmed that doing mathematics in the whiteboard room, together with the social interactions afforded in the physical environment allowed them to explore and positively engage with the mathematics content. The result was more confidence in their abilities, which may account for the lowered maths anxiety, which is clear in Mary's comment:

We practise [mathematics] and practise doing it together. So, you are not just sitting at a desk by yourself looking at a piece of paper going, 'How do I do this?' You're on a whiteboard with other people that you are talking to and you are sharing solutions. You're interactive, it's fun .... You have someone to bounce off. And you have someone to explain it to you when you need the answer and that relaxes me with maths a lot.

The social aspects of learning together in a whiteboard room offer an important advantage for maths anxious pre-service teachers like Mary, including immediate feedback from the teacher, collaborative discussion with peers and collective writing on the board that makes thinking visible. Making thinking visible is important for learning mathematics and Liljedahl (2016a, 2016b, 2018) argues that this is what makes 'thinking classrooms' in schools. Importantly, the current study verifies this result with pre-service primary teachers.

While we did not directly measure time on task, study participants' perceptions of the whiteboard room are indicative of external and internal experiences of "flow" (Csikszentmihalyi,



1975). The external experience derives from the physical and social space of the whiteboard room where active engagement is encouraged and pre-service teachers feel a sense of belonging. Further, interactions in the social space provide opportunity to develop understanding of the weekly lecture content and immediate and individualised feedback affords a balance between challenge and skill, which is central to creating flow rather than anxiety or boredom (see also Liljedahl, 2016b, 2018).

The internal experience of flow refers to individual cognitive processes. In this research, we did not specifically examine cognitive activities during time in the whiteboard room, but the physical and social space allowed participants to comfortably explore their own thinking on the vertical boards. As a result of this exploration, participants began to experience doing mathematics as enjoyable and this helped to relieve their fears of failure and feelings of anxiety in engaging with mathematics problems. The whiteboard workshop was a largely positive influence on their feelings about their own learning. Even highly-anxious-Harry noted the benefits of peer collaboration for his learning: “[The students] know how to do it and explain it. Their thought processes are the same....[Working with peers] helps more than having someone [who is] older or more experienced.” Recall that Harry seemed to feel intimidated by the instructor, so the perceived benefit for his learning in working with peers is significant.

The whiteboard room replaces a more traditional view of a mathematics classroom where students sit at desks and work alone. The arrangement of the whiteboard room is a student-centred environment that encourages peer interactions and collaboration, which Liljedahl (2016a) argues keeps students from being anonymous and their activity hidden as when sitting at an individual desk or working alone. The current study also reports a positive result for participants’ perceptions of learning activity in the whiteboard room where learners visibly explore their own thinking that is fostered by positive interactions and collaboration between peers and the teacher. The whiteboards also influence the intrapersonal dimension, since all participants perceived improvement to their mathematics content knowledge, feeling more confident with the mathematics and showing a general easing of maths anxiety in the post A-MARS results.

## Discussion

In the current study, pre-service teachers’ perspectives reflect the multiple dimensions of engagement: behavioural, cognitive and affective (Fredricks, Blumenfeld, & Paris, 2004; Wang & Eccles, 2013). The arrangement of the vertical whiteboards makes for a highly participatory environment and thus, direct involvement in positive maths learning experiences for PST (Gresham, 2018). This high level of activity seemed to force students out of avoidance behaviours or the anonymity of a more traditional mathematics classroom (Liljedahl, 2016a). Along with receiving targeted feedback, standing up to solve mathematics problems on vertical whiteboards made them practice skills in public, which helps to mitigate behaviours typical among maths anxious learners such as avoidance or disengagement with mathematics tasks (Ashcraft, 2002; Cooke & Hurst, 2012; Haciomeroglu, 2013). Importantly, this has positive results for cognitive and affective engagement where pre-service teachers can develop a desire to understand the mathematics through directed effort and concentration. Thus, they were

involved with the mathematics in a different way and we hope that they take these new attitudes towards mathematics into their futures as primary school teachers.

## Implications and Conclusion

Maths anxiety is a learned condition and, therefore, can be unlearned (Whyte & Anthony, 2012). Thus, it is important for teacher educators to have sufficient awareness and understanding of possible causes, consequences and interventions in order to identify pre-service teachers at risk (Ashcraft, 2002). The A-MARS test (Alexander & Martray, 1989) is a simple way to draw attention to pre-service teachers' maths anxiety or negative feelings towards mathematics (Hurst & Cooke, 2012). A poor level of content knowledge also contributes to maths anxiety (Cooke & Hurst, 2013; Gleason, 2013; Rayner et al., 2009) and A-MARS results could provide the impetus for engaging pre-service teachers with specific interventions to mitigate anxiety and develop content knowledge. Results in the current study provide evidence that whiteboard rooms can be a learning environment where peer-to-peer interactions are supported and pre-service teachers' maths anxiety eased possibly because mathematics avoidance behaviours are minimised (Gonzales-DeHass, Furner, Vásquez-Colina, & Morris, 2017). Further research could analyse A-MARS data according to Alexander and Martray's (1989) sub-scales and seek relationships with whiteboard room pedagogies and content learning.

The current study contributes to our understanding of the phenomenon of maths anxiety in pre-service teacher mathematics education. To date, there has been limited research into the innovative pedagogical practices afforded by a whiteboard room in pre-service teacher education. Providing opportunities for pre-service teachers to change their perceptions of mathematics is important so that the cycle of maths anxiety is interrupted and not passed on to future generations of students. Thus, on a practical level, the current study raises important considerations for teacher education programs in supporting pre-service teachers to deal with their maths anxiety. Finally, by participating in the study, the pre-service teachers are more aware of and have discussed their own maths anxiety. This is significant as literature notes the importance for pre-service teachers to recognise the condition and be aware of their own anxiety in order to take initiative in their learning (Uusimaki & Kidman, 2004).

### *Study Limitations*

This small study with six participants is a very small sample and their perspectives may not be representative of the wider population of primary pre-service teachers. However, the sample was selected to gather perspectives from students with a range of levels of maths anxiety. These were volunteers who elected to participate in the research, which may reflect a high level of engagement with the subject overall. Interviews were conducted in the middle of the term and we were unable to interview the students a second time after they had finished the semester. The post-A-MARS measures suggest improvements to the participants' maths anxiety however, more detailed interrogation is necessary in order to attribute the changes simply to the whiteboard room. The connections between lowered maths anxiety and developing content knowledge also need further exploration. In other words, there are probably other factors contributing to the positive changes in A-MARS scores, including increased comfort and

confidence with mathematics generally that may have led to more active engagement throughout the term with other facets of the subject. Easing of maths anxiety may also be implicated in knowledge development, but this was not assessed in the current study. We would also like to know more about these teachers' longer-term attitudes toward mathematics and how doing mathematics in the whiteboard room may have shifted their thinking about being teachers of mathematics in primary schools either on practicum or in their own classrooms. In future, it will also be important to know more about the very highly maths anxious students who opted out of participating in the study. This field seems wide open for future research.

### *Acknowledgements*

We would like to acknowledge and thank the pre-service teachers who participated in this study. We also thank the reviewers for their thorough and helpful comments that have helped to improve the quality of this manuscript.

### References

- Adeyemi, A. (2015). Investigating and overcoming mathematics anxiety in in-service elementary school teachers (Unpublished doctoral thesis). University of Windsor, Ontario, Canada. Retrieved from <https://scholar.uwindsor.ca/etd/5463/>
- Akin, A., & Kurbanoglu, I. N. (2011). The relationships between math anxiety, math attitudes, and self-efficacy: A structural equation model. *Studia Psychologica, 53*, 263–273.
- Alexander, L., & Martray, C. (1989). The development of an abbreviated version of the Mathematics Anxiety Rating Scale. *Measurement and Evaluation in Counselling and Development, 22*, 143–59. Retrieved from <http://psycnet.apa.org/record/1990-08641-001>
- Anderson, J. R., Conrad, F. G., & Corbett, A. T. (1989). Skill acquisition and the LISP Tutor. *Cognitive Science, 13*, 467–505. [https://doi.org/10.1016/0364-0213\(89\)90021-9](https://doi.org/10.1016/0364-0213(89)90021-9)
- Arzarello, F., Paola, D., Robutti, O., & Sabena, C. (2009). Gestures as semiotic resources in the mathematics classroom. *Educational Studies in Mathematics, 70*(2), 97–109. DOI: 10.1007/s10649-008-9163-z
- Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions in Psychological Science, 11*(5), 181–185. doi: 10.1111/1467-8721.00196
- Ashcraft, M. H., & Kirk, E. P. (2001). The relationships among working memory, math anxiety, and performance. *Journal of Experimental Psychology: General, 130*, 224–237. doi: 10.1037/0096-3445.130.2.224
- Ashcraft, M. H., & Moore, A. M. (2009). Mathematics anxiety and the affective drop in performance. *Journal of Psychoeducational Assessment, 27*, 197–205. doi: 10.1177/0734282908330580
- Australian Institute for Teaching and School Leadership [AITSL]. (2011). *Australian professional standards for teachers*. Melbourne, VIC: Education Services Australia. Available: [www.aitsl.edu.au/teach/standards](http://www.aitsl.edu.au/teach/standards)
- Baloglu, M., & Koçak, R. (2006). A multivariate investigation of the differences in mathematics anxiety. *Personality and Individual Differences, 40*, 1325–1335. doi: <https://doi.org/10.1016/j.paid.2005.10.009>
- Barany, M. J., & MacKenzie, D. (2014). Chalk: Materials and concepts in mathematics research. In C. Coopmans, J. Vertesi, M. E. Lynch & S. Woolgar (Eds.), *Inside technology: Representation in scientific practice revisited* (pp. 107–129). Cambridge, MA: MIT Press.
- Barrett, D. (2013). Preservice elementary teachers' attitudes improve and math anxiety decreases with focus upon manipulatives use. *National Teacher Education Journal, 6*(2), 5–10.
- Beauchamp, G., & Kennewell, S. (2008). The influence of ICT on the interactivity of teaching. *Education and Information Technologies, 13*, 305–315. doi: <https://doi-org.ezproxy.uow.edu.au/10.1007/s10639-008-9071-y>

- Beilock, S. L., & Willingham, D. T. (2014). Math anxiety: Can teachers help students reduce it? Ask the cognitive scientist. *American Educator*, 38(2), 28–36. Retrieved from <https://www.aft.org/periodical/american-educator/summer-2014/ask-cognitive-scientist>
- Bekdemir, M. (2010). The pre-service teachers' mathematics anxiety related to depth of negative experiences in mathematics classroom while they were students. *Educational Studies in Mathematics*, 75, 311–28. DOI: 10.1007/s10649-010-9260-7
- Beswick, K., Ashman, D., Callingham, R., & McBain, D. (2011, December). Teachers' and pre-service teachers' confidence to teach primary school mathematics. In *Proceedings of the 2011 Australian Association for Research in Education Conference* (pp. 1-10). Hobart, TAS: AARE. Retrieved from <http://www.aare.edu.au/publications-database.php>
- Brown, B. A., Westenskow, A., & Moyer-Packenham, S. P. (2011). Elementary pre-service teachers: Can they experience mathematics teaching anxiety without having mathematic anxiety? *Issues in the Undergraduate Mathematics Preparation of School Teachers*, 5(4), 1–14.
- Choppin, J. (2011). The role of local theories: Teacher knowledge and its impact on engaging students with challenging tasks. *Mathematics Education Research Journal*, 23(1), 5–25. doi: 10.1007/s13394-011-001-8
- Cohen, L. D., & Rubinsten, O. (2017). Mothers, intrinsic math motivation, arithmetic skills, and math anxiety in elementary school. *Frontiers in Psychology*, 8(1939), 1-17. doi: 10.3389/fpsyg.2017.01939
- Confrey, J. (1994). A theory of intellectual development, Part I. *For the Learning of Mathematics*, 14(3), 2–8. Available: <http://www.jstor.org/stable/40248118>
- Cooke, A., & Hurst, C. (2012, December). Mathematics competency and situational mathematics anxiety: What are the links and how do these links affect teacher education programs? In J. Knight (Ed.), *Proceedings of the Australian Association for Research in Education and Asia-Pacific Educational Research Association Conference (AARE-APERA)* (pp. 1-8). Sydney, NSW: AARE. Retrieved from <http://www.aare.edu.au/data/publications/2012/Cooke12.pdf>
- Cooke, A., & Hurst, C. (2013). Relationships between mathematics anxiety, confidence to teach mathematics, and attitudes towards mathematics in pre-service teachers. In B. DiPaola (Ed.), *Proceedings of the International Commission on Mathematical Instruction Conference: Mathematics Education in a Globalised Environment* (pp. 213-216). Turin, Italy: Gruppo Ricerca Insegnamento delle Matematiche. Retrieved from <http://hdl.handle.net/20.500.11937/27952>
- Creswell, J. W. (2014). *Research design*. Thousand Oaks CA: SAGE Publications.
- Csikszentmihalyi, M. (1975). *Beyond boredom and anxiety*. San Francisco, CA: Jossey-Bass.
- Dreger, R. M., & Aiken Jr, L. R. (1957). The identification of number anxiety in a college population. *Journal of Educational Psychology*, 48, 344–353. doi:10.1037/h0045894
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74, 59-109.
- Geist, E. (2010). The anti-anxiety curriculum: Combating math anxiety in the classroom. *Journal of Instructional Psychology*, 37, 24–31.
- Gleason, J. (2013). Relationships between pre-service elementary teachers' mathematics anxiety and content knowledge for teaching. *Journal of Mathematical Science & Mathematics Education*, 3(1), 39–47.
- Gonzales-DeHass, A. R., Furner, J. M., Vásquez-Colina, M. D., & Morris, J. D. (2017). Pre-service elementary teachers' achievement goals and their relationship to math anxiety. *Learning and Individual Differences*, 60, 40-45.
- Gresham, G. (2007). An invitation into the investigation of the relationship between mathematics anxiety and learning styles in elementary pre-service teachers. *Journal of Invitational Theory and Practice*, 13, 24-33.
- Gresham, G. (2008). Mathematics anxiety and mathematics teacher efficacy in elementary pre-service teachers. *Teaching Education*, 19, 171-184. doi: 10.1080/10476210802250133

- Gresham, G. (2018). Preservice to inservice: Does mathematics anxiety change with teaching experience? *Journal of Teacher Education*, *69*(1), 90-107. doi: 10.1177/0022487117702580
- Greiffenhagen, C. (2014). The materiality of mathematics: Presenting mathematics at the blackboard. *The British Journal of Sociology*, *65*, 502-528. doi: 10.1111/1468-4446.12037
- Gunderson, E. A., Ramirez, G., Levine, S. C., & Beilock, S. L. (2012). The role of parents and teachers in the development of gender-related math attitudes. *Sex Roles*, *66*, 153-166. doi: 10.1007/s11199-011-9996-2
- Haciomeroglu, G. (2013). Mathematics anxiety and mathematical beliefs: What is the relationship in elementary pre-service teachers? *Issues in the Undergraduate Mathematics Preparation of School Teachers*, *5*, 1-9.
- Hadfield, O. D., & McNeil, K. (1994). The relationship between Myers-Briggs personality type and mathematics anxiety among preservice elementary teachers. *Journal of Instructional Psychology*, *21*, 375-384.
- Hadley, K. M., & Dorward, J. (2011). The relationship among elementary teachers' mathematics anxiety, mathematics instructional practices, and student mathematics achievement. *Journal of Curriculum and Instruction*, *5*(2), 27-44. doi: 10.3776/joci.2011.v5n2p27-44
- Hellum-Alexander, A. (2010). *Effective teaching strategies for alleviating math anxiety and increasing self-efficacy in secondary students*. (Unpublished masters thesis), Evergreen State College, Olympia, Washington, USA.
- Hiebert, J., Miller, E., & Berk, D. (2017). Relationships between mathematics teacher preparation and graduates' analyses of classroom teaching. *Elementary School Teacher*, *117*, 687-707. doi: <https://doi.org/10.1086/691685>
- Ho, H., Senturk, D., Lam, A. G., Zimmer, J. M., Hong, S., Okamoto, Y., ... Wang, C-P. (2000). The affective and cognitive dimensions of math anxiety: A cross-national study. *Journal for Research in Mathematics Education*, *31*, 362-379. doi: 10.2307/749811
- Hudson, W., & Morris, S. (1995). International education and innovative approaches to university teaching. *Australian Universities' Review*, *38*(2), 70-74.
- Hurst, C., & Cooke, A. (2012). Seeking a balance: Helping pre-service teachers develop positive attitudes towards mathematics as they develop competency. *Open Journal of Social Sciences*, *2*(4), 210-218. doi: <http://dx.doi.org/10.4236/jss.2014.24022>
- Ingvarson, L., & Rowley, G. (2017). Quality assurance in teacher education and outcomes: A study of 17 countries. *Educational Researcher*, *46*, 177-193. doi: 10.3102/0013189X17711900
- Itter, D., & Myers, N. (2017). Fear, loathing and ambivalence toward learning and teaching mathematics: Preservice teachers' perspectives. *Mathematics Teacher Education and Development*, *19*, 123-141.
- Lavasani, M. G., & Khandan, F. (2011). The effect of cooperative learning on mathematics anxiety and help seeking behavior. *Procedia-Social and Behavioral Sciences*, *15*, 271-276. doi: <https://doi.org/10.1016/j.sbspro.2011.03.085>
- Liljedahl, P. (2016a). Building thinking classrooms: Conditions for problem solving. In P. Felmer, J., Kilpatrick & E. Pedkhonen (Eds.), *Posing and solving mathematical problems: Advances and new perspectives* (pp. 361-386). New York, NY: Springer.
- Liljedahl, P. (2016b, 18 April). Engaging students: *Understanding Flow* (PowerPoint). Simon Fraser University. Retrieved from: <http://www.peterliljedahl.com/presentations>
- Liljedahl, P. (2018). On the edges of flow: Student problem solving behavior. In S. Carreira, N. Amado & K. Jones (Eds.), *Broadening the scope of research on mathematical problem solving: A focus on technology, creativity and affect* (pp. 505-524). New York, NY: Springer.
- 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*, 404-406. doi: <https://doi.org/10.1016/j.tics.2012.06.008>
- McLeod, B. D., Weisz, J. R., & Wood, J. J. (2007). Examining the association between parenting and childhood depression: A meta-analysis. *Clinical Psychology Review*, *27*, 986-1003. doi: <https://doi.org/10.1016/j.cpr.2007.03.001>

- Mensah, J. K., Okyere, M., & Kuranchie, A. (2013). Student attitude towards mathematics and performance: Does the teacher attitude matter. *Journal of Education and Practice*, *4*(3), 132–133.
- Mizala, A., Martínez, F., & Martínez, S. (2015). Pre-service elementary school teachers' expectations about student performance: How their beliefs are affected by their mathematics anxiety and student's gender. *Teaching and Teacher Education*, *50*, 70–78.
- New South Wales Board of Studies. (2012). *NSW Syllabus Mathematics K–10 – Volume 2: 7–10*. Sydney, NSW: NSW Board of Studies. Retrieved from <http://www.boardofstudies.nsw.edu.au/k-6/>
- Novak, E., & Tassell, J. L. (2017). Studying preservice teacher math anxiety and mathematics performance in geometry, word, and non-word problem solving. *Learning and Individual Differences*, *54*, 20–29.
- Núñez-Peña, M. I., Bono, R., & Suárez-Pellicioni, M. (2015). Feedback on students' performance: A possible way of reducing the negative effect of math anxiety in higher education. *International Journal of Educational Research*, *70*, 80–87. doi: <https://doi.org/10.1016/j.ijer.2015.02.005>
- O'Sullivan, C., Mac an Bhaird, C., Fitzmaurice, O., & Ni Fhlionn, E. (2014). *An Irish Mathematics Learning Support Network (IMLSN) Report on Student Evaluation of Mathematics Learning Support: Insights from a large scale multi-institutional survey*. National Centre for Excellence in Mathematics and Science Teaching and Learning (NCEMSTL), Ireland. Retrieved from: <http://eprints.maynoothuniversity.ie/6890/>
- Peker, M. (2009). Pre-service teachers' teaching anxiety about mathematics and their learning styles. *Eurasia Journal of Mathematics, Science & Technology Education*, *5*, 335–345. Available: <https://doi.org/10.12973/ejmste/75284>
- Perry, A. B. (2004). Decreasing math anxiety in college students. *College Student Journal*, *38*, 321–324.
- Pietsch, J. (2005). *Collaborative learning in mathematics*. (Unpublished doctoral dissertation). University of Sydney, Sydney, New South Wales. Retrieved from <http://ses.library.usyd.edu.au/handle/2123/1088>.
- Preciado-Babb, A. P., Metz, M., Sabbaghan, S., & Davis, B. (2015). Insights on the relationships between mathematics knowledge for teachers and curricular material. In T. G. Bartell, K. N. Bieda, R. T. Putnam, & H. Dominguez (Eds.), *Proceedings of the 37th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 796–803). East Lansing, MI: Michigan State University.
- Pruner, M. J. (2016). *Observations in a thinking classroom*. (Unpublished doctoral dissertation). Simon Fraser University, Burnaby, British Columbia, Canada. Retrieved from <http://summit.sfu.ca/item/16614>
- Radford, L. (2009). Why do gestures matter? Sensuous cognition and the palpability of mathematical meanings. *Educational Studies in Mathematics*, *70*, 111–126.
- Rayner, V., Pitsolantis, N., & Osana, H. (2009). Mathematics anxiety in preservice teachers: Its relationship to their conceptual and procedural knowledge of fractions. *Mathematics Education Research Journal*, *21*(3), 60–85. doi: <https://doi-org.ezproxy.uow.edu.au/10.1007/BF03217553>
- Ren, L., & Smith, W. M. (2018). Teacher characteristics and contextual factors: Links to early primary teachers' mathematical beliefs and attitudes. *Journal of Mathematics Teacher Education*, *21*, 321–350. doi: <https://doi.org/10.1007/s10857-017-9365-3>
- Richardson, F., & Suinn, R. (1972). The mathematics anxiety rating scale: Psychometric data. *Journal of Counselling Psychology*, *19*, 551–554. doi: <http://dx.doi.org.ezproxy.uow.edu.au/10.1037/h0033456>
- Romberg, T. A., & Kaput, J. J. (1999). Mathematics worth teaching, mathematics worth understanding. In E. Fennema & T. A. Romberg (Eds.), *Mathematics classrooms that promote understanding* (pp. 3–17). London: Routledge.
- Sandison, C. E., Forrester, T., & Denny, S. (2015). 'Work like a mathematician': A study of secondary students' level of engagement "doing" mathematics in a whiteboard room. In B. Ferruci & L. M. Thien (Eds.), *Revitalising mathematics teaching and learning culture towards sustainable living* (pp. 53–66). Penang, Malaysia: SEAMEO RECSAM.
- Seaton, K. A., King, D. M., & Sandison, C. E. (2014). Flipping the maths tutorial: A tale of n departments. *AustMS Gazette*, *41*(2), 99–113.
- Stake, R. E. (1995). *The art of case study research*. Thousand Oaks CA: SAGE Publications.

- Stipek, D., Salmon, J. M., Givvin, K. B., Kazemi, E., Saxe, G., & MacGyvers, V. L. (1998). The value (and convergence) of practices suggested by motivation research and promoted by mathematics education reformers. *Journal for Research in Mathematics Education*, *29*, 465–488.
- Suárez-Pellicioni, M., Núñez-Peña, M. I., & Colomé, À. (2016). Math anxiety: A review of its cognitive consequences, psychophysiological correlates, and brain bases. *Cognitive, Affective & Behavioral Neuroscience*, *16*, 3–22. doi: 10.3758/s13415-015-03790-7
- Suinn, R. M., & Edwards, R. (1982). The measurement of mathematics anxiety: The mathematics anxiety rating scale for adolescents – MARS – A. *Journal of Clinical Psychology*, *38*, 576–580.
- Swan, M. (2006). *Collaborative learning in mathematics: A challenge to our beliefs and practices*. London: National Institute for Advanced and Continuing Education (NIACE) for the National Research and Development Centre for Adult Literacy and Numeracy (NRDC).
- Teacher Education Ministerial Advisory Group (TEMAG). (2014). *Action now: Classroom ready teachers*. Retrieved from: <http://www.studentsfirst.gov.au/teacher-education-ministerial-advisory-group>
- Thiel, O., & Jenssen, L. (2018). Affective-motivational aspects of early childhood teacher students' knowledge about mathematics. *European Early Childhood Education Research Journal*, *26*, 512–534. doi: 10.1080/1350293X.2018.1488398
- Tobias, S. (1978). *Overcoming math anxiety*. New York, NY: W. W. Norton.
- Tobias, S. (1990). Math anxiety: An update. *NACADA Journal*, *10*(1), 47–50. doi: [www.nacadajournal.org/doi/pdf/10.12930/0271-9517-10.1.47](http://www.nacadajournal.org/doi/pdf/10.12930/0271-9517-10.1.47)
- Towers, J., Martin, L. C., & Heater, B. (2013). Teaching and learning mathematics in the collective. *The Journal of Mathematical Behaviour*, *32*, 424–433. doi: <https://doi.org/10.1016/j.jmathb.2013.04.005>
- 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*, 219–219.
- Uusimaki, L., & Kidman, G. (2004, July). *Challenging math-anxiety: An intervention model*. Paper presented at the International Conference of Mathematics Teacher Education (ICME), Copenhagen, Denmark.
- Uusimaki, L., & Nason, R. (2004). Causes underlying pre-service teachers' negative beliefs and anxieties about mathematics. *Proceedings of the 28th Conference of the International Group for the Psychology of Mathematics Education*, *4*, 369–376.
- Vinson, B. (2001). A comparison of pre-service teacher's mathematics anxiety before and after a methods class emphasizing manipulative. *Early Childhood Education Journal*, *29*, 89–94.
- Vukovic, R. K., Roberts, S. O., & Green Wright, L. (2013). From parental involvement to children's mathematical performance: The role of mathematics anxiety. *Early Education & Development*, *24*, 446–467. doi: 10.1080/10409289.2012.693430
- Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University.
- Wake, G., & Pampaka, M. (2008). The central role of the teacher—even in student centred pedagogies. In O. Figueras, J. L. Cortina, S. Alatorre, T. Rojano & A. Sepúlveda (Eds.), *Proceedings of the Joint Meeting of PME32 and PME-NA, Vol. 4* (pp. 377–384). Mexico: Cinvestav-UMSNH.
- Wang, M. T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, *22*, 31–39. doi: 10.1111/j.1532-7795.2011.00753.x
- Whyte, J., & Anthony, G. (2012). Maths anxiety: The fear factor in the mathematics classroom. *New Zealand Journal of Teachers' Work*, *9*(1), 6–15.
- Wilder, S. (2012). *Gender difference in factors pertaining to math anxiety among college students*. ProQuest Dissertations Publishing 3510769. University of Akron, Ohio, US.
- Woodard, T. (2004). The effects of math anxiety on post-secondary developmental students as related to achievement, gender and age. *Inquiry*, *9*(1), 1. Retrieved from: <https://eric.ed.gov/?id=EJ876845>

### *Authors*

Sarah Sanders  
Villawood East Primary School  
email: sarah.sanders11@det.nsw.edu.au

Wendy Nielsen  
School of Education, University of Wollongong  
email: wnielsen@uow.edu.au

Caz Sandison  
School of Mathematics, University of Wollongong  
email: sandison@uow.edu.au

Tricia Forrester  
School of Education, University of Wollongong  
email: tricia@uow.edu.au