

Synthesising the Literature Concerning Math Anxiety to Inform a Project on Pre-service Teacher Retention Rates

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Abstract

This article reviews literature regarding numeracy and mathematics anxiety and considers the role of teacher efficacy as a predictor of teachers' competence and commitment to teaching. This examination of previous studies leads to discussion of a proposed project that is predicted to confirm the expected correlations between high Anxiety / poor Numeracy levels and lowered retention rates of University pre-service Education students. The study will inform pedagogy in addressing problems in pre-service teachers, especially for groups at high risk such as low SES and Indigenous students - these students often miss out on targeted help. The findings should lead to better long-term outcomes for pre-service teachers and their future students. It has high significance as many current University pre-service Education students exhibit mathematics problems. The method would involve both general surveys of current students in Numeracy courses and follow up interviews. An intervention strategy would be developed and offered to at-risk students.

Keywords: STEM, Conference Proceedings, Teacher Quality, Teacher Retention

Introduction

Both the quantity and quality of mathematics teachers entering the profession are of major concern to governments, universities and schools. This article looks at the known problems that many pre-service teachers bring to their studies of numeracy and seeks to provide a way for these to be resolved for the benefit of the students themselves, the current institution at which they study and the future students they will teach. It is a given understanding that high quality teachers of mathematics are required to instil a love of mathematics in students and allow all to develop their potential abilities in numeracy, but current outcomes demonstrate that this is not being achieved for many students within school mathematics programs. Hence, this knowledge provides a wake-up call for universities to look at their pre-service teacher programs.

University students studying to become teachers in Australia come from diverse backgrounds and have a wide range of attitudes and abilities towards mathematics. A large number of students wanting to become primary school teachers have been found to have negative feelings about mathematics (Cohen & Green, 2002; Levine, 1996). According to Taylor and Galligan (2006), negative attitudes towards mathematics often manifest in a phenomenon known as math anxiety which is commonly seen as a barrier to the success of students' performance in the subject. A significant body of research suggests that pre-service teachers experience higher levels of mathematics anxiety than other university students (e.g Iossi, 2007; Bursal & Paznokas, 2006; Swars, Daane & Giesen, 2006; Haylock, 2001; Vinson, 2001; Trujillo & Hadfield, 1999; Harper & Daane, 1998). Pre-service teachers are expected to teach their students for numerate participation in a global world, although they themselves often lack the necessary mathematical foundations and strategic and critical skills (Klein,

2008). Durrani and Tariq (2009) indicate that undergraduates revealing high levels of math anxiety tend to hold negative attitudes towards the development of numeracy skills. They continue by saying that these students lack confidence, are not motivated to develop numeracy skills and express little enjoyment of numeracy. All the above indicate that feelings towards mathematics play a major role in some students' math capabilities. "By ignoring the powerful role that anxiety plays in mathematical situations, we are overlooking an important piece of the equation in terms of understanding how people learn and perform mathematics" (Maloney & Beilock, 2012).

This problem has been documented for a great many years in many countries and, despite various attempts to resolve the issues, remains an unsolved challenge. Negative attitudes to math, math anxiety and poor numeracy skills seem to be closely linked, even if specific studies have not been done to confirm directly the combined linkages. However, the resulting effects of all three are similar, namely to produce a lack of confidence in the ability of pre-service teachers to teach numeracy skills. In comparison, little has been formally done to compare the retention rates of students who have this problem. Negative attitudes towards mathematics may impede pre-service teachers' ability to engage in mathematical content and pedagogical subjects designed to improve their mathematical understandings (Ebby, 1999). This finding indicates that, besides the retention rate aspect which directly affects the financial situation for students and universities, these students may not necessarily receive the full benefit of courses that they do pass. Clearly there is a need to provide assistance to these students. Our university, the University of Southern Queensland (USQ), provides support in the form of self-help on-line tutorials, access to courses specifically designed to remedy math deficiencies and individual Student Support services, yet it is not clear that students necessarily take advantage of them, especially if they manage to achieve a bare pass in the relevant courses. In addition, there are numerous examples of students from Indigenous and low SES backgrounds being less willing to access services for many reasons.

This article clarifies what is meant by the word 'numeracy' and then looks at aspects from the extensive literature on math anxiety and efficacy issues. Finally, a look at what has already been achieved will be related to what has to be done next. Whilst this project is specifically aimed at USQ's own students, the problems are clearly worldwide and hence this article provides the literature basis for any education pre-service teacher provider to look at their own situation.

Literature Review

Numeracy

The term 'numeracy' has taken on several meanings since its first use in the late 1950s. Currently in Queensland, "Numeracy involves abilities that include interpreting, applying and communicating mathematical information in commonly encountered situations to enable full, critical and effective participation in a wide range of life roles" (Queensland School Curriculum Council, 2001, p2). Other places use similar ideas. Numeracy necessarily involves understanding some mathematical ideas, notations and techniques, it also involves drawing on knowledge of particular contexts and circumstances in deciding when to use mathematics, choosing the mathematics to use and critically evaluating its use. Each individual's interpretation of the world draws on understandings of number, measurement, probability, data and spatial sense combined with critical mathematical thinking. The

summary that we use at USQ encapsulates these ideas, namely that numeracy is being able to apply math in the context of the real world (i.e. to life).

Education Queensland (2007) stressed that teachers must be well equipped to ensure that their students have the confidence to apply mathematics in their everyday lives. In other words, teachers need to be numerate themselves in order to have any chance of undertaking this task successfully. Many pre-service teachers, especially those keen to teach in primary and early years' classrooms, lack robust mathematical knowledge, confidence and a positive disposition in application of mathematical ideas and strategies. They often revert to traditional ways of working even when they are well versed in, and approve of, more innovative and inquiry-based methods (Foss & Kleinsasser, 1996). Related to this is the phenomenon whereby some pre-service teachers feel uncomfortable with proposed 'new' methods and resist them from the start. For example, as Nicol (2006, p. 31) found in her research, pre-service teachers collectively agreed that "teaching in ways that respect students' thinking and sense-making was not worth the time, the effort or the consequences". Hence a lack of personal numeracy seems to be reflected in the type of pedagogy that pre-service teachers are prepared to utilise, which has enormous ramifications for how universities might need to structure their pre-service courses for these students.

Math Anxiety in Teachers

The following results form part of the unpublished thesis on math anxiety in primary school children undertaken by one of the authors (Flegg, 2007). 17 of the class teachers whose students took part returned teacher questionnaires. Nearly a third of these disliked math and all of these were female. In addition, females were more likely to have had problems with math at school themselves. Collating these two areas gave a positive correlation between disliking teaching math and having difficulties themselves at school. As females make up the vast majority of primary teachers in Queensland, this is a very disturbing statistic if it were representative of the wider population of teachers. More recent research carried out in the United States of America (USA) stated: "In early elementary school, where the teachers are almost all female, teachers' math anxiety carries consequences for girls' math achievement by influencing girls' beliefs about who is good at math" (Beilock, Gunderson, Ramirez & Levine, 2009). This research puts the gender relationship at the forefront of the picture whilst also making the point that most teachers of this level in the USA are female, a similar statistic to that in Australia. It also indicated that boys were not affected greatly by the anxieties of their female teachers, a result which has yet to be confirmed for Australian students.

Additional questions elicited that almost all the teachers had positive things to say about the teaching of math, although those having difficulties mentioned personal confidence issues in the classroom. The thesis focused on math anxiety in children and elicited from these teachers that probably between 10-30% of their students had some form of math anxiety issue. If children are already anxious in primary school, nothing we are doing in the classroom seems to be providing the necessary support as these figures are also reflected in the pre-service teacher populations. For instance, an on-line survey was available to USQ students as part of their Foundations of Numeracy course. Anecdotally, the great majority of the students on the course were female, although the survey result didn't distinguish this. Approximately 30% of students who took the survey were math challenged (USQ internal survey result for EDX1280, July 2012). This is in line with other indicators noted in this article and reinforces the vital need for action.

It is interesting to note that recent USA research has concluded that "... negative math attitudes can prevent individuals from performing at their best" (Gunderson, Ramirez, Levine & Beilock, 2011) and that math attitudes in children are especially influenced by both parents and teachers. This reinforces the results previously indicated in Australia that parents and teachers are the primary cause of math anxiety in young children (Flegg, 2007) and demonstrates that working within the classroom and with pre-service teachers may not solve the problem, although it could be expected to significantly help.

Math Anxiety in Pre-service Teachers

Many primary school teachers express anxiety about their ability to teach mathematics well (Conrad & Tracy, 1992; Tosh, 1985a; Tosh, 1985b). It will be demonstrated that these concerns remain valid today. Their concerns relate to teachers' ability to teach mathematics well, especially as many teachers struggled themselves with the mathematics component of their own study, and this lack of confidence could be adding to student anxiety levels. Additionally, these teachers, due to their own problems with mathematics, may not be providing the positive reinforcement of mathematics required within the classroom (Flegg, 2007). All teachers are required to be numerate, but primary teachers have the key introductory task. Why might they not have this core understanding? It could be based on their own lack of prior math knowledge / skills or they could be suffering from math anxiety themselves.

Tosh (1985b) linked poor attitudes in her own pre-service teachers with math anxiety and felt that it needed to be addressed urgently. She found some had difficulties in all three areas she thought important, namely content, pedagogy and enthusiasm. Previous studies had looked at these math related problems from a psychiatric perspective (as another type of anxiety) and these had not been seen to be successful. Changing the emphasis from the negative anxiety approach to one of building up a student's self-confidence was much more successful. That problems often stemmed from childhood experiences seemed self-evident, but the discussion was one of a cycle whose entry point wasn't important since lack of self-confidence bred a lack of future success. Ten years later, Martinez (1996) administered a 'Math Anxiety Self-quiz' to his primary pre-service teachers and found that the majority felt that they were "highly math anxious". He believed that, whilst knowing the mathematics quite well, these students could be giving out negative signals to their classes without realising it. Many lacked confidence in their own ability, which confirmed findings from earlier reports.

Wyness (1996) discussed the idea that, as teachers are often alone in their classroom, exactly what they do is unrecorded and may not be "as well structured" as expected. In other words, whilst most teachers know what they should be doing, whether they actually do it is another question and this may affect answers to studies if the study is responded to at all. This lack of response could be for many reasons, but workload increase must certainly be one reason, especially in Queensland where a study of hours of contact time in OECD countries found Queensland primary teachers had the greatest load (McLennan, 2004). Workload is important because it relates to other issues in schools which make consistent results from studies in this area problematic.

Stuart (2000) postulated that the development of negative beliefs about mathematics can be influenced by parents, siblings and fellow peers. Parental influence was subsequently found as a major factor in creating math anxiety in young school children (Flegg, 2007). However, many teachers' negative beliefs about mathematics originated from prior school experiences.

For example, negative feelings towards mathematics can be traced back to the frustration and failure in learning the subject caused by unsympathetic teachers who incorrectly assumed that computational processes were simple and self-explanatory (Cornell, 1999). Grootenboer (2001) reported similar findings from his study on the perception of pre-service primary teachers of their mathematics teachers. There is strong evidence that many pre-service teachers have a fear of mathematics and see themselves as unable to learn effectively (Haylock, 2001). In the United States, mathematics anxiety is particularly prevalent among college students majoring in elementary education. Studies have consistently shown that elementary education majors have one of the highest levels of mathematics anxiety on college campuses (Kelly & Tomhave, 1985; Hembree, 1990). Rech, Hartzell and Stephens (1993) compared pre-service teachers to the general college population and found that pre-service teachers had poorer attitudes about math and decreased math competence.

These issues have been repeatedly investigated over many years, as other studies demonstrate (Zevenbergen, 2005; Goulding, Rowland & Barber, 2002) and nothing specific has been done to address the issues raised for the general population. Contradictions still exist about which students are most likely to display high levels of math anxiety, compared to anxiety as a personality trait or generalized high-stakes test and evaluation anxiety (Mellamby & Zimdars, 2010; Hembree, 1990). In a number of studies, age and gender were discovered to be significant predictors of anxiety towards mathematics (Baloglu & Kocak, 2006; Baloglu, 2002; Hembree, 1990), but not in others (Andile, 2009; Sirmaci, 2007). In some recent studies, the previous experience of mathematics and statistics are also deemed reliable predictors of anxiety (Ashcraft & Moore, 2009; Baloglu & Kocak, 2006; Baloglu, 2002). In addition, no unifying statements can be easily made about the impact of math anxiety on student achievement (Kyttälä & Björn, 2010). According to Payne and Israel (2010), high levels of math-anxiety often result in impaired performance but Lee (2009) showed that math anxiety was a well-delineated, valid construct that was highly correlated with achievement scores. He further hypothesized that all three constructs he studied relate to the societal and educational environment of students since certain populations of students scoring high on the math-anxiety scale also performed well on the mathematics scores of the Programme of International Student Assessment (PISA). This phenomenon could shed light to Bandura's (1997) social cognitive theory that asserts students' beliefs about the value of a learning activity, their expectation of success and their enjoyment of it will motivate them to undertake it.

Emotion and Math-Anxiety

In a research study to find out the role emotion plays in learning mathematics, Uusimaki and Kidman (2004) designed an Online Anxiety Survey to measure three positive and three negative feeling responses as perceived by 16 third-year pre-service primary student teachers enrolled in a mathematics education curriculum unit at a major metropolitan university in Eastern Australia. The 16 participants (15 female and 1 male) were selected from a pool of 45 self-identified math-anxious students who volunteered for the study. The criteria for selection were degree of math anxiety, access to internet, and availability to attend workshops.

The participants had to go through four phases. The first phase was to identify the origins of math-anxiety. This was possible through semi-structured interviews of half hour duration. Phase two was the enactment of the intervention program where the participants had to partake in four 60 minute activities introduced in workshop situations. The third phase was the summative evaluation where all participants were required to produce a written reflection

about their experiences in the project. From their written reflections, the researchers identified potential relationships between perceptions of higher mathematical competence and lower levels of anxiety. Following the written reflections, the final phase of semi-structured interviews was conducted to further investigate any changes to perceptions that may or may not have occurred.

According to Uusimaki and Kidman (2004), the Online Anxiety Survey was effective in being able to record the emotional state of the participants before and after each of the four mathematical activities. They saw statistically significant increases in most of the participants' levels of positive feelings (i.e., comfort, confidence and feeling fine) and significant reductions in their negative feelings (i.e., nervousness and worry). It is the fear of failure and worry that affects performance even when the mathematics is well within the skill level of, as in this study, the pre-service student teacher.

Efficacy

Math-anxious pre-service teachers also had lower levels of mathematics teaching self-efficacy (Bursal & Paznokas, 2006; Swars et al, 2006). Thus there is argument that mathematical anxiety among pre-service teachers must be overcome if they are to develop the knowledge necessary to become effective mathematics teachers. Patricia Ashton defined efficacy as the extent to which teachers feel confident they are capable of bringing about learning outcomes (Ashton, 1984). Ashton identified two dimensions of teaching efficacy, namely general (the extent to which a teacher believes her students can learn material) and personal (the extent to which a teacher believes her students can learn under her instruction). Ashton argued that teachers' beliefs about their ability to bring about outcomes in their classrooms, and their confidence in teaching in general, play a central role in their abilities to effectively serve their students.

Subsequent understandings of teaching efficacy have refined Ashton's understanding of personal efficacy. In a seminal review of teacher efficacy, Tschannen-Moran and Woolfolk Hoy operationalized teachers' sense of control over student outcomes in the Teachers' Sense of Efficacy Scale (TSES) (Tshannen-Moran & Woolfolk Hoy, 2001). Rather than thinking about efficacy as a proxy for a global sense of confidence, they defined teacher efficacy as teachers' perceptions of their resources and strategies for bringing about student behavioural and instructional outcomes. Rather than ask "How much can you help your students think critically", the TSES asks "How much can you do to help your students think critically". This minor change in wording illustrates a critical issue in teacher efficacy research, namely that teachers' sense of efficacy reflects the judgements they make about their capabilities given the emotional and instrumental resources they can gather in a specific context.

Bandura (1997) identified four specific sources of efficacy beliefs: mastery experiences, vicarious experiences, verbal persuasion and arousal. Mastery experiences are direct encounters with success through engagement in a behaviour that brings about a desired outcome. For example, pre-service teachers who facilitate laboratory experiments in which students demonstrate conceptual understanding may believe their actions led to student learning. These judgements are likely to increase their efficacy for conducting lab experiments in the future. This may be why some studies have found a connection between teacher education course-work and pre-service teacher efficacy. If pre-service teachers watch experienced teachers successfully facilitate laboratory experiments, they might also develop a sense of efficacy because they saw how to implement the actions necessary to bring about

students' success. This would be an example of a vicarious or observed experience leading to higher efficacy.

When pre-service teachers do not have opportunities to observe, their mentor teachers might remind them of the teaching skills they have developed and provide them with specific suggestions. This would be an example of verbal persuasion, which appeals to the teacher's ability to bring about success. Finally, arousal is a physiological state involving the release of hormones that signal an individual to prepare for action. Arousal can be interpreted as both pleasant and unpleasant. On the one hand, the body's natural release of hormones while teaching can help teachers feel alert or excited to take on the challenges of the lesson. On the other hand, heavy release of hormones (as in the case of extreme nervousness) can be paralyzing rather than helpful.

Moreover, teacher efficacy beliefs emerge, in part, as a function of teachers' global and specific judgements about themselves within the context of their classroom. In the field of teacher beliefs, there has been a lot of debate about how best to study the relationship between teachers' beliefs about themselves and the impact of these beliefs on classroom learning. Although teacher efficacy is related to self-concept, self-esteem, locus of control and sense of responsibility, it is theoretically and empirically distinct from these constructs. On a global level, teachers hold beliefs about who they are in their classroom, their teaching self-concept, how they feel about themselves in their classrooms and their teaching self-esteem. Teachers' self-concepts and self-esteem are considered global because they are broad, descriptive mental representations teachers hold about the work they do in their classrooms. In contrast, scholars studying teacher efficacy attempt to identify specific, task-related judgements teachers make about their ability to bring about task-specific outcomes.

Scholars studying teachers' locus of control and their sense of responsibility are primarily focused on teachers' perceptions of their roles in student achievement. Role attributes are beliefs about the part a teacher can play in bringing about outcomes. Guskey (1988) characterizes teachers' perceptions of control as based primarily in the teacher (internal) or other factors (external) and variable across situations. If control over an outcome is attributed internally, individuals are more likely to engage in a specific behaviour. The critical distinction between locus of control and self-efficacy is the emphasis on product rather than process, where locus of control asserts that individuals are motivated to act based upon perception of control over the outcome. If teachers believe control lies within the student (e.g., smart/dull) or other external factors (e.g. family/community), they may be less likely to engage in actions that bring about desired outcomes even if they feel they can successfully execute those actions.

Empirical studies have recognized teacher efficacy as a major predictor of teachers' competence and commitment to teaching—more powerful than self-concept, self-esteem, and perceived control. Four seminal reviews of the impact of teacher efficacy by Ross (1998), Goddard, Hoy & Woolfolk Hoy (2000), Labone (2004) and Wheatley (2005) reveal consistent findings: teachers who report a higher sense of efficacy tend to be more likely to enter the field, report higher overall satisfaction with their jobs, display greater effort and motivation, take on extra roles in their schools and are more resilient across the span of their career. They are also more likely to learn and use innovative strategies for teaching, implement management techniques that provide for student autonomy, set attainable goals, persist in the face of student failure, willingly offer special assistance to low achieving

students and design instruction that develops students' self-perceptions of their academic skills. Moreover, Woolfolk Hoy and Davis (2005) argue that teachers who feel efficacious about their instruction, management and relationships with students may have more cognitive and emotional resources available to press students towards completing more complex tasks and developing deeper understandings. This is because teachers with a high sense of efficacy may be less afraid of student conflict and more likely to take greater intellectual and interpersonal risks in the classroom.

On the other hand, pre-service teachers with little or no teaching experience may lack a sense of efficacy; therefore, programme developers need to think carefully about how to structure entry into the field in a way that promotes mastery. Rohrkemper and Corno (1988) cautioned teachers not to ignore the value of “functional failure.” Teachers are encouraged to create context in which students can learn from mistakes and learn to persist even when unsuccessful.

Summary

The following table summarises key ideas that have been highlighted above and leads directly onto the final section which addresses why the project is thought potentially to provide significant new information:

Table 1: Key Ideas from the Literature

Reference	Key ideas	Conclusions
Ebby (1999) (page 2)	Negative attitudes towards mathematics may impede pre-service teachers' ability to engage in mathematical content and pedagogical subjects designed to improve their mathematical understandings.	Improvement in attitudes towards mathematics may improve retention and progress.
Tosh (1985b) (page 4)	... linked poor attitudes in her own pre-service teachers with math anxiety ...	Importance of building up the self-confidence of students.
Ashton (1984) (page 6)	... teachers' beliefs about their ability to bring about outcomes in their classrooms, and their confidence in teaching in general, play a central role in their abilities to effectively serve their students.	Promotion of efficacy will positively impact competence of teachers and hence the outcomes of their teaching.
Beilock et al (2009) (page 3)	... puts the gender relationship at the forefront of the picture whilst also making the point that most teachers of this level ... are female	Reinforces the notion that, in primary school, this is mainly a female problem
Maloney & Beilock (2012) (page 2)	By ignoring the powerful role that anxiety plays in mathematical situations, we are overlooking an important piece of the equation ...	Demonstrates the need for action.

Where to Next?

Issues with the teaching of mathematics for pre-service teachers, whether based on a genuine lack of understanding of the math or just a perception of it, clearly remain current as the more recent studies mentioned have demonstrated. That these issues have been discussed for a great many years without any clearly defined method of prevention is also very apparent. Nevertheless, a great deal of work has clearly been done to understand the processes that will form the basis of any organised approach. The proposed research study will extend the literature by investigating the relationship with retention rates and demonstrating for USQ students a more targeted approach to providing assistance which could be useful elsewhere. The majority of USQ Education students are on-line (more than 60% in 2012); they come from all age groups, include a wide range of backgrounds and reside all over Australia and overseas. The project intends to question more than 1000 USQ pre-service Education students and to answer the following proposed research questions relating to these students: (1) What is the relationship between high Anxiety / poor Numeracy levels and Retention rates? (2) Are there clearly defined groups of at-risk students? (3) Are at-risk students accessing targeted math help effectively? In addition, it should help to close any gaps in support availability that would allow students to miss out on targeted help with their math levels.

Following ethics clearance, this project will survey current and past numeracy students about their anxiety levels with mathematics and relate this to their progression and retention rates. Questions will also elicit information about how much they have accessed the help currently available and what they would also like to be available to them. Initially, on-line questionnaires will be utilised, but follow-up investigations will of necessity require a more individualised approach. Students who identify as Indigenous or low SES would be followed up first, as these groups are thought to be especially at risk, but it is clear from the numbers involved that the issue is more widespread than these two specific groupings. From the results, either encouragement or alternative methods would be utilised to assist these students. In addition, aspects which were shown to be of a more general concern would be incorporated into the numeracy program.

In conclusion, the literature makes it clear that this is a widespread problem that has been recognised for many years and yet has not been satisfactorily addressed. Whilst successful attempts have been made with groups of students by concerned individuals, nothing on an institutionalised basis has happened. At USQ, this project will address this issue directly to assist current and future students and provide evidence in the literature of the outcomes of the intervention. As USQ students come from so many places, including overseas, the results should indicate trends that have direct relevance to a much wider audience.

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