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Investigating Mathematical Anxiety Among Non-Specialist Undergraduate Students

Teaching mathematics to non-specialist undergraduate students in the UK has become particularly problematic in recent years due to a general decline in the mathematical skills exhibited by students leaving schools and entering higher education. This paper reports on a small scale preliminary study of the mathematical anxiety exhibited by undergraduate computing students and finds that anxiety is not related to mathematical achievement but is related to negative experiences prior to university entry and that the assessment processes they experience seem to cause the greatest anxiety levels. This has repercussions for the learning and teaching environment which the students are exposed to.

Introduction

In an article recently published in Mathitudes (Rossnan, 2006) the topic of mathematical anxiety is discussed in relation to the mathematical education of children. The article discusses what teachers and parents can do to overcome the effects of mathematical anxiety so that mathematical learning in later years and into adulthood is not impeded by such negative feelings towards mathematics.

Within the United Kingdom (UK) education system there is currently a good deal of debate among policy makers and practitioners regarding the apparent decline in the general mathematical skills possessed by students in the post-14 education system. A report commissioned by the UK government (Smith, 2004) has emphasised the importance of mathematical skills in both further education and employment whilst calling for the reform of mathematics teaching to ensure that it is both relevant to the needs of higher education and employment and interesting for students. A further recent study of students within the 14-19 age group concerning the development of general skills concluded that among UK higher education lecturers and admissions staff there are serious concerns about even the basic numeracy and literacy skills possessed by students. Not surprisingly, the report goes on to comment that there are also "… perceived problems with higher level mathematical skills, essay writing and independent learning skills." (Wilde et al, 2006, p 6).

Coupled with these pedagogic issues relating to mathematics training is the expansion of the UK higher education system stemming from the UK government's vision of the growth of the knowledge economy and the aspiration that 50% of school leavers should go on to gain a higher education qualification of some sort (Finegold, 2006). This expansion of higher education has resulted in many universities accepting students onto courses with very diverse (and non-standard) sets of qualifications and encouraging applications from mature students who may be returning to education (perhaps on a part-time basis) after a gap of many years. This tends to produce first year undergraduate cohorts with widely varying levels of skill, aptitude and experience in mathematics and so the teaching of mathematics both as a specialised subject and also as a support for other disciplines (such as engineering, computing or the health services) has become quite problematic.

As a consequence, there is now an increased momentum of research within the UK exploring issues of mathematical anxiety and related issues such as self-efficacy. To date, most of the research has been undertaken within the USA so it seems timely that UK universities are now beginning to explore these issues within their own student bodies.

At London South Bank University all students studying computing must take a mathematics module during their first year of study. This module makes up one eighth of the first year curriculum and has proved difficult for some students. It was thought likely among the teaching staff that mathematical anxiety was one factor causing students to perform poorly on the module. Some students were demonstrating a

lack of engagement and apparently poor mathematical skill levels even in what might be thought of as basic mathematics. To begin investigation of this phenomenon a small initial study was undertaken in February 2007 with a randomly selected balanced group of 16 students (8 male and 8 female) from the first year computing cohort who had started their studies in September 2006. The students were asked to complete a questionnaire to measure their current levels of mathematical anxiety and then to attend an individual interview during which qualitative aspects of the students' previous mathematical experience could be examined in a little more detail. This small-scale initial study was the precursor to a larger quantitative study of mathematical anxiety to be undertaken during 2008-09.

The results of this initial study are reported here. There were three broad questions that the study addressed. Firstly, what could be concluded, if anything, about the levels of mathematical anxiety among the first year computing students and could such measurements of anxiety levels be used to identify mathematically weaker students? Secondly, could mathematical anxiety be linked with previous positive or negative experiences described by the students? Thirdly, could teaching of the module be enhanced in such a way as to reduce the feelings of anxiety among the students?

Developing Mathematical Anxiety - A Brief Look at the Literature

Mathematical anxiety is generally felt to be distinct from attitude towards mathematics, the latter seeming to be inadequate in describing the variety and intensity of feelings that students are reported to experience in the classroom. Mathematical anxiety refers to the reaction that students have when asked to perform a mathematical task or to think about mathematics in an educational context and this reaction might include worry, stress, helplessness, or fear. It is possible, of course, that mathematics might invoke a complete lack of anxiety which could be reflected in displays of happiness, confidence or satisfaction at undertaking mathematical work although these reactions are apparently less common.

Mathematical anxiety "… is often developed as a result of a student's prior negative experience when learning math in the classroom or at home." (Rossnan, 2006, p 2) although such negative experiences need not be only related to the learning process. Indeed, it has been suggested that any negative life experience that involves some contact with numbers can be a source of future anxiety (Curtain-Phillips, 2004). While this might include problems occurring later in life with debt, tax calculation or generally understanding bank or credit card statements it is conceivable that feelings of anxiety towards mathematics may have their origins in pre-school experiences, although it is likely that mathematical anxiety is most often learned in school situations (Yenilmez *et al*., 2007). If not addressed, these feelings can persist into college and university education with mathematical anxiety manifesting itself as panic, paranoia (everyone knows the answer except me!), passiveness (lack of engagement), and a general lack of confidence (Lai, 2005).

Some researchers such as Pries and Biggs (2001) describe a classic feedback loop in which poor mathematical experiences lead to avoidance of mathematics with a consequent deterioration in preparation for further work, weakening performance and hence further poor experiences. Thus a 'vicious circle' increases (or at least maintains) anxiety levels with consequent effects on mathematical performance. This is supported by a recent study of European university students studying either business administration, economics or finance (Yenilmez *et al*., 2007) which concluded that poor levels of mathematical success were associated with higher levels of mathematical anxiety and that the same was true of general academic success (other than in mathematics).

To understand the full extent of the issues that can be raised by mathematical anxiety and its consequent effects on learning, we need only look at the literature where we see a number of publications describing such effects. These range from the impact that anxiety has on the future educational choices made by students (Lang, 2002) to the employment based issues that can, quite literally, be matters of life or death such as in the case of medical staff making complex drug dosage calculations (Glaister, 2007).

Given the serious consequences that anxiety has on students unfortunate enough to suffer from it, we need to discuss what can be done to remedy such feelings. Mathematical anxiety can certainly be eased and in the next section we consider how some learning and teaching approaches described in the literature might help to ease anxiety. Note that we have not included psychological interventions which have also been suggested as our focus in this research was

on developing appropriate learning and teaching methods only.

Potential Strategies to Reduce Math Anxiety with Adults or College Students

Researchers have suggested that students need to experience a cycle of learning which reflects the positive aspect of the feedback loop described earlier and that early success in a mathematics learning task can be very beneficial in reducing anxiety (Metje *et al.*, 2007). The key question is, of course, how to instigate the positive feedback process and there seem to be two main aspects to this. The first is to explore ways by which students can help themselves through the learning experience. The second is to advise tutors on appropriate learning and teaching strategies designed to help alleviate anxiety.

Zopp (1999) suggests that students can help themselves by joining support groups, learning stress management techniques, exploring their preferred personal learning styles and improving their study skills. Arem (2003) expands the notion of study skills development by asking students to: maintain an inventory of their study skills; explore how they feel most comfortable approaching learning; improve basic classroom skills such as note taking; attend classes and keep up-to-date with work (and seek help if necessary); and reward themselves for successful work.

As far as module delivery is concerned there is a need to carefully consider the way in which classroom experience is managed. Traditional pedagogic approaches have tended to include timed assessments, in-class question and answer sessions and imposed authority by the tutor – all of which are anxiety inducing among susceptible students (Curtain-Phillips, 1999). Teaching methods need to be sympathetically reviewed but this can be problematic for maths specialist staff who may never have experienced anxiety themselves and so may not empathise with student concerns (Metje *et al.*, 2007).

When designing a lecture or other teaching session, the literature suggests that a tutor needs to be aware of:

i) Appropriate models of learning. It has been suggested, for example, that highly anxious students are more receptive to expository methods of learning while less anxious students prefer discovery methods (Clute, 1984);
ii) The possibility of allowing students to describe and reflect on their feelings during and after the class through a journal or other type personal record (Dodd, 1999);
iii) Making sure that mathematics classes are pitched at an appropriate level and structuring classes so that early successes are possible for all students (Metje *et al.*, 2007);
iv) Providing a supportive learning environment and bridging the gap between concrete learning and abstract thought (Taylor & Brooks, 1986).

In general, the tutor must work with students to help them overcome the anxiety inducing aspects of mathematics classes and it is with this objective in mind that we began to explore the experiences of our own computing students.

Assessing Mathematical Anxiety

Assessing the level of anxiety felt by students in situations that require some sort of interaction with mathematics has been the subject of research for many years and in 1972 the Mathematics Anxiety Rating Scale (MARS) was developed (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 questions 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.

In this study, a slightly modified version of the RMARS questionnaire was used in which the modifications were made to tailor the statements to the UK education environment and to update some of the terminology (for example the use of ‘whiteboard’ rather than ‘blackboard’, ‘calculator’ rather than ‘tables in the back of the book’). The questionnaire consisted of a set of 24 statements and for each of these the students were asked to indicate how anxious they would feel on a 7-point Likert scale ranging from “Not at all anxious” (denoted by 1) to “Very anxious” (denoted by 7). Statements encompassed situations involving assessment (thinking about a mathematics test the day before), classroom learning (watching a teacher solve an equation using algebra on the whiteboard) and learning support (buying or borrowing a mathematics text book).

Having completed the questionnaire, students were then asked to attend individual interviews. The interviews were conducted by the same interviewer over a period of four weeks, were recorded and later transcribed. Each interview was semi-scripted in that the interviewer followed a protocol of prescribed questions. The interview protocol was designed to explore the students' previous mathematical experiences and their feelings towards the study of mathematics. The interviews were transcribed and then coded so that common responses and general themes from the responses could be identified (Miles & Huberman, 1987).

RMARS Questionnaire Results

It should be noted that from the 7-point Likert scale of responses, the minimum RMARS score achievable for each student is 24 (24 questions each scoring 1 corresponding to no anxiety), the theoretical median score is 96 (moderate anxiety) and the highest possible score is 168 (high anxiety). The questionnaire data were derived from Likert scales which have, in a number of published studies, been taken as interval data. However, a statistician would probably rate this type of data as no better than ordinal (Diamantopoulos & Schlegelmilch, 1997) and so the analysis here will proceed cautiously by assuming these data to be ordinal and to use the median and inter-quartile range (IQR) as measures of average and dispersion and to conduct, where possible, significance tests using non-parametric tests of medians (for example the Mann-Whitney test for the equality of two population medians).

Looking at the data overall we find that the median anxiety score for all 16 students was 78.5 with and IQR or 71.75. The maximum was 160 and the minimum was 26. Thus on average the students did not exhibit particularly high levels of anxiety but the spread of scores was large. Comparing the male and female students we find no significant difference between the median scores of the two sexes (male = 95, female = 74) when compared using the Mann-Whitney test ($p = 0.674$).

If we now look at the general relationship between mathematical anxiety and performance by comparing the total anxiety score for each student with that student's final module assessment score (a mark out of 100 with the pass mark set at 40) then we obtain a scatter diagram as shown in Figure 1. The Pearson product moment correlation coefficient is 0.214 ($p = 0.426$) indicating slight (but not significant) positive correlation.

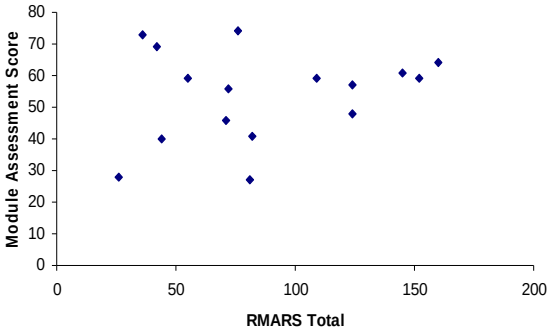

Figure 1. Anxiety and Assessment Results.

This result is not what we might expect since some students who have actually performed badly on the module exhibited low levels of anxiety and those who ultimately performed well tended to have high anxiety levels. The extent to which mathematical anxiety is linked to general student performance in mathematics is unclear. There have been very few studies of this within the UK although there is evidence that the ability to complete certain types of mathematical task is linked to anxiety (Ma, 1999) and that there are strategies that can be employed to reduce anxiety and enhance performance (Sheffield & Hunt, 2006).

We can also examine the questionnaire results by comparing the results for individual statements on the questionnaire. In order to do this the median and inter quartile range of student responses for each question was calculated and plotted as shown in Figure 2.

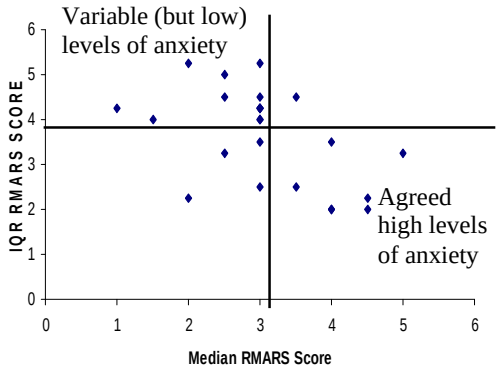

Figure 2. Median and IQR Student RMARS Scores for Each Question.

On each axis we have marked the median value so that the plot area is divided into four

sections each differing by the average anxiety described by students and the degree of variation in those anxiety scores. Statements that students seemed to agree were causing high levels of anxiety are shown in Table 1.

Table 1
Statements Causing Agreed High Anxiety

RMARS Statement	Median Score
Thinking about an up-coming mathematics test	5
Waiting for the results of a maths test	4.5
Being given an un-announced maths test	4.5
Solving a square root problem	4
Working on an abstract mathematical word problem	4
Being given a homework assignment due in the next class	4

There were also statements that had generally low levels of anxiety but high variability i.e. some students found these situations caused them anxiety while others did not. These are shown in Table 2.

Table 2
Statements Illustrating Generally Low but Variable Anxiety

RMARS Statement	Median Score
Walking into a maths class	1
Reading a word associated with mathematics	1.5
Listening to a lecture on mathematics	2
Watching a teacher solve an equation using algebra on the whiteboard	2.5
Walking onto campus and thinking about a mathematics module	2.5

Two statements seemed to cause agreed lower levels of anxiety as shown in Table 3.

Table 3
Agreed Situations of Low Anxiety

RMARS Statement	Median Score
Having to use a calculator to solve a problem	2
Listening to another student explain a maths formula	2.5

Listening to the Student Voice

Listening to students recount experiences during their interviews highlighted the breadth of those experiences and of the student's responses to them. Students were asked to describe whether they could recall positive experiences in mathematics before they were admitted to university and then whether they could recall negative experiences. Some examples are now quoted as illustration in Table 4 in which students recall personal encouragement they have received. To maintain anonymity the students are referred to only by letter.

Table 4
Examples of Positive Encouragement

Interview Question: Can you recall examples of personal encouragement you have had in mathematics before applying to university?
Student K (Female) Yes, my family always encouraged me to do well and one of my IT teachers. I think because of her really, I enjoyed doing IT and that just made me want to do it more and my grades were always really good.
Student N (Female) Because my auntie - we grew up together so she was good at school so she used to give me encouragement, she used to say 'you have to study'. She used to give me example from my uncle, my uncle was a doctor, she used to say 'if you study good you will be like him'.
Student C (Male) In terms of mathematics my parents were always encouraging. My dad had to use maths on a daily basis so my dad would always have given me encouragement, support and help. My mum always encouraged me there it was always made to be something that was quite important.
Student E (Female) My teacher actually, she was my support teacher and she told me that you are good in maths and she used to help me and I used to get help from her and she encouraged me. 'Whatever you are going to do, whatever you want to do in future, do maths as well because you are good in maths' - but I don't like to do maths!

Similarly a number of negative personal experiences relating to mathematics were also recalled by the students prior to admission to university and examples of these are illustrated in Table 5 below.

Table 5
Examples of Personal Discouragement

Interview Question: Can you recall any examples of personal discouragement you have had in mathematics before applying to university?
Student H (Female) Yes, but not specifically at school although there have been occasional times at school. My GCSE Geography teacher for example, took great pride in telling us which of us in the class were going to get As and Bs and then made sure the rest of us knew we were going to get what he called were 'good' grades of Ds and Es and he made sure that we knew what he meant.
Student D (Male) When I was in Access [a pre-university course] again, I wasn't doing that good and my friends kept telling me 'you're not that good, so please stay away from maths'
Student M (Male) Yes, I had friends before who kind of, … they were discouraging me and saying you can go and earn more money by doing you know, working rather than paying your school fees or something like that. I'm wasting money or something but it's good I didn't listen to what they told me.

Other examples of other generally positive and negative experiences are given in Table 6.

Table 6
Other Positive and Negative Experiences

Interview Question: Can you recall examples of other positive or negative mathematical experiences you have had prior to joining the university?
Student B (Male) I remember they used to like if you are good at something maths, any unit they would give you a card among all the students outside the class its like about 300 student 400 student and one day I was really down, really, really down and all of the sudden you know the Principal of the school he just you know called my name and I came over he said 'because was he was really good at maths blah, blah, blah we are gonna give him this card', it was a big card like that and that was a really big encouragement, it was really really big and it just made my day and you know, it was really good to the end of the year.
Student F (Male) Well the system in Denmark is different from the system in this country. In Denmark we used to work in groups a lot and we had homework and we had to do homework in groups we communicated in groups so if one person cannot solve something the other person can help you to solve it and the other person explains you how to do it. At the end of the group we have discussion and when we attended the next day we have to show the tutor what we had done. He'll ask us a question each individual so he can see that everyone has been doing something. I enjoyed doing that.
Student J (Male) The thing is with maths when I was doing A Levels in [College name] I just had this maths teacher that all he did was give negative feedback and I just found boring and I didn't get into maths at all, I didn't engage with the subject so everything was just going over my head. I just didn't care because you know all I cared for was the marks and I didn't pass anyway but I didn't care but now I do care about what I do and how I learned and how I get there.

In order to summarise how this group of students had been influenced by prior mathematical experiences, all the interview transcripts were examined with particular reference to the experiences described by students and their levels of anxiety as ascertained by the RMARS questionnaire. This information was also compared to the students' previous mathematical attainment as exhibited by their highest mathematical qualification on entry to the computing programme. This attainment was categorised as strong, intermediate or weak. The results of this analysis are shown in Table 7 and students have been listed in decreasing order of mathematical anxiety score.

The information in Table 7 allows three general observations to be made. Firstly, there is no statistical relationship between RMARS score and the level of mathematical attainment on entry to the university. Carrying out a Kruskal-Wallace significance test (a non-parametric equivalent of one-way analysis of variance) with RMARS score as the response variable and mathematical attainment as the control factor leads to the acceptance of the null hypothesis of no difference in sample medians ($p = 0.223$). Secondly, RMARS scores do not seem to be related with positive experiences recalled by students i.e. students who were not able to recall having positive experiences in previous mathematical education do not seem to exhibit greater mathematical anxiety. Partitioning the RMARS scores into two samples – those students who can recall positive

experiences and those who can not – and conducting a Mann-Whitney tests on medians (one sided) shows no significant increase in the median RMARS score for the second group who lack the positive experiences. Thirdly, negative mathematical experiences do produce a significant effect on RMARS scores. Students reporting negative mathematical experiences prior to joining the university have a significantly higher median RMARS score than those who do not report such experiences. Conducting a one-sided Mann-Whitney test of medians shows a significant difference between sample medians ($p = 0.015$).

Table 7
Summary of Student Experiences

Student	RMARS Score	Positive?	Negative?	Attainment
N	160	Yes	Yes	Intermediate
M	152	No	Yes	Intermediate
D	145	No	Yes	Intermediate
E	124	Yes	No	Strong
B	124	Yes	Yes	Intermediate
F	109	Yes	No	Intermediate
G	82	Yes	No	Weak
L	81	Yes	No	Weak
H	76	No	Yes	Strong
K	72	Yes	No	Strong
J	71	No	Yes	Weak
A	55	No	No	Weak
I	44	Yes	No	Intermediate
O	42	No	No	Intermediate
C	36	Yes	No	Strong
P	26	Yes	No	Weak

Summary and Conclusions

This study has been concerned with investigating mathematical anxiety among a small sample of undergraduate computing students and as such the results are really only indicative due to the small number of students involved. There are, though, a number of issues raised in relation to the three broad questions posed earlier and we now return to consider these.

Firstly, what does this study tell us about the levels of mathematical anxiety among the first year computing students? It seems clear that levels of anxiety are extremely variable among these students but there is no apparent connection between mathematical anxiety and sex or final module assessment score. Also, previous mathematical attainment does not seem to be linked to anxiety score. It seems that students who have good mathematical scores are just as likely to show high levels of anxiety as those students who are less skilled. Thus high anxiety does not seem to be a defining feature of weaker students (or indeed of stronger students) and so using the measurement of mathematical anxiety as a means for determining which students may be requiring mathematical support does not seem promising.

Secondly, could mathematical anxiety be linked with previous positive or negative experiences described by the students? Here, the evidence does seem to be consistent with the literature in that although reported positive experiences among students do not seem to differentiate those students with lower anxiety, students who report negative mathematical experiences do seem to have generally higher levels of anxiety.

Thirdly, could teaching of the module be enhanced in such a way as to reduce the feelings of anxiety among the students? It seems that students are agreed that the situations associated with anxiety are those related to the module assessment process. Low but variable anxiety is produced by on-campus classroom activity (listening to the teacher, arriving at a mathematics class etc.) so the classroom learning experience of the students seems to be generally viewed in a positive light. However, it seems that efforts need to be concentrated on helping students to understand the requirements of the assessment process and not to fear assessment.

We may find some clue as to why the assessment process is viewed by these students as anxiety inducing by considering the learning and teaching approach that has evolved over time on this and other modules taken by these students. As a result of the increased diversity of general skills possessed by students now being admitted to UK higher education institutions, and the fact that many have to work part-time to fund their education, some of the weaker students find themselves under pressure of time in their studies. It has been noted by teaching staff that this can effect their engagement with, and attendance on, some of the modules they are studying – particularly those that are perceived by the students as more difficult or perhaps less relevant. As a purely practical means of encouraging regular attendance and better engagement module teams now tend to assess their modules by means of regular (sometimes weekly) small-scale assessment tasks that require regular

participation on the part of the student. The argument for this being that students are engaged in what Kolb terms 'active experimentation' and by regularly trying out what they have learned and reflecting on those experiences the learning cycle, and the student, is engaged (Kolb 1984). However, as an unintended consequence students find themselves in an assessment-oriented learning environment in which they seem to be moving from one assessment task to the next (across different modules) on a regular basis. Considering just the mathematics module, we have already described how certain mathematical practices tend to cause anxiety and these relate to imposed authority, public exposure, and timed deadlines (Curtain-Phillips, 1999). Students taking the computing programme are now seemingly being exposed on a regular basis to each of these anxiety inducing practices as in each module (including mathematics) their learning is tightly structured, task oriented (by the teacher) and they are instructed to undertake regular 'practice and drill' exercises and assessments often with tight deadlines of just a few days. Then they have the results fed back to them in-class which they inevitably compare with each other.

It seems clear both from the literature and from the results of this small study that mathematical anxiety is a phenomenon that is readily apparent in students at all levels of study but that the links with aptitude and attainment are currently not well understood. Anxiety is clearly linked with previous negative educational experiences and a diverse student entry will undoubtedly contain many students with just those experiences. Unfortunately, instead of relieving those anxieties the learning and teaching approaches adopted on the undergraduate computing programme seem to emphasise those practices that induce further stress among some students and so this needs to be addressed.

As a result of this study, faculty mathematics teaching staff will now be reviewing the mathematics module to see how the assessment process (both formative and summative) can be shaped so as to appear less anxiety inducing for all students. Staff will be seeking ways of engaging and interesting students in the module without imposing the burden of additional assessment activities and timed tasks so as to increase the flexibility of the learning environment so it might be better tailored to the needs of the students.

Further research work is planned for 2008-09 in that a larger quantitative study will be undertaken exploring student anxiety responses to the mathematics curriculum that we offer. This will allow us to explore the robustness of the results of this initial small study (and some of its qualitative findings) with quantitative data based on larger student samples.

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