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Dealing with mathematical anxiety: Should one size fit all?

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Abstract: Many students who have to study mathematics as an enabling subject within higher education experience mathematical anxiety to a greater or lesser extent. This affliction can impact student learning and achievement in mathematics and so a number of strategies have been suggested for alleviating mathematical anxiety or at least moderating its effects. This paper reports on a comparison of the mathematical anxiety experienced by two groups of students each studying a different subject discipline. The results indicate that the groups have quite different levels of anxiety and the differing contributing factors between the groups suggest that approaches to remediation need to be tailored to reflect these factors.

Keywords: Mathematical anxiety, mathematics teaching, student engagement

Introduction

For many years educators have recognised the important role that core mathematical skills play in helping people make sense of an information-rich society. Yet a number of issues have arisen with the teaching of these mathematical skills and particularly with a perceived lack of engagement among some students with mathematics teaching. One of the issues identified within the last 20 years is that of mathematical anxiety (Brian, 2012). As Furner and Gonzalez-DeHass (2011) state: 'Math anxiety is a real issue that can impact a young person's goals, many career related decisions they may make in life, and their overall future.' (p.226) and over the last ten years or so there has been considerable interest among both researchers and teaching practitioners in finding ways to encourage student engagement with mathematics learning (Bai et al., 2012; Finn & Zimmer, 2012; Kahu, 2013; Watkins & Mazur, 2013). This interest has focussed on curriculum design and the content of mathematics syllabi and on some of the 'softer' aspects of engagement including mathematical self-efficacy and mathematical anxiety (McMullan et al., 2012; Warwick & Howard, 2014). Poor self-efficacy beliefs and high mathematical anxiety can be experienced by students at all educational levels but in this paper we focus on the UK higher education (HE) system and the mathematical anxiety that is present among students just commencing their course of study, as few researchers have focussed on the HE context (Núñez-Peña et al., 2013).

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Mathematical anxiety is known to be an inhibitor of student engagement with, and performance in, mathematics (Furner & Gonzalez-DeHass, 2011). Being able to identify individual students with high levels of anxiety is the first problem to be faced and fortunately there are questionnaire instruments that have been devised which give reliable indications in this respect (Richardson & Suinn, 1972). The somewhat less tractable problem though is how we devise learning, teaching and assessment strategies which are effective in reducing the anxiety levels of students and hence lower at least one of the barriers to a student's engagement with mathematics. The problem is particularly acute for students who are not studying mathematics as their primary subject, but find that they need to develop some more advanced mathematical skills in order to support their primary subject of study (see for example McMullan et al. (2012)).

Unfortunately, much of the current research relating to the alleviation of mathematical anxiety has not necessarily differentiated between the subject specialism of the students who have to study mathematics as part of their curriculum. This is quite understandable since, for efficiency reasons, supporting mathematics modules are often run with a broad mix of students (perhaps as part of a common first year of study) and subject contextualisation is expected to take place in separated seminars or outside the mathematics classroom. So, for example, a quantitative skills module may incorporate business, marketing, accounting and HR students who all require these specific skills. However, it may be the case that students from different parent courses have differing levels of mathematical anxiety and that the generators of anxiety may not be the same for different subject groups. This has yet to be explored in any great depth within the UK HE sector.

This paper presents the results of a small exploratory study of mathematical anxiety among new undergraduate students at a UK university. The study had two primary aims. The first was to test whether there was a significant difference between the levels of mathematical anxiety felt by two groups of students studying quite different sub-degree level courses. Such students often have weaker prior qualifications and experiences (which rule them out of immediate entry to undergraduate degree programmes) and so can have quite marked issues with mathematical anxiety. The second was to explore whether there are differences between the causes of mathematical anxiety between the two groups. The paper then draws some tentative conclusions about the alleviation of mathematical anxiety in the light of the empirical findings.

Mathematical Anxiety

Mathematical anxiety has been subject to quite extensive research over the last 20 years particularly in relation to gender differences and the development of mathematical anxiety through schooling. The need to better understand the causes and alleviation of mathematical anxiety is primarily related to our increasingly information rich society and the need for all people to be able to handle, manipulate and make decisions based on (often quantitative) information. If sections of society develop anxieties over mathematics then this excludes such people from certain professions, academic courses and careers. Indeed, as described by Rubinsten, Bialik, and Solar (2012) '… it has been suggested that, as our society becomes increasingly dependent on numbers and math, failure to acquire numerical skills may come to act as a "critical filter," limiting occupational success …' (p. 2). In fact, Mathematical anxiety has been shown to be a contributing factor in choices of course and career (Singer & Stake, 1986; Chipman, Krantz & Silver; 1992) and the under-representation of women in some careers related to science, technology and engineering has been linked to mathematical anxiety (Shapiro & Williams, 2012). Interestingly, the research on gender differences in mathematical anxiety is somewhat inconclusive with many studies showing increased levels of anxiety among females while others show no such difference (Rubinsten, Bialik, & Solar, 2012). Furthermore, while it was for some time assumed that the onset of mathematical anxiety was associated with the study of higher level mathematical techniques such as calculus, more recent studies have shown that mathematical anxiety can have its origins in the very early schooling of children and perhaps as early as first grade (Maloney & Beilock, 2012). Thus, by the time students are ready to enter the HE sector, it is quite possible that feelings of mathematical anxiety are already well established in some students. To date, however, there has been somewhat less research conducted on the effects and treatment of mathematical anxiety exhibited by these students.

There are a number of reasons why students entering HE exhibit signs of anxiety when they realise that they will be studying mathematics as part of their undergraduate curriculum (Jansen et al., 2013; Maloney et al., 2013; Taylor & Fraser, 2013). These include:

a) Poor learning experiences in their previous education either stemming from poor teaching or from disappointing assessment results;
b) The length of time that a student has been out of education. It is not unusual for students to return to HE after many years of work having decided to formalise their work-based learning through a formal qualification. Inevitably such students will not have practiced a number of mathematical skills for many years;
c) Not seeing the relevance of mathematics to their main subject of study. HE institutions will often title mathematics modules in such a way as to emphasise the links to the primary subject of the course but even so students sometimes just can't see why they should be learning more mathematics;
d) Finding mathematics uninteresting;
e) Believing that they are just not good at mathematics and never will be – often despite evidence to the contrary.

When one adds to this list the possibility of students being embarrassed in front of their peers due to actual or perceived mathematical deficiencies it is unsurprising that negative attitudes towards mathematics become apparent. Indeed for some it is regarded as a badge of honour to be the sort of person who just does not 'get' mathematics!

Negative attitudes can, of course, take many forms from a simple dislike of mathematics to a dread and fear of undertaking any mathematical task and in this latter case the fear (or anxiety) can be so severe as to impact on assessment performance or even influence students' choices of degree or career (Chipman, Krantz & Silver; 1992). It is clear that mathematical anxiety affects the achievement of mathematical outcomes with a number of researchers demonstrating the correlation between anxiety and summative assessment results (Núñez-Peñ et al., 2013). Researchers have also explored the mechanisms through which anxiety impacts on mathematical performance and such explanations have included both educational causes and physiological explanations involving the effects of anxiety on available working memory and brain function (Lyons & Beilock, 2012; Maloney & Beilock, 2012).

In severe cases the anxiety can result in avoidance behaviour by the student so that classes are missed, assessments not attempted and sometimes module failure ensues. This makes it important that we find ways to determine the levels of anxiety felt by students and to this end research instruments have been devised. Probably the best known is the Mathematics Anxiety Rating Scale (MARS) (Richardson & Suinn, 1972). The MARS questionnaire consisted of 96 questions designed to assess anxiety related to two areas: learning mathematics and mathematics evaluation. Further work by Plake and Parker (1982) produced a simpler Revised Mathematics Anxiety Rating Scale (RMARS). This consisted of a reduced set of 24 statements each describing a mathematical activity and respondents are asked to rate themselves on a Likert scale ranging from 'not at all anxious' to 'extremely anxious' for each of the 24 situations described. The RMARS questionnaire is relatively easy to administer and for students to complete.

The treatment of mathematical anxiety has also been quite well researched at a number of different educational levels although less work has been undertaken at HE level. An interesting literature review by Iossi (2007) focussing on post-secondary students identifies a number of suggested strategies for reducing mathematical anxiety and these are categorised as: curricular strategies (such as retesting, self-paced learning, mathematical anxiety courses etc); instructional strategies (such as improved communication and feedback, self-regulation, manipulatives etc.); and non-instructional strategies (such relaxation therapies or psychological treatment). Some researchers have developed approaches that extend across these boundaries. For example, Park, Ramirez and Beilock (2014) report positive results from asking students to write about their feelings before undertaking mathematics tasks. Their findings indicated that the practical exercise of expressive writing about mathematics can reduce the impacts of anxiety on brain function and subsequently improve the mathematical performance of highly anxious students.

Other suggestions for reducing anxiety have included flipping the classroom (Wilson, 2013), improving the student's perception in relation to confidence, anxiety and the value of mathematics (Wismath & Worrall, 2015), and helping students and trainee teachers to develop coping strategies (Finlayson, 2014). We shall return to the treatment of mathematical anxiety in the next section.

Methodology

In order to measure the level of mathematical anxiety exhibited by students a version of the RMARS questionnaire was used. As stated above, the questionnaire consists of a set of 24 statements each describing a situation in which some aspect of mathematics is present.

These statements include quite passive activities such as 'listening to a mathematics lecture' to more active situations such as 'solving a mathematics problem'. The statements encompass both lectures, work outside the classroom and assessment activities.

For the purposes of this study the statements within the RMARS questionnaire were contextualised to the education experience of our students so that, for example, 'blackboard' was replaced with 'whiteboard' etc.

For each of the statements, students were asked to state how anxious they would feel in such a situation by using a Likert scale ranging from 1 (not at all anxious) to 5 (extremely anxious). An overall measure of student anxiety was obtained by simply adding the scores across all 24 questions giving a total anxiety score ranging from 24 (the lowest anxiety score possible) to 120 (the highest anxiety score possible).

Experience of teaching a variety of students within the HE sector has shown that the students most likely to experience and suffer from the effects of mathematical anxiety are those students who enter courses with the weakest prior qualifications. Even though these students all have a GCSE in mathematics through the UK education system (or an equivalent qualification from another system) their previous experiences with mathematics can be very varied and these students would tend to find places on Higher National Diploma (HND) courses or Foundation Degrees (FdA). Academically, both of these are broadly equivalent to the first two years of undergraduate study and, if successful, students would have the opportunity to progress to a full Batchelor's degree course. In this study, data collection was limited to students studying at the HND and FdA levels so as to capture the responses of students most likely to be maths anxious.

In addition, it was decided to compare responses from two courses in different academic schools, which had an emphasis on mathematics as a crucial enabling skill but which were not purely mathematically focussed. The HND in Computing and the FdA in Accounting were chosen as courses that matched these criteria and had sufficiently large numbers of students to allow a random sample to be drawn.

In this small study a sample of 53 HND Computing students were selected along with 40 FdA Accounting students. The RMARS questionnaire was administered to both groups of students during course induction and the results input into SPSS for analysis.

In this paper we compare the responses for the two groups by using binary logistic regression (see for example Anderson (1982)). This statistical procedure is a variant of linear regression in which the dependent variable is the student's course of study. The 24 items in the RMARS questionnaire were used as independent variables in the regression to assess the impact each had in differentiating between the courses i.e. whether each item was a significant predictor variable of the student's course of study. Whilst linear regression predicts values for a dependent variable measured on a continuous scale, binary logistic regression will use the independent variables to ascertain the probability with which to classify respondents as (in this case) either HND Computing or FdA Accounting. In our case, probability values between 0 and 0.5 indicated that the respondent was an HND Computing student, with probabilities greater than 0.5 indicating an FdA Accounting student.

Regression coefficients are interpreted in terms of how the odds of classification will change as the values of the independent variable change. This will be illustrated in the next section.

Results and Discussion

The total anxiety score for students in each of the two groups is shown in the boxplot of Figure 1.

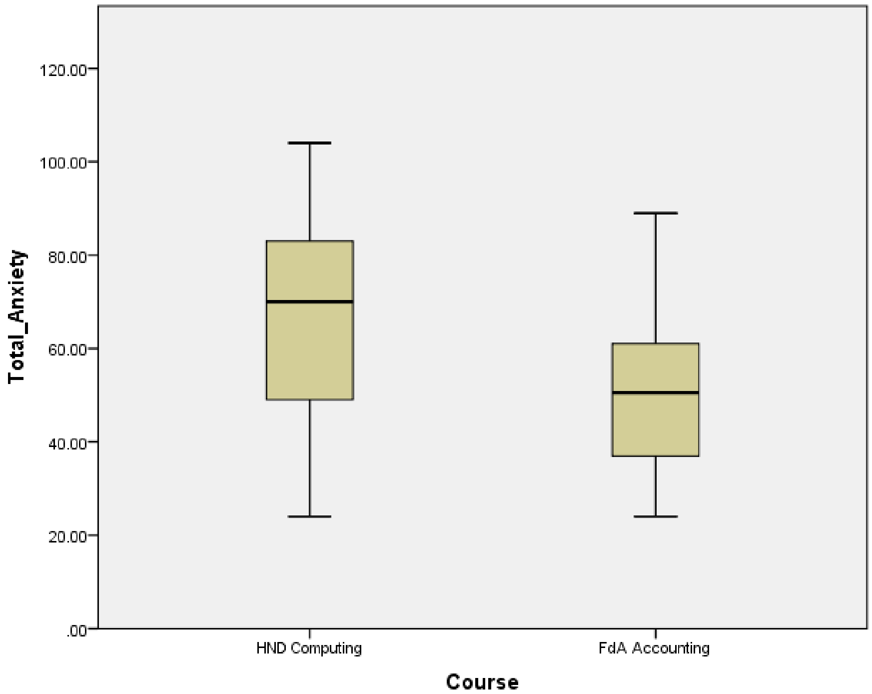

Figure 1. Distribution of total anxiety scores for each student group

Figure 1 shows that the median total anxiety score for students on the FdA Accounting course is considerably lower than the median for HND Computing students. It also seems clear that the interquartile range for the FdA students is less than that for HND students. Comparing these two distributions using the Mann-Whitney U test leads to rejection of the null hypothesis ($p = 0.001$) that the distribution of Total_Anxiety is the same across courses.

It would seem therefore that the HND Computing students are exhibiting, on average, greater levels of mathematical anxiety than the FdA Accounting students and that there is also a greater variation in their anxiety scores. It would seem that the issues surround mathematical anxiety are likely to be more apparent among the HND Computing students than those students studying accounting. It is not immediately apparent why this should be the case. The mathematical entry criteria for both courses are the same, and exploration of the ethnicity and age profiles of the two groups show no significant differences.

Considering the RMARS items individually, calculating the average level of anxiety associated with each RMARS item and ranking the items for each group of students there was no significant difference in the ranking of the items by each student group indicating broad agreement as to which items were anxiety inducing and which were not.

In fact considering those RMARS items that have the largest average anxiety scores then the top 3 for both groups of students are the same (although in a different order):

1. Thinking about a mathematics test the day before;
2. Being given a surprise test in a mathematics class;
3. Waiting to get a mathematics phase test result in which you expected to do well.

These are related to summative assessment and confirm the results of other studies that mathematical assessment can be a stressful process for students (Sparfeldt et al., 2009). There was no such agreement however as to the items that were the least anxiety inducing.

In order then to try and distinguish which of the RMARS items are the best indicators of differences between the two groups a binary logistic regression was undertaken with the student's course as the qualitative dependent variable (only two courses were considered hence 'binary' logistic regression). Key findings from this regression are shown in Table 1.

*Table 1***.** Key results from binary logistic regression

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	48.649	24	.002
	Block	48.649	24	.002
	Model	48.649	24	.002

Hosmer and Lemeshow Test

Chi-square	df	Sig.
10.363	8	.240

Model Summary

Cox & Snell R Square	Nagelkerke R Square
.407	.547

Broadly speaking the omnibus test of model coefficients illustrates that the inclusion of the independent regression variables makes a significant improvement in the explained variation in the dependent variable (p = 0.002), the Nagelkerke R Square value (analogous to R^2 in linear regression analysis) indicates approximately 55% of the variation is explained by the regression, and the non-significant Hosmer and Lemeshow test confirms the null hypothesis that the model is a good enough fit for the data (p = 0.24).

In the regression model, there are five terms that are statistically significant. These include the constant term and four items from the RMARS questionnaire and are shown in Table 2.

*Table 2***.** Statistically significant independent variables

	B	S.E.	Wald	Sig.	Exp(B)
RMARS item1 Watching a teacher solve an equation using algebra on the whiteboard	-.992	.484	4.191	.041	.371
RMARS item 3 Being given a homework assignment of difficult problems to be handed in at the lecture next week	-.767	.396	3.761	.049	.464
RMARS item 14 Taking an exam in the mathematics module	1.565	.582	7.229	.007	4.785
RMARS item 20 Being given a surprise test in a mathematics class	1.349	.617	4.771	.029	3.853
Constant	3.419	1.111	9.466	.002	30.526

The predictive accuracy of the regression model is shown in Table 3.

Table 3. Accuracy of regression predictions

		Predicted Course		
		HND Computing	FdA Accounting	%
Observed Course	HND Computing	44	9	83.0
	FdA Accounting	8	32	80.0
Overall Percentage				81.7

The model is able to correctly categorise 83% of HND Computing students and 80% of FdA Accounting students giving an overall predictive accuracy of 81.7%.

Looking at Table 2 in a little more detail it is possible to unpick some of the logistic regression results in order to relate these findings to our student groups.

Firstly, the sign of the regression coefficient (shown in the column headed B) is an indication of the effect that that RMARS item has. For example, RMARS questionnaire item 1 was the statement ‘Watching a teacher solve an equation using algebra on the whiteboard’ and it has a negative coefficient. This would indicate that increasing the response value for this item (i.e. that as the student finds this situation more anxiety inducing) reduces the probability that this student is an FdA Accounting student. A similar effect is noted with item 3 ‘Being given a homework assignment of difficult problems to be handed in at the lecture next week’. However for item 14 ‘Taking an exam in the mathematics module’ and item 20 ‘Being given a surprise test in a mathematics class’ the regression coefficient is positive so that greater anxiety induced with these situations increases the probability that the student is an FdA Accounting student.

Secondly, we can use Table 2 to estimate the magnitude of these effects. The number shown in the final column in the table (headed Exp(B)) has a particular interpretation. It shows the proportional change in the odds of a student being and FdA Accounting student. Thus if a student’s response on the Likert scale for item 1 increases by one point, then the odds that the student is an FdA Accounting student are reduced by about one third. In contrast, a single point increase in the Likert response for item 14 will increase the odds that the student is an FdA Accounting student nearly five-fold. A word of caution is required here. These results are, like most regression results, somewhat indicative as correlations between the independent variables can lead to complications in the interpretation of regression results (such as confounding effects) so we are treating these results as indicative only. We also need to be aware that the sample sizes are small.

We can draw a number of conclusions from Table 2.

The four statistically significant independent variables identified from the logistic regression relate to active assessment processes (items 3, 14 and 20) and to the more passive activity of watching a lecture (item 1). While it would be no surprise to learn that assessment activities are considered to be anxiety inducing, what is somewhat surprising was that responses to assessment items were not uniform across both groups of students and in fact can be used to differentiate one group from the other.

Enhanced levels of anxiety in two of the items that relate specifically to in-class assessment (items 14 and 20) are indicative of FdA Accounting students. On the other hand enhanced anxiety in items 1 and 3 which relate to classroom engagement and doing mathematics homework are indicative of HND Computing students.

While it is true that both groups of students identified summative assessment activities as the most anxiety inducing, there are other RMARS items that indicate differences between the groups. Thus while there are common anxiety causes that can be worked on to try and alleviate some of the problems for all students there are also specific areas that can be addressed for particular groups of students. This has not been widely addressed in the literature and is worthy of further consideration.

As a consequence of these findings there are some indications as to how we might address issues of mathematical anxiety in our students although further research would be necessary as this is only a preliminary study. These suggestions encompass all three general categories identified by Iossi (2007).

Among the students in this study there was clearly an issue with the extent to which assessment generates anxiety. It has been observed (Kazelskis et al, 2000) that it is sometimes difficult to distinguish between mathematical anxiety and more general test anxiety and the RMARS instrument does not distinguish between these two constructs. However the fact that anxiety is generated by summative assessment processes means that there is still an issue here to address with students. Recommendations for dealing with this type of issue primarily revolve around relaxation techniques that can be taught to students. Other suggestions relate to how learning and assessment is structured (Embse & Hasson, 2012). Some anxieties can be reduced by allowing students to undertake group assessments, or to structure assessment in smaller chunks so that the consequences of poor performance in any one element of assessment are reduced from the student’s perspective. Such processes where students can accrue assessment marks over a period of time are less stressful than high stakes exams or larger pieces of work (Núñez-Peña et al., 2012). The way teachers prepare students for an assessment is also important and assessment can be categorised as an opportunity to demonstrate what students can do rather than a hurdle that must be cleared to avoid failure. Other researchers recommend the development of study skills and examination technique as ways of giving students the tools in their armoury to demonstrate their mathematical knowledge without having to worry so much about the means of demonstration (Matzin et al., 2013).

While these types of remedy will be beneficial in reducing test anxiety for both cohorts of students in this study (and particularly as this was a distinguishing element for FdA students) the HND students were identified by anxiety relating to classroom experience and by unsupervised homework problems. These two items are related to the classroom climate and to how learning is structured for students outside the classroom. Here it is encouraged that students must be in an environment where it is acceptable to make mistakes and that making mathematical errors are not a sign of weakness but a source of information for the teacher. Similarly asking questions is a key part of the learning process. Furner and Gonzalez De-Hass (2011) recommend that ‘… the classroom should be perceived as a community of learners where students treat one another with respect and engage in constructive relationships that promote student motivation and ability to engage in the academic work of the classroom.’ (p.237). A similar suggestion is made by Núñez-Peña et al. (2013) who advocate the use of small group assignments and incremental learning in the classroom so that students can generate supportive relationships where the consequences of errors (which will inevitably be made by students) are reduced in the mind of the student.

Both of these collegiate ways of working have further application outside the classroom and if the community of learners concept can be maintained outside the classroom too (the teacher can do much to foster this in the way that private study time is organised and tasks set) then the idea of mathematical homework being a solitary process where progress stops as soon as a difficulty is encountered is dispelled.

It has also been observed that mathematical anxiety often has its roots in the teacher of mathematics i.e. that the anxiety can be transferred from teacher to pupil or the teaching can just be of a poor standard. The implication here is that it is key for teaching staff to be appropriately chosen for their mathematical knowledge and classroom craft.

Conclusion

This paper has explored the idea that students studying different subject specialisms but who may have to take common underpinning mathematics modules may have quite different levels of mathematics anxiety and sources of mathematical anxiety. In this small study, two cohorts of students were found to have quite different levels of mathematical anxiety and the factors that differentiated the groups in terms of sources of anxiety were assessment processes, classroom working and unsupervised working. Although a much larger study would be needed to confirm these findings across a wider selection of academic subjects, there seems to be an indication that teachers need to be tailoring their learning, teaching and assessment strategies to address the particular sources of anxiety for the individual cohorts in their class. In this sense a one-size-fits-all approach to mathematical anxiety may not be appropriate and we should be looking at the characteristics of the student cohorts to be better understand their learning needs.

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