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# Mathematics Anxiety in Pre-service Primary Teachers with Low Hurdle Test Achievements

C. Lozanovski\* and J. Poulton\*\*

*\*Faculty of Arts & Sciences, Australian Catholic University, Australia*  
[con.lozanovski@acu.edu.au](mailto:con.lozanovski@acu.edu.au)

*\*\*School of Education, Melbourne Institute of Technology, Australia*

We report on a case study of first year undergraduate pre-service primary teachers that are required to pass the compulsory mathematics competency test as part of the mathematics education unit. These students struggled with this task and many required multiple attempts before success whilst others remain unsuccessful. The students were surveyed after the fourth attempt had been completed. The instrument used was an abbreviated version of the MARS instrument (AMAS). Interestingly, the anxiety students experienced appeared to be related to test anxiety. According to the instrument used the overall mathematics anxiety was less than average. This suggests issues related to the quality of the test procedure in addition to a deficiency of knowledge in mathematical content. We propose that simply increasing the number of attempts via an online solution masks the underlying problem. We make some practical suggestions for mathematics competency testing that may circumvent such problems without the need for watering down standards.

Keywords: Mathematics Anxiety, AMAS, Pre-service Primary Teachers,  
Mathematics Hurdle Test

*"Forget safety. Live where you fear to live." Rumi*

## Introduction

The Group of Eight - Go8 (Brown, 2009) released the results of an intensive investigation on the state of mathematics in Australia, presenting a key finding that the mathematical sciences across the country have deteriorated to a "dangerous level". One of the focal points of their investigation was on pre-service primary teachers, their knowledge of mathematics and their confidence in teaching mathematics. The review states that "Phobia [of mathematics] is surprisingly common in these groups and, presumably, it transfers to the school students" (see Page 4, Brown, 2009). Battista (1986) establishes a link between the quality of mathematics primary school teachers and the standard of pre-service preparation. He points out that key contributing factors are poor knowledge and attitudes towards mathematics. More recently, Vinson (2001)

and Gresham (2007) concluded that these dire attitudes toward mathematics by teachers can manifest anxiety in their students. It is important to note that attitude alone does not adequately describe affective and cognitive processes when experiencing anxiety. Swetman et al, (1993) relate teacher anxiety towards mathematics to poor lesson planning, such as when teachers choose to focus on non-mathematics related activities thereby diluting mathematical content.

There appears to be a significant relationship but moderate correlation between test anxiety and mathematics anxiety (Schnell et al, 2013). Regression analyses show that the level of mathematics anxiety can be used to predict math performance whereas test anxiety explains additional variance for overall academic performance (Schnell et al, 2013). Mathematics and test anxiety may have intersecting features but do not constitute the same psychological phenomena. Test anxiety is typically experienced in examination conditions where the cognitive facet of distress has a negative consequence on performance (Chapel et al, 2005) and, therefore, outcome.

Mathematics anxiety is defined by Richardson and Suinn (1972) as involving the “feelings of tension and anxiety” when dealing with quantitative issues such as solving mathematical problems in all aspects of life. The feelings of tension and anxiety are multi-faceted, consisting of an attitudinal (revolt, loathing, etc), a cognitive (worry, stress, etc) and an affective (nervousness, panic, etc) dimension (McLeod 1994, Bibby 2002, Hart 1989). It is not unheard of to have students burst into tears whilst attempting to carry out a simple arithmetic task (Ashcraft, 2002). When mathematics anxiety in a teacher or student is triggered during computational tasks their working memory is compromised (Ashcraft and Krause, 2007). Since working memory is essential for the cognitive process during mathematical problem solving (Raghubar et al, 2010) this results in low mathematics achievement (Buelow and Frakey, 2013). However, mathematics anxiety can produce even more profound negative effects on students' immediate decisions involving the study of mathematics. The worst manifestations of the condition result in secondary and tertiary students dropping courses altogether or avoiding quantitative disciplines (avoidance behaviour) which results in the exclusion of possible and important career paths. A more subtle effect is seen if students experiencing mathematics anxiety choose to become primary teachers where a cyclical transfer of anxiety from teacher to students occurs, this is a degenerative process (Bibby, 2002). Pre-service teachers with higher levels of mathematics anxiety tend to have lower levels of mathematics teacher efficacy (Gresham 2008).

The causal ordering of mathematics anxiety-achievement is a contentious issue (Ma and Xu 2004, Sherman and Wither 2003, Ma 1999). Does mathematics anxiety cause a low achievement in mathematics or is the converse true, or is there some other factor causing both? Whatever the case may be, however, there is a large enough body of work, including numerous meta-analyses, which reinforces a negative correlation between mathematics anxiety and achievement in mathematics (Pourmoslemi et al, 2013). For example, the meta-analysis by Ma (1999) concludes a population correlation of -0.27, which is significant at the 1/100th level, indicating the unlikelihood that this population correlation occurred by chance alone. The meta-analysis considered 26 (all post 1975) independent studies, ranging from Grades 4 to 12, across various countries. However, Hembree's (1990) meta-analysis which draws similar conclusions also considers undergraduate students.

Students entering First Year University that require enrolment in a quantitative discipline as part of their course requirements can experience severe problems if they have mathematics anxiety. In this study we consider the impact of mathematics anxiety on a cohort of first year pre-service primary teachers that are required to pass a hurdle assessment task. It is common place in the Australian university sector for education students to encounter, course level, mathematics hurdle tests. For example, Federation University has introduced a hurdle test for all students studying a mathematics subject. This hurdle test is a multiple choice test that is based at ACSF (Australian Core Skills Framework) level 4. Content covered by this hurdle test includes number operations, measurement, fractions, decimals ratio, percentage, chance and statistics. This hurdle test has been introduced as an integral part of the course to prepare students for the numeracy test that is being introduced by AITSL (Australian Institute of teaching and School Leadership) in 2015. The details of the numeracy test are still being finalised by AITSL (2014).

We used the AMAS instrument, as motivated by the review of the section II, in this study. The methodology is then given in section III followed by the analysis in section IV. A subset of the AMAS instrument is related to test anxiety. This is one of the lines of enquiry of the analysis presented in section IV. The study is concluded with a brief discussion.

## **Instruments**

The first attempts at the development of a mathematics anxiety instrument dates back to the fifties (Dreger and Aiken 1957, Taylor 1953), the so-called Manifest Anxiety Scale (MAS).

However, this was superseded by the preferred instrument which involved 98 items with a 5-point Likert scale, the so-called Math Anxiety Rating Scale (MARS), introduced by Richardson and Suinn (1972). As the research area grew there was a need to reduce the number of items, at least for the time needed to implement the instrument, which lead to various abbreviated versions of the MARS instrument. This includes the 6 item Anxiety Toward Mathematics Scale (ATMS) (Sandman, 1979), the 12 item Mathematics Anxiety Scale (MAS) (Fennema and Sherman, 1976), the 24 item Mathematics Anxiety Rating Scale–Revised (MARS-R) (Plake and Parker, 1982), the 25 item abbreviated Math Anxiety Rating Scale (aMARS)<sup>1</sup> (Alexander and Martray, 1989) and there are also two versions of MARS for adolescents, MARS-A (Suinn, 1982) and elementary school populations, MARS-E (Suinn, 1988). Alternatively, for elementary school students, there is the Math Anxiety Scale for Children (MASC) (Chiu and Henry, 1990). A new tool to measure math anxiety in elementary school students has been proposed and investigated by Jameson (2014). Recently, the validity and reliability of the Single-Item Math Anxiety scale (SIMA), consistent with aMARS, was investigated by Núñez-Peña et al (2014).

It is important to note that Alexander and Martray (1989) reported two major shortcomings of the original instrument by Richardson and Suinn (1972) and its abbreviations. First, the proposed underlying construct of the MARS is uni-dimensional,

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<sup>1</sup> Sometimes referred to as the Shortened Math Anxiety Rating Scale (sMARS).

but later studies revealed that there may be more than one underlying construct in mathematics anxiety (Alexander and Martray 1989, Bessant 1995, Brush 1981, Ferguson 1986, Kazelskis 1998, Plake and Parker 1982, Resnick et al, 1982, Rounds and Hendel 1980, Satake and Amato 1995). In order to address these issues, Suinn and Winston (2003) revisited and developed a short version of the MARS instrument known as the short-version (MARS-SV). In parallel, Hopko et al (2003) fashioned the Abbreviated Math Anxiety Scale (AMAS)<sup>2</sup> for similar reasons, producing supporting empirical validity and reliability evidence. For these reasons, in this study, the 9-item AMAS instrument shall be implemented given that our participants are undergraduate students as in the study of Hopko et al (2003).

## Methodology

The cohort that volunteered for this investigate consists of 32 participants (out of a possible 44<sup>3</sup>) enrolled in the Federation University Bachelor of Education (K-6) degree at the School of Education, Melbourne Institute of Technology. As part of the first year mathematics education unit, EDBED1006, they are required to satisfactorily pass a hurdle task. Failure to jump this hurdle prevents a student from enrolling in the third year mathematics education unit. The pass mark is 90% and the ACER issued test consists of 32 multiple-choice questions<sup>4</sup> covering the five strands of primary level mathematics. Therefore, the pass mark is set to 29/32 by rounding up or 28/32 by rounding down. The later was chosen. Students are required to complete the test within 25 minutes without calculators. The test is distributed in hard-copy and completed within a controlled environment. Any student failing the test can resit, multiple times if necessary.

It was necessary to provide four (and more) opportunities for failing students to attempt the test. In the first sitting only 18.18% of students passed with the required mark. By the completion of the second sitting another 16.67% passed (with a total of 31.82% of students with a pass mark). This showed some improvement however it should be noted that the test of the second sitting was identical to the first except students were given 10 extra minutes to complete. This modification was permitted in order to address students' complaints that they could have passed if only they had more time. The test of the third sitting was new, produced by the Mathematics Unit at the Federation University, but covered all the aspects of the five strands as in the first test. Students were provided with 6 extra hours of tutoring covering these five strands. The completion of the third test saw no significant improvement in the outcomes with the total of students with a pass mark increasing slightly to 36.36%. Students were offered another 6 hours tutoring covering the five strands. The fourth sitting proved marginally better with only one student passing increasing the total percentage of 38.64% --not even half the cohort. As of writing, there are plans for a fifth sitting to take place at the end of semester.

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<sup>2</sup> Note that AMARS is a distinct instrument to aMARS. Hence aMARS is sometime renamed sMARS

<sup>3</sup> Note that although the mathematics hurdle is compulsory, participation in the study was purely voluntary.

<sup>4</sup> Typically, each multiple-choice question has five distracters.

The highest level of mathematics completed by 27 (out of 32) of the students of the sample, before commencing their degree, was Year 12 Further Mathematics (VCE). Four students only completed Year 11 general mathematics, while one student only completed Year 10 mathematics. Therefore, one would assume a mathematics competency (hurdle) test at a Year 9 level would pose no particular issues with regard to content knowledge. In addition, as stated above, students were provided the opportunity to attend intense mathematics workshops over a number of weeks before each re-sit. Some students also employed private tutors to cover the same material.

The AMAS survey was conducted, after the fourth test, at the end of a scheduled lecture. Students were seated pair-wise on separate tables<sup>5</sup> during the process minimising peer-influence and related contaminations.

## Analysis

The Likert scale of the AMAS instrument begins from 0 where no anxiety is experienced and ranges from 1 for low anxiety to 5 where the anxiety experienced is high. The overall average relative to the Likert scale for the sample cohort is 1.89 which seems rather low (as compared with the results of Hopko et al (2003), see below and Figure 1.).

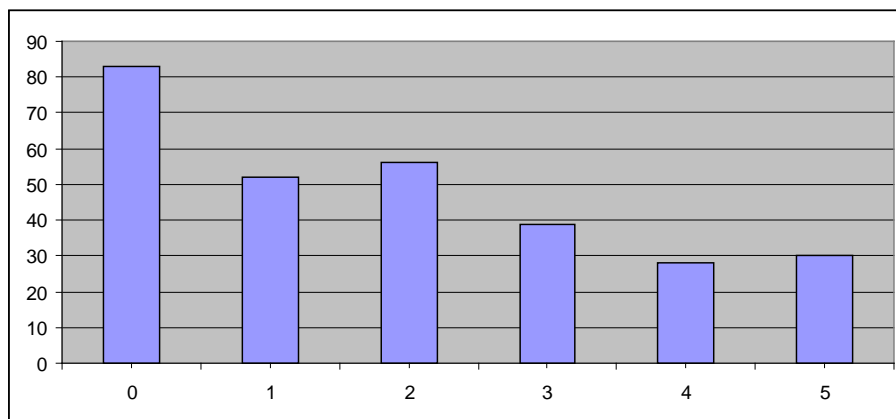


Figure 1. Frequency plot for each Likert scale

There are only four questions with an average Likert scale greater than the overall average and they are questions 2, 4, 5 and 8, see Figure 2.

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<sup>5</sup> As part of the standard teaching space during lectures for Education and other disciplines.

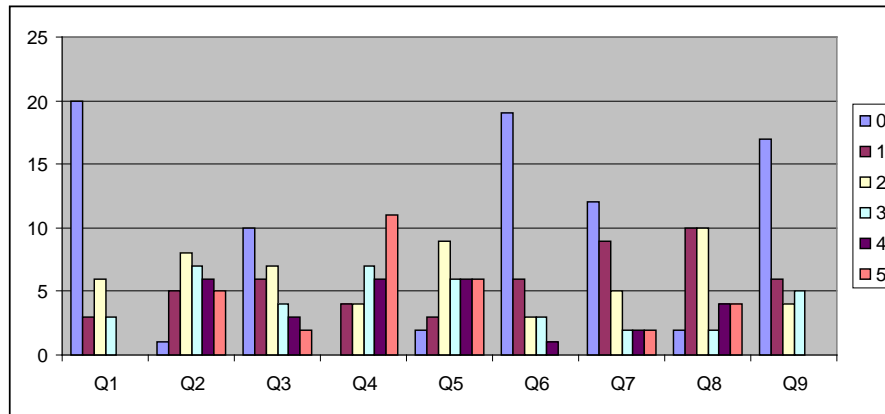


Figure 2. Total response for each question of the AMAS instrument.

It is interesting to point out that all of these questions are related to testing mathematical knowledge in some way. That is, question 4, 5 and 8 are directly related to taking mathematics examinations, being given mathematics assignments and being given a ‘pop’ quiz in mathematics, respectively. The second question is associated with the thought of sitting a mathematics test (a day before the test date). The most worrisome question was number four (see Figure 3), the act of actually sitting a formal examination in a mathematics course, with an average Likert scale of 3.5 well above the average for the sample.

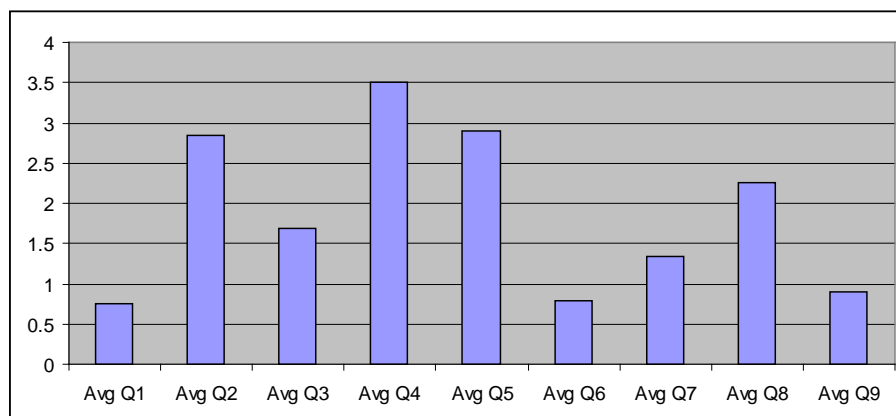


Figure 3. Average Likert scale for each question

The total scores from the results of the AMAS instrument can be defined as representing a summation of the nine items. Therefore, the total scores range is from 0 (no total anxiety) to 45 (highest possible total anxiety). The results from the current survey are an average of 16.75 with a standard deviation of 8.96. This is a lower average, for example, than the replication sample of Hopko et al (2003).

These results suggest that any mathematics anxiety experienced is, to some degree, based on the cluster of questions associated with test anxiety. This conclusion is supported by the recent investigation by Schnell et al (2013) on the comparison of the

Test Anxiety Questionnaire (Hodapp et al, 2011), a revised and shortened version of the German Test Anxiety Inventory (TAI-G), with mathematics anxiety. However, it should be noted that the survey in this study was conducted after the fourth test. This implies further investigation is required to support these findings. We are collating more data as more cohorts progress through the degree.

The relevant descriptive statistics of the four attempts (thus far) by students are given in Table 1. The sample means appear on equal footing however the sample standard deviations (and variance) converge, from large to small, as a function of attempts made. This suggests that extrapolating, with respect to the  $n^{\text{th}}$  attempt, as  $n$  increases a pass mark will only be achieved by statistical outliers as opposed to any successful application of pedagogy and revision afforded to the remaining students. That is, of the remaining students at the 4<sup>th</sup> attempt, improvement may not be expected (without altering the test and/or test conditions in some way making it easier to obtain a pass mark) beyond the expectation of outliers. (Also, notice that the skewness shifts from a positive skewness at attempt 1 to a negative skewness and then almost to zero skewness at attempt 4.)

	1 <sup>st</sup> Attempt	2 <sup>nd</sup> Attempt	3 <sup>rd</sup> Attempt	4 <sup>th</sup> Attempt
Mean	22.318	24.528	22.800	23.190
Standard Deviation	4.569	3.009	3.175	2.462
Sample Variance	20.873	9.056	10.083	6.062
Standard Error	0.689	0.502	0.635	0.537
Skewness	0.275	-0.289	-0.828	-0.020
> Pass Mark (28)	8 (out of 45)	6 (out of 36)	2 (out of 25)	1 (out of 21)

Table 1. Results of data analysis over the four attempts.

This is made evident by analysis of the t-tests for each pair of consecutive attempts, e.g. between attempt 1 and attempt 2, etc. For attempts 1 and 2, where a random sample of 36 data values are taken from the attempt 1 sample, the sample statistic is 2.326. The one-tailed test p-value is approximately 0.013 and the two-tailed p-value is approximately 0.026 (df = 35). Since both p-values are well below  $\alpha = 0.05$  there is significant statistical difference between the two sample's mean values. Moreover, a calculation of the Pearson correlation coefficient yields a value approximately equal to 0.017 and therefore no significant correlation is expected. Repeating the procedure for attempts 2 and 3, where a random sample of 25 data values are taken from the attempt 2 sample. The sample statistic is 1.785. The one-tailed test p-value is approximately 0.043 and the two-tailed p-value is approximately 0.087 (df = 24). In this case, although the one-tailed test p-value is less than  $\alpha$  the two-tailed test p-value is greater by a larger absolute value. Therefore, one would learn towards there being some, but not significant, statistical difference between the two sample's mean values. Supporting this view is the Pearson correlation coefficient with a value approximately equal to 0.028. Finally, for attempts 3 and 4, a random sample of 21 data values are taken from the attempt 3 sample. The sample statistic is 0.686. The one-tailed test p-value is approximately 0.250 and the two-tailed p-value is approximately 0.501 (df = 20). Clearly, both p-values are well above  $\alpha$  and therefore no statistical difference between the two sample's mean values is expected. The Pearson correlation coefficient value is approximately equal to 0.245, significantly larger than both of the previous values.



## **Discussion**

The cluster of AMAS questions, namely 2, 4, 5 and 8 can be thought of as a factor which intersects both mathematics anxiety and test anxiety. This factor appears most influential in the present study. It suggests that test anxiety plays an increasing role as a function of test re-sits, in the case of on-going failing students. In fact, an analysis of the data suggests that after a given number of attempts, marks appear to converge about some mean value with no statistical difference as the number of attempts increases. Occasionally, a particular student will achieve a pass mark or obtain a far worse mark than the mean of their previous attempts. These cases are viewed as outliers in the analysis. This produces a dilemma for teaching staff and university administration given the percentage of students affected.

On the one hand, teaching staff expect a certain standard of mathematical content knowledge to be shown by the cohort. On the other hand, universities cannot simply reject or discontinue the enrolment of a large percentage of a cohort in any particular discipline let alone pre-service teacher education. A common solution to this dilemma is to simply place the mathematics hurdle online and allow students to re-sit an infinite number (in principle) of times. In some instances, the hurdle is unregulated and the hurdle questions are chosen randomly from a database of a finite number of questions. Unfortunately, from a statistical point of view, this merely suggests that a pass mark is achieved as an outlier rather than a genuine application of sound content knowledge.

In an effort to address test anxiety specifically, it is proposed that the following steps be taken with the next cohort of students. They are to be informed of the place of the test in the context of teacher certification, its general content and be given examples of specific kinds of questions; thus increasing their familiarity with the activity. In order to address mathematics anxiety specifically, students will be encouraged to self-evaluate in terms of their skills in general mathematical categories (Numeration, Measurement, Additive thinking and Multiplicative thinking) and to take responsibility for preparing for the pending test by using on-line support programs and available tutoring.

We also suggest that a content course running parallel with the usual mathematics pedagogy courses would be a significant step toward solving this problem. The envisaged course would focus on revision, mathematics problem solving and periodic (mock) practice tests. At the completion of the course students would then sit the hurdle test as the only and final piece of formal assignment. Practice tests could be implemented at the completion of each strand.

Finally, it should be pointed out that there were examples of students failing the mathematics hurdle test that passed the mathematics pedagogy component of the course with distinction. It may be of interest to study such disconnection between general mathematics competency and competency as a pedagogue.

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