The Prevalence of Mathematical Anxiety in a Business School: A Comparative Study across Subject Areas

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Received: October 29, 2016 Accepted: November 20, 2016 Online Published: December 1, 2016

Abstract: Mathematical anxiety is a phenomenon linked to poor attainment in mathematics and restricted development of mathematical skills among those who are afflicted by it. Unfortunately most undergraduate courses in business related areas require the further study of mathematics to enable effective business decision making and students who suffer from mathematical anxiety are placed at risk of underperformance or failure in such quantitative modules. This paper summarizes the results of a survey (n = 330) of students joining a university business school with a view to ascertaining the degree of mathematical anxiety exhibited by incoming students. Results of the survey show no significant differences in anxiety attributable to age or gender but significant differences attributable to level of study and subject area. Implications of the findings for a redesigned teaching approach are discussed drawing on suggestions from the literature surrounding mathematical anxiety.

Keywords: Mathematical Anxiety, Pedagogy, Mastery, Assessment

1. Introduction

In a recent report (Kuczera, Field, & Windisch, 2016), the Organisation for Economic Co-operation and Development (OECD) described the rather lamentable literacy and numeracy skills exhibited by the young (16 to 19 year olds) in both the United Kingdom (UK) and the USA. The report included the fact that nearly 30% of young people in England have a numeracy level below level 2 and that in the USA this figure is nearly 40% (see Figure 1 below). In fact the UK and the USA were placed in the bottom two positions of the 23 countries included in the study. In this context, level 2 numeracy skills include, for example, the application of multiple steps or processes involving calculation with whole numbers, decimals, percentages and fractions, estimation, and the interpretation of simple data in the form of statistics tables and graphs. Even more worryingly the OECD report highlighted the fact that about 10% of university students in England have literacy or numeracy levels below level 2.

While the report recognises that much needs to be done to increase numeracy skills at school level the focus of this paper is on UK higher education. In this context the reports notes that, rather than simply denying such students university entrance (which is viewed as discriminatory since numeracy weaknesses are often linked to parental background) universities should do more to improve numeracy skills at the intermediate level.

Unfortunately, the issues highlighted in this report are not new and there has, for a number of years, been recognition that there is a 'mathematics problem' within the UK (Smith, 2004; Warwick, 2009). This mathematics problem is evidenced by the lack of basic mathematical skills exhibited by students on entering university and a general perception among young people that mathematics is boring and irrelevant (Smith, 2004). The problem seems to be particularly acute among those students who have to take mathematical subjects in support of their main topic of study – for example nursing students learning how to undertake crucial drug calculations (McMullan, Jones, & Lea, 2012), psychology students learning how to analyse empirical research findings (Nunez-Pena, Suarez-Pellicioni, & Bono, 2013) or business students learning to underpin their decision making processes with quantitative analysis of relevant data (Clark & Schwartz, 1989, Fullerton & Umphrey, 2002). It is usually the case that in non-STEM subjects (STEM refers to Science, Technology, Engineering, Mathematics), mathematics rarely appears on a student's timetable labelled as mathematics, but instead appears in a variety of modules as an underpinning (and often assumed) skill required for structuring and interpreting information within the context of the student's degree subject specialism. In this way, the presence of mathematics within the curriculum can sometimes be an unpleasant surprise to students.

Recognising the poor level of quantitative skills exhibited by many new students, researchers have explored a number of ways in which university students can be supported as they tackle the mathematical elements of their course either through exploring pedagogical approaches (Kay & Kletskin, 2012) or through centralised mathematics support centres (Pell & Croft, 2008; Mac an Bhaird, Morgan, & O'Shea, 2009). In addition to this, many institutions undertake diagnostic testing of their undergraduate students on entry in order to try and identify those students at risk of failing in mathematics and, therefore, those that will require additional support. While this may identify gaps in a student's mathematical knowledge, it does nothing to address some of the underlying causes of poor engagement with, and hence performance in, mathematics.

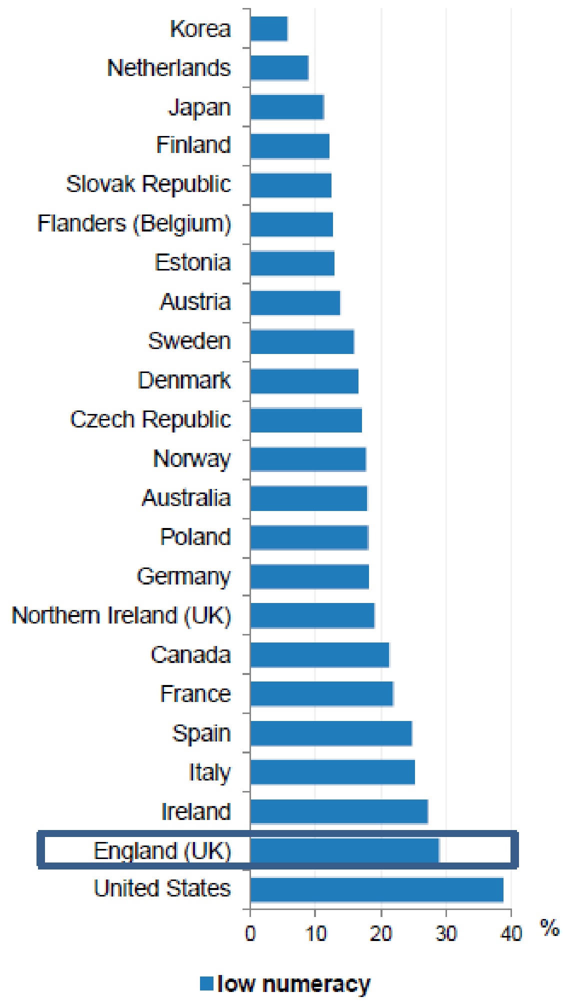

Figure 1: Percentage of youngsters falling below level 2 numeracy skills (Kuczera, Field, & Windisch, 2016)

One factor that is known to cause disengagement with mathematics and inhibit mathematical performance is mathematical anxiety. Research has shown mathematical anxiety to be quite widespread among students at all stages of formal education and while its derogatory effects on mathematical skills development has been well documented (Carey, Hill, Devine, & Szucs, 2016; Eden, Heine, & Jacobs, 2013) it is rarely addressed within learning and teaching strategies in UK higher education institutions. In particular there seems to be little formal exploration of mathematical anxiety issues among new university students as they embark on their undergraduate studies so that it becomes difficult for lecturers to identify common starting points for mathematical topics (Metje, Frank, & Croft, 2007) and adopt teaching pedagogies that support skills development among the maths anxious students.

This paper reports the findings of an empirical study of first year students studying in the School of Business at a UK university.

2. The Importance of Quantitative Skills

Does it really matter how our students feel about studying mathematics? Of course as educators we would like our students to enjoy their studies and to give their tutors positive feedback scores but for the students themselves there are important reasons why positive engagement with mathematics is necessary.

In the short term, mathematical anxiety is linked to achievement in mathematics (Ma, 1999), performance across modules supported by mathematics, and hence to degree classification. These results influence entrance into employment and choices of career (Ashcraft, 2002) so there is an immediate advantage to be gained by students who can overcome their phobia of mathematics.

In the longer term however educators need to recognise that the requirements of employers are constantly evolving so we should not just be teaching technical skills or making good perceived gaps in knowledge. The Education and Training Foundation summarise the situation well (Foundation, 2015) when they state that:

> "Employers are less interested in what they consider to be academic mathematics (e.g. algebra, calculus, etc.), but instead want applied and practical skills including approximation, mental arithmetic, capability with visual data, a solid grasp of units of measurement, the ability to check their own calculations and simple problem solving." (p. 9).

So for our non-specialist students the focus should now be on the development of these more generic mathematical skills and the ability to handle and manipulate data whatever the subject context rather than the more technical skills and theoretical development. Of course, theory and technique still have a place and in some subject areas these remain highly important (for example in drug dosage calculations) but we cannot afford to neglect the development of all our students as well-rounded in quantitative skills. It is, after all, part of the process of becoming an independent learner capable of responding to the changing nature of the work environment.

Hand-in-hand with the development of practical mathematical skills should be the development of mathematical confidence. Indeed a student's practical mathematical skills are of little value without the confidence to apply them in a variety of settings. As Higgins (2011) states:

> "In a world that is becoming increasingly reliant on Science, Technology, Engineering and Mathematical skills, we need to ensure young people are not only equipped with the requisite skills to function competently in the worlds of employment and higher

education, but also that they are confident with their own mathematical knowledge and ability." (p. 1).

This is where we begin to see difficulties arising with some of our students. While some students enter university with excellent mathematical skills appropriate to their course of study and are ready to engage with further study, there is a significant number who do not. For these students mathematics is something to be avoided because, for a variety of reasons, they have very negative attitudes towards mathematics. These negative attitudes can lead to a strategy of avoidance, of poor engagement with further mathematics training and hence to poor assessment and feedback results generating a vicious circle of underachievement (Warwick & Howard, 2014). To produce work-ready graduates with the requisite mathematical practical skills and confidence requires that we find ways to address these negative attitudes. To fail to do so would mean, as some have argued, that for these students a lack of mathematical competence means an inability to function fully at work.

3. The Causes of Mathematical Anxiety

There has been a wealth of research that confirms the negative correlation between mathematical anxiety and the development of mathematical skills and performance in mathematical assessments (Ma, 1999; Eden, Heine, & Jacobs, 2013; Wahid, Yusof, & Razak, 2014). The greater the level of anxiety felt by the individual then the poorer are the results of mathematical assessments with consequent impact on engagement and further skills development. Despite the well documented effects of mathematical anxiety, its causes are still an under researched topic. There are three main schools of thought (Carey, Hill, Devine, & Szucs, 2016). First is the deficit theory which proposes that it is poor performance in mathematical tasks and assessments that generates anxiety when future tasks are approached; second is the debilitating anxiety model which suggests that anxiety experienced by the individual impacts on cognitive function in some way so as to impair performance on mathematical tasks; and third (the reciprocal theory) is a hybrid theory that combines the first two theories into a feedback process (or vicious circle) with anxiety impairing performance which increases anxiety which further impairs performance. This feedback process has been suggested by a number of researchers (Jansen, et al., 2013; Warwick & Howard, 2014; Wu, Barth, Amin, Malcarne, & Menon, 2012). Which of these models is correct is not yet known although it seems that "… complex models involving feedback loops between multiple factors, including mathematical anxiety and maths performance, are likely to provide the best explanations of the relationship between mathematical anxiety and maths performance." (Carey, Hill, Devine, & Szucs, 2016, p. 4). If this feedback process can be confirmed as a core element of the link between anxiety and performance then it offers opportunities for the reduction of mathematical anxiety through interventions designed to turn the vicious circle into a virtuous circle since feedback can be positively reinforcing as well as negatively debilitating.

What does seem clear though is that mathematical anxiety is present in our students at the time of entry to university having developed during the process of formal schooling from the earliest ages onwards (Eden, Heine, & Jacobs, 2013). However the link between mathematical anxiety and mathematical performance is described, there are other factors that have been recognised as influential. These have been broadly partitioned into three groups: environmental variables, cognitive variables and personality variables (Devine, Fawcett, Szucs, & Dowker, 2012). Environmental variables try to capture the influence of parents, teachers and educational experiences, cognitive variables refer to intellectual capabilities and personality variables reflect the individual's self-efficacy beliefs, test and other anxieties. With a very diverse student intake within the School of Business consisting of students from a variety of ethnic, social and educational backgrounds, it was necessary to explore the extent of the mathematical anxiety problem on the School's major degree programmes and considers what could be set in place to reduce mathematical anxiety, enhance student performance and thereby improve student retention on courses. Thus the research reported in this paper was designed in order to answer the following research questions:

a) What is the extent of mathematical anxiety among new students taking courses in the School of Business which involve the study of quantitative subjects?
b) Is there any statistically significant effect on mathematical anxiety attributable to age, gender, subject area of study or level of study?
c) Are there any specific and identifiable differences in responses where a significant difference in total anxiety was found between student groupings?
d) What are the implications of the results in relation to mathematics teaching approaches for these students?

4. Methodological Approach

Students from a UK university School of Business were surveyed to assess their levels of mathematical anxiety. The School in question runs a variety of undergraduate programmes with students studying either a full three-year honours degree (BSc or BA with study at levels 4, 5 and 6) or a sub-degree qualification (Higher National Diploma or Foundation Degree) consisting of study at level 4 and 5 only. Three large programmes from the school were selected for this study these being Business Studies (BA and HND), Accounting and Finance (BA and FdA) and Informatics (BSc and HND). All students joining these courses at level 4 were asked to complete the RMARS questionnaire (Plake & Parker, 1982) at the start of their first year studies. The RMARS questionnaire consists of a set of 24 statements and respondents are asked to rate themselves on a five-point Likert scale ranging from 'not at all anxious' to 'extremely anxious' for each of the 24 situations described in the statements. The situations range from describing passive learning activities (such as 'listening to a lecturer explain a mathematics problem') to active assessment processes.

In addition, each respondent was asked to give their gender and age. The survey resulted in a total sample of 330 students across the six courses of study and allowed research questions a) and b) above to be assessed. Statistical tests used in relation to question b) were non-parametric in nature since standard parametric tests were considered to be inappropriate in application to Likert scale data which many consider to be ordinal in nature.

In order to examine question c), we applied Exploratory Factor Analysis (EFA). Exploratory Factor Analysis is a statistical method designed to determine whether there is any underlying structure that connects a number of observed variables. The intention is to try and identify a smaller set of (preferably) uncorrelated constructs or factors from within the larger set of observed variables many of which might be correlated with each other. The factors can be thought of as representing an unobserved structure among the observed variables that gives the researcher an opportunity to identify and describe what can be quite complex inter-relationships between the observed variables. Exactly how many such factors are identified is dependent on the data and on the amount of variability within the observed variables that each additional factor is able to explain. There are suggested rules for determining the number of factors (Williams, Brown, & Onsman, 2012) and in this paper we have used the conventional Kaiser criterion which suggests to retain those factors with eigenvalues equal or higher than 1.

Once the factors have been identified then each observed variable is assigned a factor loading and these are weights related to the correlation between each observed variable and the factor. The higher the load the more relevant the observed variable is in defining the factor's dimensionality. Conventionally when describing factors we suppress observed variables that have a factor loading below a certain threshold so that just the most relevant observed variables are identified.

Finally, question d) was answered by examining the literature on the treatment of mathematical anxiety in particular identifying pedagogical approaches that would be sympathetic to the diverse student cohorts that the school typically enrols. All data analysis was undertaken using the Statistical Package for the Social Sciences.

5. Survey Results

The total anxiety score for each student was calculated by summing the Likert scale responses across all 24 statements in the RMARS questionnaire. This gave each student a score ranging from 24 to 120. The sample of data (n = 330) was broken down between courses as shown in Table 1.

Table 1: Sample course totals

Course	Frequency	Percent
BA Business Studies	69	20.9
BA Accounting and Finance	108	32.7
HND Business	27	8.2

	FdA Accounting	18	5.5
	HND Informatics	53	16.1
	BSc Informatics	54	16.4
	Total	329	99.7
Missing	System	1	0.3
Total		330	100.0

In terms of gender, 54% of the sample was male and 46% female and the distribution of ages across the sample is shown in Table 2.

Table 2: Sample age distribution

	Age Group	Frequency	Percent
Valid	18 or less.	89	27.0
	19 - 21	158	47.9
	22-25	40	12.1
	26-30	20	6.1
	31-40	13	3.9
	Over 40	10	3.0
Total		330	100.0

The boxplots of total anxiety scores across the 6 courses is shown in Figure 2 below. The median total anxiety score was 50 and the inter-quartile range was 38 – 70 (recall that the range of score possible was 24 – 120). Now, dividing the range of total anxiety scores into 4 classes of equal width, the percentage of the sample falling into each class is shown in Table 3.

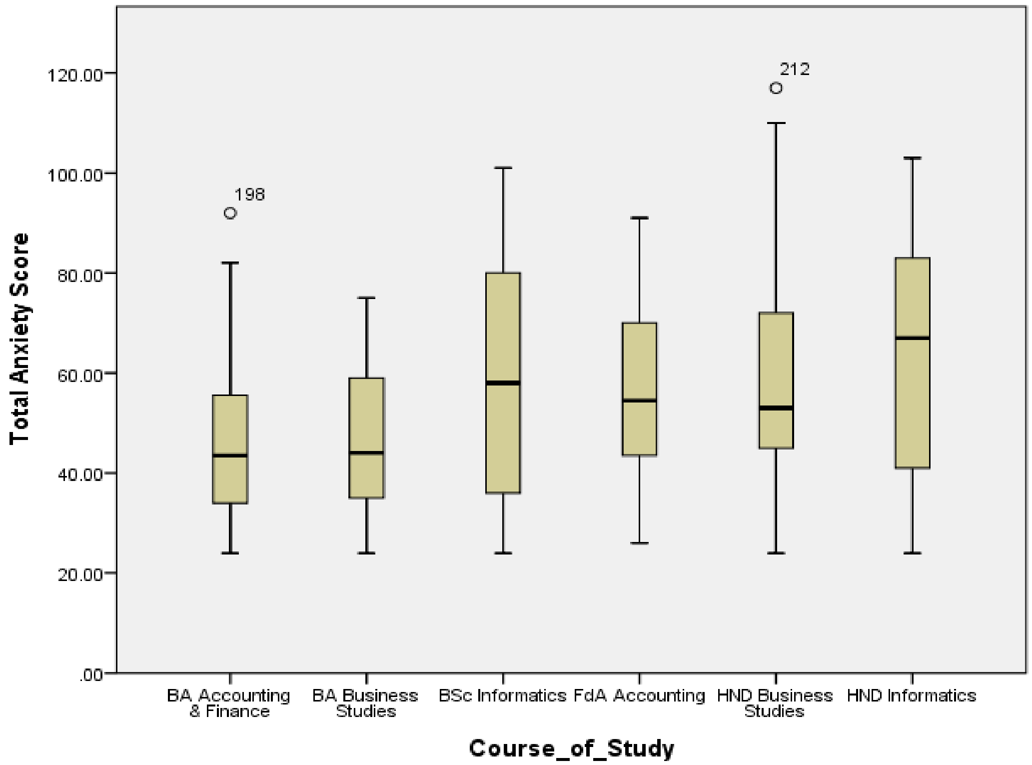

Figure 2: Boxplots of total anxiety scores by academic course

Table 3: Levels of mathematical anxiety across the sample

	Anxiety Level	Class	Frequency	Percent
Valid	Low Anxiety	24 – 47.9	145	43.9
	Slight Anxiety	48 – 71.9	106	32.1
	Moderate Anxiety	72 – 95.9	64	19.4
	High Anxiety	96 – 120	15	4.5
Total			330	99.9

When tested using the Mann-Whitney U test it was found that there was no significant difference between the total anxiety scores of males and females ($p = 0.143$) and neither was there a significant difference between the total anxiety scores of students when broken down by age ($p = 0.052$) using the Kruskal-Wallis one-way analysis of variance (ANOVA).

The respondents were then partitioned into those studying at degree level (BA Business Studies, BA Accounting and Finance and BSc Informatics) and those studying sub-degree courses (HND Business Studies, FdA Accounting and HND Informatics). Comparing the total anxiety scores for respondents within these two groups (n = 231 and n = 98 respectively) the Mann-Whitney U test returned a significant result (p = 0.000) and it is clear from the box plot illustration in Figure 3 that the sub-degree level students were exhibiting higher median levels of anxiety than the degree level students with a greater variation in scores too.

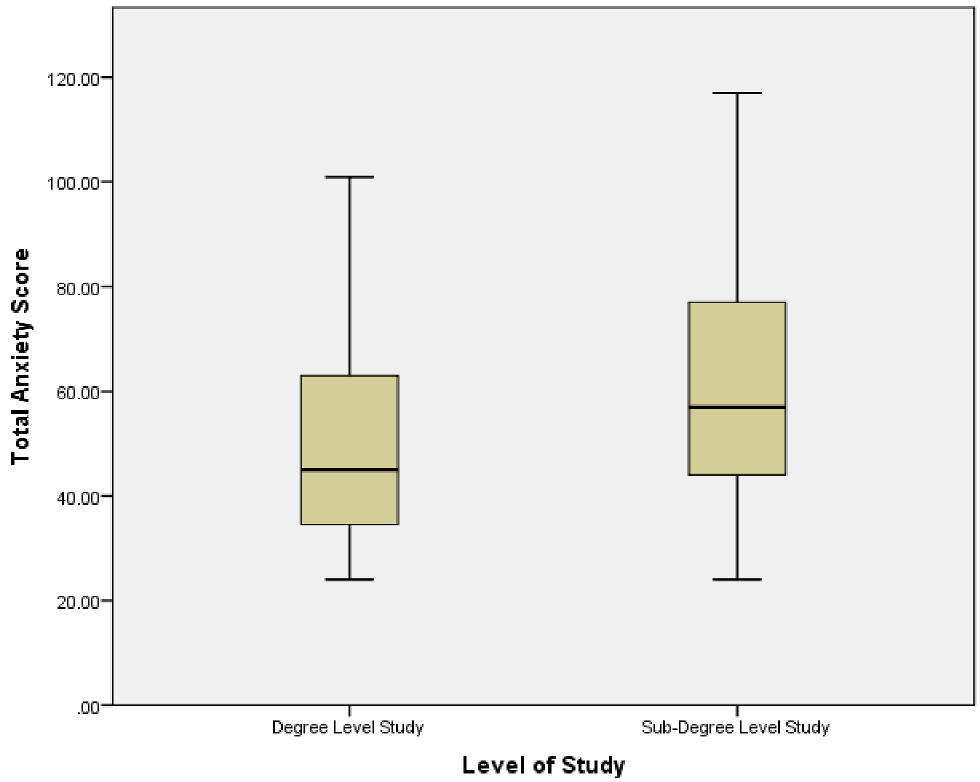

Figure 3: Boxplot of total anxiety scores by level of study

These results indicate that the sample may be treated as homogeneous as far as gender and age are concerned but that there is a need to further explore and understand the differences between the levels of anxiety exhibited by the differing study levels of students.

If we now consider only the sub-degree students, we find that there is no significant difference in the total anxiety scores of students across the three sub-degree courses (p = 0.523) demonstrating that the higher levels of anxiety are exhibited by sub-degree students in all subject areas. Turning now to the degree students, we find that there is a significant difference between the three degree courses (p =

0.008) with the BSc Informatics students showing higher levels of mathematical anxiety than either the Accounting and Finance students or the Business Studies students. Moreover for the Informatics students, there is no significant difference between their scores and those of all other sub-degree students ($p = 0.369$). Thus we have two distinct groups of students in terms of mathematical anxiety. Those students who are taking degree level studies in Business Studies and Accounting and Finance (generally low mathematical anxiety), and students who are taking sub-degree level courses together with the Informatics degree level students (generally high mathematical anxiety).

Table 4 shows all 24 RMARS statements and the average (arithmetic mean) anxiety score for each statement for these two groups of students. Two things are immediately apparent. First is that the average score for every single statement is higher for the high mathematical anxiety students than for the low mathematical anxiety students so that the high mathematical anxiety students are indicating raised level of mathematical anxiety across every statement on the RMARS questionnaire. Second, the top eight statements that indicate the most anxiety among the students are identical across the two groups with only a slight alteration in the ordering. Moreover these statements are all concerned with situations in which students have to demonstrate their mathematical knowledge either in an assessment situation or in solving or working on a problem.

At the other end of the scale, those statements which induce the least amounts of anxiety are mainly concerned with the more passive aspects of student learning. The exception here is that the activities of acquiring a mathematics book and looking through it (items 21 and 24) induce considerably more anxiety in the high mathematical anxiety group.

Table 4: Mean mathematical anxiety (MA) Likert scores by RMARS statement

	Low MA		High MA	
RMARS Statement	**Mean**	**Rank**	**Mean**	**Rank**
Being given a surprise test in a mathematics class	2.82	1	3.25	1
Waiting to get a mathematics test result in which you expected to do well	2.73	2	3.23	2
Thinking about a mathematics test the day before	2.65	3	3.12	3
Being given a homework assignment of difficult problems to be handed in at the lecture next week	2.45	4	2.88	4
Being asked a mathematical question in class	2.28	5	2.71	5
Taking a mathematics assessment test in a module	2.25	6	2.68	7
Getting ready to revise for a test in mathematics	2.07	7	2.65	8
Solving an algebraic equation yourself	2.03	8	2.71	6
Picking up a mathematics book to begin working on a coursework	1.96	9	2.44	12
Reading or interpreting graphs or charts	1.93	10	2.44	13
Starting a new topic in the mathematics module	1.92	11	2.41	14
Working on an abstract mathematical problem such as "If X = outstanding bills and y = total income, calculate how much you have left for recreational expenditure"	1.91	12	2.65	9
Walking into the university and thinking about the mathematics module	1.84	13	2.35	18
Seeing a mathematical formula in a general business lecture.	1.73	14	2.49	10
Looking through the pages of a mathematics book	1.71	15	2.26	21
Reading words associated with mathematics such as 'average' or 'equation'	1.67	16	2.34	19

Listening to a lecture on mathematics	1.66	17	2.36	16
Watching a teacher solve an equation using algebra on the whiteboard	1.64	18	2.45	11
Being told how to solve an equation using algebra	1.63	19	2.41	15
Buying or borrowing a mathematics text book	1.59	20	2.09	24
Getting a course timetable and seeing a mathematics module on it	1.58	21	2.36	17
Listening to another student explain a mathematical formula	1.53	22	2.26	22
Walking into a mathematics class	1.53	23	2.31	20
Having to use a calculator or tables to solve a mathematics problem	1.46	24	2.14	23

Finally, we applied EFA to these two groups of students to see whether there was any indication of different underlying structures within the patterns of anxiety exhibited through the RMARS responses. Taking the group of students taking the BA Business Studies or the BA Accounting and Finance the EFA produced the factor structure as described in Table 5. Then applying EFA to the remaining student group with the higher anxiety scores produced a factor structure as shown in Table 6.

Table 5: Factor loadings for low anxiety students

	Factor			
RMARS Statement	1	2	3	4
Buying or borrowing a mathematics text book				.689
Being given a homework assignment of difficult problems to be handed in at the lecture next week				.601
Thinking about a mathematics test the day before		.797		
Reading or interpreting graphs or charts			.714	
Getting a course timetable and seeing a mathematics module on it	.632			

Listening to another student explain a mathematical formula	.671		
Walking into a mathematics class	.793		
Starting a new topic in the mathematics module	.631		
Walking into the university and thinking about the mathematics module	.660		
Being asked a mathematical question in class		.618	
Working on an abstract mathematical problem such as "If X = outstanding bills and y = total income, calculate how much you have left for recreational expenditure"			.703
Seeing a mathematical formula in a general business lecture.			.738
Taking a mathematics assessment test in a module		.730	
Getting ready to revise for a test in mathematics		.647	
Being given a surprise test in a mathematics class		.799	
Listening to a lecture on mathematics	.654		
Having to use a calculator or tables to solve a mathematics problem			.639
Being told how to solve an equation using algebra			.691

Table 6: Factor loadings for high anxiety students

	Factor		
RMARS Statement	1	2	3
Buying or borrowing a mathematics text book			.769
Being given a homework assignment of difficult problems to be handed in at the lecture next week			.641
Thinking about a mathematics test the day before		.702	
Getting a course timetable and seeing a mathematics module on it	.626		
Listening to another student explain a mathematical formula	.689		

Walking into a mathematics class	.789	
Looking through the pages of a mathematics book	.777	
Starting a new topic in the mathematics module	.800	
Walking into the university and thinking about the mathematics module	.660	
Picking up a mathematics book to begin working on a coursework	.730	
Reading words associated with mathematics such as ‘average’ or ‘equation’	.644	
Taking a mathematics assessment test in a module		.750
Getting ready to revise for a test in mathematics		.625
Being given a surprise test in a mathematics class		.840
Listening to a lecture on mathematics	.693	
Having to use a calculator or tables to solve a mathematics problem	.742	
Being told how to solve an equation using algebra	.765	

6. Discussion of Results

We now discuss these empirical findings in the context of the research questions set out earlier.

What is the extent of mathematical anxiety among new students taking courses in a university Business School which involve the study of quantitative subjects?

The research has demonstrated that mathematical anxiety is present to varying degrees across the range of students included in the sample. More specifically, nearly a quarter of the students are moderately or highly anxious about mathematics as measured by the RMARS questionnaire. This is supportive of other estimates of the extent of mathematical anxiety which suggest that roughly 20% of the population are highly maths anxious individuals (Eden, Heine, & Jacobs, 2013). On average, though, the median score in our study for total anxiety was 50 which indicates that the average student might be considered only slightly anxious about mathematics.

Generally speaking, the situations that cause the most anxiety are those in which the student is ‘put on the spot’ in terms of having to display their knowledge. This could be either through being asked a question in the classroom, by having to take a test of some type, or just by working on a problem in, say, algebra. The fact that mathematics assessment causes anxiety is not surprising since students are always aware of the importance of summative assessments in any subject and test anxiety is also a recognised phenomenon (Sapp, 2013; Sparfeldt, Rost, Baumeister, & Christ, 2012). In fact it can be difficult to know with questionnaires such as RMARS the extent to which we are measuring mathematical anxiety or just more general test anxiety (Kazelskis, et al., 2000). Either way, however, this anxiety needs to be addressed in learning, teaching and assessment methods whatever its source.

Is there any statistically significant effect on mathematical anxiety attributable to age, gender, subject area of study or level of study?

We found no significant difference in anxiety levels attributable to gender or age. The evidence from other published studies is somewhat mixed in relation to these characteristics with some studies reporting gender and age differences and others reporting none. A recent study provides an excellent summary of this conflicting evidence relating to gender (Devine, Fawcett, Szucs, & Dowker, 2012) while the influence of age is a little more complex. Some studies have shown a statistically significant influence of age on mathematical anxiety (Mutodi & Ngirande, 2014) but this is often interrelated with level of study for example in studies of school age children. All students in this research were at the same level of study (i.e. UK university entrance at level 4) and the age of the students had no significant effect.

The research did show, however, that students taking the BA Accounting and Finance and the BA Business Studies had significantly lower levels of mathematical anxiety than those taking BSc Informatics and the sub-degree courses. Interestingly a previous study at another UK university found that first year business students exhibited significantly higher levels of mathematical anxiety than those taking an accountancy course (Joyce, Hassall, Montano, & Anes, 2006) and they were able to show that educational background was an influencing factor in this regard. Our research, however, has shown no significant difference in mathematical anxiety between Business Studies and Accounting students ($p = 0.623$).

A surprising result from our research is that the students taking BSc Informatics had significantly higher levels of mathematical anxiety than the students taking the BA Business Studies and the BA Accounting and Finance. There has been little research to date on direct comparisons between mathematical anxiety experienced by students in differing subject areas in the UK although one study of students undertaking STEM and non-STEM apprenticeships in the UK (Johnston-Wilder, Brindley, & Dent, 2014) did report findings that included the fact that non-STEM apprentices had significantly higher levels of mathematical anxiety than STEM apprentices. This directly contradicts the findings of our research. In explaining their findings Johnston-Wilder, Brindley, and Dent report that female apprentices tend to have higher levels of mathematical anxiety than males and will tend towards non-STEM apprenticeships. Also, non-STEM apprentices tend to have lower levels of mathematical achievement than those taking STEM apprenticeships. Both these factors would help to explain the increased mathematical anxiety recorded by non-STEM apprentices in their study.

In the current study we examined the entry qualifications of the students entering the six courses under study. Firstly we examined the entry tariff recorded for the students and for the three degree courses we carried out a one-way ANOVA which produced a significant result (p = 0.010). Subsequent contrast tests confirmed that when the BSc Informatics tariffs are compared with the BSc Business Studies and the BA Accounting and Finance combined there is a significant difference in entry tariffs (p = 0.003) with the average entry tariff for the BSc Informatics students lower than for either of the other two degree courses. Furthermore, taking the BSc Informatics course and the three sub-degree courses we found, again applying a one-way ANOVA, no significant difference between the average entry tariff for each course (p = 0.095). Thus we find that the average entry tariff groups the courses in much the same way as the mathematical anxiety scores have done.

It was no surprise to report that students taking sub-degree courses showed higher levels of mathematical anxiety than students taking degree courses. Students on sub-degree courses tend to have weaker academic qualifications (as demonstrated by the entry tariff data) and this would include weaker qualifications in mathematics. The consequence though is that we perhaps need to work with these students in a rather different way so that we can perhaps address the vulnerability of these students to negative experiences brought about by their raised levels of mathematical anxiety.

Are there any specific and identifiable differences in responses where a significant difference in total anxiety was found between student groupings?

Comparing Tables 5 and 6 there are differences in the way that the EFA has identified the explanatory factors. Taking Table 5 first, the three factors identified for the students with higher mathematical anxiety seem to have interpretations as follows:

Factor 1: situations related to learning and teaching in mathematics. This includes both passive learning (listening to a lecture on mathematics) and active engagement (having to use a calculator or tables to solve a mathematics problem).

Factor 2: situations related to being assessed in mathematics through a test process.

Factor 3: working on mathematics problems outside the classroom using resources they have acquired.

These sources of anxiety then seem to have quite distinct origins and this can be helpful in trying to determine ways to reduce mathematical anxiety.

For the students in the lower anxiety group there is a larger number of factors that have been identified with some slightly different interpretations.

Factor 1: passive aspects of learning and teaching possibly involving intellectual non-engagement with mathematical topics.

Factor 2: situations in which the student is required to demonstrate the extent of their mathematical knowledge either through assessment by test or being asked questions.

Factor 3: engaging in learning through active participation in mathematical activities and thought processes.

Factor 4: working on mathematics problems outside the classroom using resources they have acquired.

With these students we see a differentiation between the passive aspects of learning which may require no intellectual engagement with mathematics and active participation in which the student is required to use their knowledge and the risk of having to put their mathematical knowledge to the test seems to be a possible source of anxiety. As before, being formally tested in mathematics and having to work on homework problems also seem to induce mathematical anxiety.

What are the implications of the results in relation to mathematics teaching approaches for these students?

This survey has generated a large volume of data which has been summarised above. We now draw the discussion to a conclusion and try to identify a small number of key lessons that can be gleaned from the data. While there has been research into the alleviation of anxiety through the use of general stress coping mechanisms (Park, Ramirez, & Beilock, 2014; Brunye, et al., 2013; Maloney & Beilock, 2012) we will confine ourselves here to discussion of the impacts these results have on learning, teaching and assessment processes. There are four general conclusions to be noted:

First, we have not observed any differences in mathematical anxiety related to gender or age so in these respects our student cohorts can be treated as homogeneous in terms of mathematics learning, teaching and assessment. However, on entry to the university nearly a quarter of students in the sample exhibited severe mathematical anxiety and so we need to examine how we can, as far as possible, develop a learning pathway for students that avoid some of the anxiety peaks associated with some types of learning and assessment activities.

Second, it seems clear that a primary trigger of mathematical anxiety is assessment, irrespective of whether it is summative assessment in the form of tests and quizzes, or formative assessment through in class questioning. Formative and summative assessments are core components of any taught module so we cannot simply eliminate the need for assessment, but we can perhaps look at it in a different way. Research seems to indicate that mathematical anxiety can, to a certain extent, be avoided through developing a teaching approach that emphasises mastery goals (Furner & Gonzalez-DeHass, 2011). In the authors' own words "In a mastery goal classroom, success is defined by improvement, value is placed on effort and the process of learning, satisfaction is gained from working hard and learning something new, and evaluation is private." (Furner & Gonzalez-DeHass, 2011, p. 236). This links well with the notion of encouraging a positive feedback process as mentioned in the hybrid anxiety theory described earlier. It is important that we counter any negative feedback mechanism linking engagement and performance by accentuating success and personal improvement in whichever way this can be demonstrated. Learning for the student becomes very much a personal process. However, reflecting on the way that mathematics is taught within the School of Business (on some modules) there is a quite different culture of 'bite sized' learning, with regular summative assessment (supposedly to encourage attendance and engagement) with an assumption that all students are at the same level at the start of the module. Clearly this pedagogy is not appropriate for those learners who exhibit mathematical anxiety since the regular summative assessments tend to push students towards a performance orientation which, for highly maths anxious students, could easily become performance avoidance (non-engagement, disruptive behaviour or just non-attendance).

Instead it is suggested that student evaluation should focus on the personal development of individual students so that feedback and evaluation is oriented towards a student's progress and development and that when assessment is required it could take alternative forms so that students have the opportunity to demonstrate their mastery of the subject in ways which suit their learning and thinking styles (Furner & Duffy, 2002).

Interestingly, this kind of flexibility in assessment strategy runs counter to the views of some students (Iannone & Simpson, 2015). In their study of UK undergraduate mathematics students, Iannone and Simpson found that students had a preference for traditional unseen written exams in mathematics as their preferred form of summative assessment since they viewed these as the best discriminator of ability and the fairest (i.e. no piggy-backing in group work, internet access in coursework or blind guessing in multiple choice tests).

Thirdly, the fact that mathematical work carried out away from the university (homework assignments) cause anxiety indicates that we need to think closely about how we support students when they are off site. Here there is the opportunity to help students to structure their mathematical learning away from the classroom in a way which is not anxiety inducing. This can involve the use of student groups which undertake forms of collaborative or cooperative learning as this has been shown to reduce mathematical anxiety (Lavasani & Khandan, 2011; Dogan, 2012) and support should be provided in the form of e-resources and tutor support (perhaps via an online forum or the use of webinars) and web links and online lectures (Iossi, 2007).

Fourthly, active engagement with mathematics in the classroom increases mathematical anxiety in some students and so we need to look at how we structure classroom activities. Again, this suggests the use of mastery goals, the encouragement of 'risk taking' in the classroom together with the perception of the classroom as a safe environment in which it is ok to make mistakes (Finlayson, 2014), and of knowing the students and their capabilities and anxieties early in the academic year so that appropriate starting points for topics can be decided (Metje, Frank, & Croft, 2007) and anxiety issues addressed. In fact it is suggested that until a student with mathematical anxiety has confronted this anxiety it is not easy for that person to overcome the fear (Furner & Gonzalez-DeHass, 2011). Thus the use of RMARS or other similar evaluation tools should be used to identify those students who are likely to be in that group of students with high levels of mathematical anxiety.

7. Conclusion

This study has highlighted the need to look again at the way mathematics is taught within the School of Business. The survey has highlighted the existence of a number of students with high levels of mathematical anxiety in a certain cluster of courses and the literature suggests how this can be tackled. The next stage of the research will be to review the approach taken for teaching and assessing mathematics for those students on courses with high levels of mathematical anxiety and then assess the impact of the new pedagogy.

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