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Addressing maths anxiety and engaging students with maths within the curriculum

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Abstract

Maths anxiety is a situation-specific anxiety condition which is particularly prevalent in mature students. Previous negative learning experiences with maths condition the brain into maths avoidance behaviours which impacts on students' choices, their self-efficacy, and their curriculum progression. Otherwise-capable students find themselves unable to study effectively and put-off studying until the last minute. This paper discusses some of the strategies implemented as part of an ongoing collaborative project between the Department for Lifelong Learning (DLL), the Mathematics and Statistics Help centre (MASH), and the Specialist Learning Difference (SpLD) service at the University of Sheffield, the aim of which is to reduce anxiety and engage students to the learning of university mathematics.

Keywords: maths anxiety, embedding, formative tests, flipped learning.

1. Introduction

Maths anxiety can be described as "an emotion that blocks a person's reasoning ability when confronted with a mathematical situation" (Spicer 2004), and is negatively related to mathematics achievement (Woodard 2004). The brain of the maths-anxious student shows an activation of emotional areas when confronted with a mathematics problem, the strength of which is correlated with the degree of maths anxiety. This wastes working memory and attentional resources to address the anxiety, instead of allocating them to the maths problem (Young et al., 2012). This means that whilst the student is in a state of anxiety, their brain is unable to process maths effectively. Lyons and Beilock (2012) also showed that the anticipation of doing maths actually activates brain regions associated with pain, although the act of actually doing maths does not, which demonstrates that maths anxiety is a conditioned anticipatory fear of maths. It is therefore not surprising that the main behavioral symptom of maths anxiety is maths avoidance (Woodard, 2004; Ashcraft and Krausse, 2007). For students with maths anxiety, the brain views maths as a visceral threat to be avoided at all costs. This usually means opting-out of maths as soon as possible, and where this is not possible, avoidant behavioural strategies are employed, such as not studying regularly, and leaving study until the last minute are common (Jackson, 2008; Woodard, 2004). Given this approach, students with high levels of maths anxiety are 'at-risk' of failing, which impacts on progression and student retention rates.

The Department for Lifelong Learning (DLL) at the University of Sheffield provides Foundation courses, primarily for mature students, in which all students have to study a core maths module.

Due to the background and disrupted schooling of the DLL cohort, they often have high levels of anxiety, especially surrounding subjects perceived as 'difficult' in school, such as maths. Staff at DLL and the Maths and Statistics Help centre (MASH), which offers 1:1 help with mathematics and statistics education, both observed the impact of anxiety in students over several years. It was decided that a curriculum-based collaborative approach, encouraging attendance at MASH, was necessary to address the issues associated with maths anxiety. The project team have been trialing and evaluating changes to the maths curriculum to improve student confidence over two academic years and this paper evaluates the strategies implemented in 2015/16 and discusses the changes to the curriculum in 2016/17.

2. Strategies

The first step for addressing maths anxiety is to raise student awareness of what maths anxiety is and how their negative beliefs are affecting them (Uusimaki and Kidman, 2004; Martinez and Martinez, 1996). Once students understand the issues, they are able to start addressing their anxiety and engaging with other teaching strategies. Students with maths anxiety tend to find the classroom stressful as they are afraid of looking stupid in front of their peers, so a simple strategy is to release the lecture notes and resources early enough for anxious students to read through them in advance. Students are given access to the core learning materials in advance of the lessons, and use contact time to focus on processing and implementing the knowledge.This is known as a flipped learning model. In a study by Charles-Ogan and Williams (2015), those using the flipped learning approach had a significantly higher increase in maths test scores when compared to a group receiving traditional teaching.

Having only one exam at the end of a course (high-stakes testing) exacerbates maths anxiety, whilst untimed, unassessed, repeatable (low-stakes) tests actually reduce maths and test anxiety as well as boosting confidence (Simzar et al 2015). Feedback is known to help reduce the negative impact of maths anxiety on academic achievement; unfortunately, feedback tends to be limited in most courses (Núñez-Peña et al., 2015). Formative test scores are a form of feedback as students are being reassured of their knowledge and alerted to topics in which they are weaker (Friedman, 1987), which is especially important for a sequential curriculum such as maths. Anonymous online tests are particularly useful as students can check their understanding without peers knowing their score, and after the initial design, can be used on further cohorts of students. Multiple retrials of formative tests allows students to rewrite past feelings of failure by observing their performance improvements (Juhler, Rech, From, and Brogan, 1998). This is most effective when the question format is kept constant, but the numbers in the question are randomly generated.

3. Methods

3.1. Awareness and background information

In order to raise awareness of maths anxiety and begin to address students' issues, a maths anxiety workshop was designed by MASH in collaboration with the SpLD service at the University of Sheffield. The workshop is delivered to DLL students in the first maths lesson each year. The sessions is embedded into the timetabled schedule rather than being optional and voluntary, as maths-anxious students are unlikely to attend events with "maths" in the title. The workshop uses an active, reflective approach and aims to increase awareness, dispel common maths myths, and encourage engagement with the suggested strategies (Marshall et al, 2017). Visual representations are used to summarise recent neuroscience research so that students can understand how anxiety affects the brain and why maths avoidance is common. The usage of brain images makes psychological arguments more convincing (McCabe and Castel, 2008), which

strengthens the notion that the students' anxieties are due to neurological factors, rather than a notion that they "can't do maths".

In Autumn 2015, all students taking the Foundation Maths class were asked to fill in a short survey prior to the workshop and to give feedback straight after to evaluate the workshop. One of the questions asked the students to rate their levels of maths anxiety before the session on a 5-point Likert scale ranging from "None At All" to "Very High". As the whole class attended the session, it was important to distinguish between the groups when assessing the effectiveness of the strategies. In addition, they were encouraged to fill in the "Attitudes to Maths" survey which went out to all students at the University of Sheffield prior to the workshop. This questionnaire included the 23-item UK Maths Anxiety Rating scale (MAS-UK) which was constructed by Hunt et al. (2011), and is a reduced version of the Maths Anxiety Rating Scale (MARS) originally developed by Richardson and Suinn (1972). The results of the whole survey were published in the 2016 MSOR conference proceedings (Marshall et al, 2016).

3.2. Formative assessment

Weekly self-check tests were created in the university virtual learning environment (VLE) which allowed information on who used the tests to be collected. By allowing parameter randomisation in the online questions each time a new test was started, students could revise topics where they had made mistakes and try again without repeating the same question. Feedback can be added to these online tests, along with links to online materials that give students an alternative to the lecture notes. If students got a question wrong, an example of how to approach the question was given in the feedback and, where available, a link to a further resource on the topic was given. In February 2016, students were asked to fill in another survey to investigate the usefulness of the self-check tests for reducing anxiety and increasing confidence, along with other questions on their strategies for studying effectively. Students were also asked to fill in the MAS-UK scale again to assess changes from baseline.

3.3. Classroom strategies

Given that past negative learning experiences are the main source of maths anxiety, creating a positive learning environment is vital. After further research on building maths confidence, the module leader adopted a flipped learning model. This approach promotes independent thinking and flexible learning by allowing access to lecture material and additional online resources such as videos and web pages, in addition to tutor-created slides, well in advance of the lesson. In keeping with the success of the VLE-based tests from the previous year, new and more extensive online tests with parameter randomisation were created using Numbas (numbas.org.uk), a free open-source e-assessment tool by Newcastle University (Foster, Perfect and Youd, 2012). These tests were then embedded within the university VLE and made available to students alongside the learning resources.

During pre-lesson study time, students could submit questions on Padlet (padlet.com), an online notice board, that would then be answered during a face-to-face interactive lecture. Padlet was chosen as it allows students to ask questions anonymously, avoiding the risk of humiliation in class, and thus reducing their maths anxiety. The interactive lecture was designed to clarify specific points for the whole cohort, and also to gauge what the students had learned from the flipped resources. In order to do this in an anonymous but engaging way, multiple-choice quizzes were given using the Plickers (plickers.com) platform. Students vote for an answer to each question by holding up a unique paper-based QR code, a random-looking pattern corresponding to one of the four options. Plickers quizzes give students immediate feedback on their understanding

whilst enabling them to view the distribution of answers across the multiple choices by the whole class. It is also a useful tool to enable the lecturer to identify common areas of misunderstanding, and address them immediately.

In addition to the flipped learning resources and the interactive lectures, students also attended a follow-up tutorial where they were able to practice non-assessed exam-style questions in a tutor- and peer-supported environment. The module leader asked for feedback about these new strategies implemented in the 2016/17 academic year so far. This feedback was given via a brief questionnaire asking how enjoyable and useful students found the various resources; there was also an open-text box for students to give additional feedback if desired. The new strategies will be more formally evaluated in the future using the exam results, the end-of-module feedback, and observed changes in engagement within the classroom.

4. Results

4.1. Comparison of maths attitudes results

The results of the maths attitudes survey for the rest of the University of Sheffield were compared with the responses for the DLL cohort to look for differences. A Mann-Whitney U-test showed a significant difference in maths anxiety scores (U=16221.5, p=0.015) between the DLL cohort and the rest of the participants. The median anxiety score for DLL was 22.5 compared to 16.0 in the general university population. Previous research on this dataset showed that absence of A-level Mathematics was the strongest predictor of high maths anxiety (Marshall et al., 2016). As this is a Foundation course, only 10% of DLL students filling in the survey had A-level Mathematics, and 39% had either a GCSE Maths grade below a C or alternative numeracy qualifications instead. For students who had taken GCSE/O-level maths, 95% of the general university population achieved a GCSE grade A*-C on their first attempt, compared to only 61% of the DLL students. A Mann-Whitney test on the full survey data showed a significant difference (U=6112, p=0.001) in maths anxiety scores for those who did and did not achieve a GCSE grade A*-C on the first attempt. The median anxiety score for those achieving A*-C on the first attempt was 15 compared to 29 for those who didn't.

4.2. Awareness workshop feedback

91% of the 57 students filling in the awareness workshop feedback agreed or strongly agreed that the session was interesting and 87% agreed that the session was useful. 44% of the 57 respondents filling in the feedback survey classified themselves as having moderate to very high levels of maths anxiety. The self-reported scores were strongly related (ρ=0.67) to the official MAS-UK measures for those who had taken part in both surveys. 78% of those classified as moderate to very high levels of anxiety felt less anxious as a result of the session and 59% felt more confident about their maths ability. A lot of positive feedback about the session and the impact it had on students self-confidence was also given to departmental staff during the term, shown by some of the qualitative student feedback:

"I first started the course with a huge amount of maths anxiety. Since the first MASH maths anxiety session, I have been able to control my anxiety which has helped me understand maths better. I feel much more confident to give maths questions a go and have the ability to figure out where I went wrong."

"I am more confident in dealing with maths since starting in September. It is reassuring knowing support is there if and when needed."

4.3. Formative assessment

Overall, 80% of students took at least one of the nine initial online self-check tests created for the 2015/16 cohort and 51% completed at least three different tests. Those in the high anxiety group completed the most different tests on average although the difference was not significant (median=6.5). Only 20 students filled in the questionnaire about the online tests, and of these, only 14 had initially classified themselves as having moderate to high anxiety. As part of the survey students were given 5-point scales to rate helpfulness from 'unhelpful' to 'helped a great deal'. They were asked about different aspects of the test and how helpful the aspect was regarding reducing anxiety, increasing confidence and increasing understanding. Figure 1 summarises the percentages who found the tests in general, and the option for retesting, helpful.

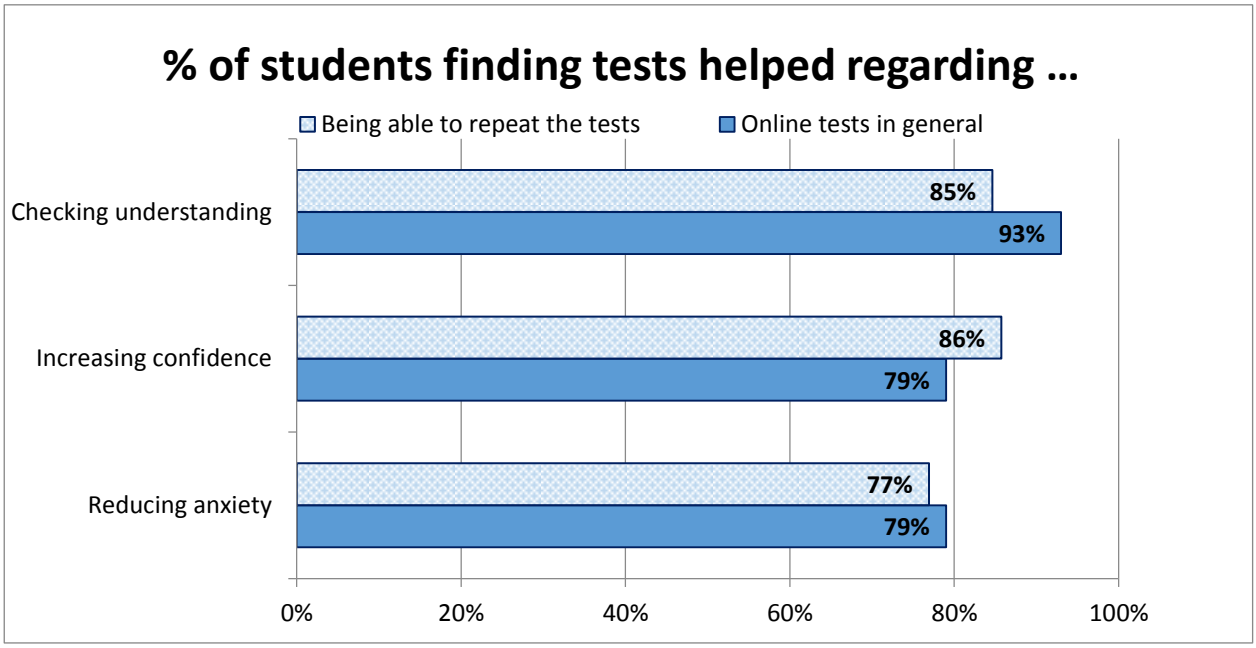

Figure 1: Survey feedback summary of percentage of students with moderate to high anxiety who said aspects of the online tests helped at least a bit.

It is clear from the results in Figure 1 that most students found the online tests helpful. This was also reinforced by student comments:

"*Using the tests to check my understanding helped out massively when I came to finding out the material I knew and didn't.*"

Due to these results, further formative, repeatable online tests were created and implemented in the second year of the study, using the Numbas platform.

4.4. Classroom strategies

27 students from the DLL 2016/17 cohort filled in a brief, informal questionnaire asking how enjoyable and useful they found each aspect of the course, based on 5-point scales from 'I hated it' to 'I enjoyed it a lot', and from 'useless' to 'very useful', respectively. The questionnaire asked about the 'aspects of the course', i.e. the new resources designed and curated for the academic year 2016/17. Figure 2 summarises these results by showing the percentages of students who

found each aspect enjoyable or useful, by choosing either of the two positive options in each 5-point scale.

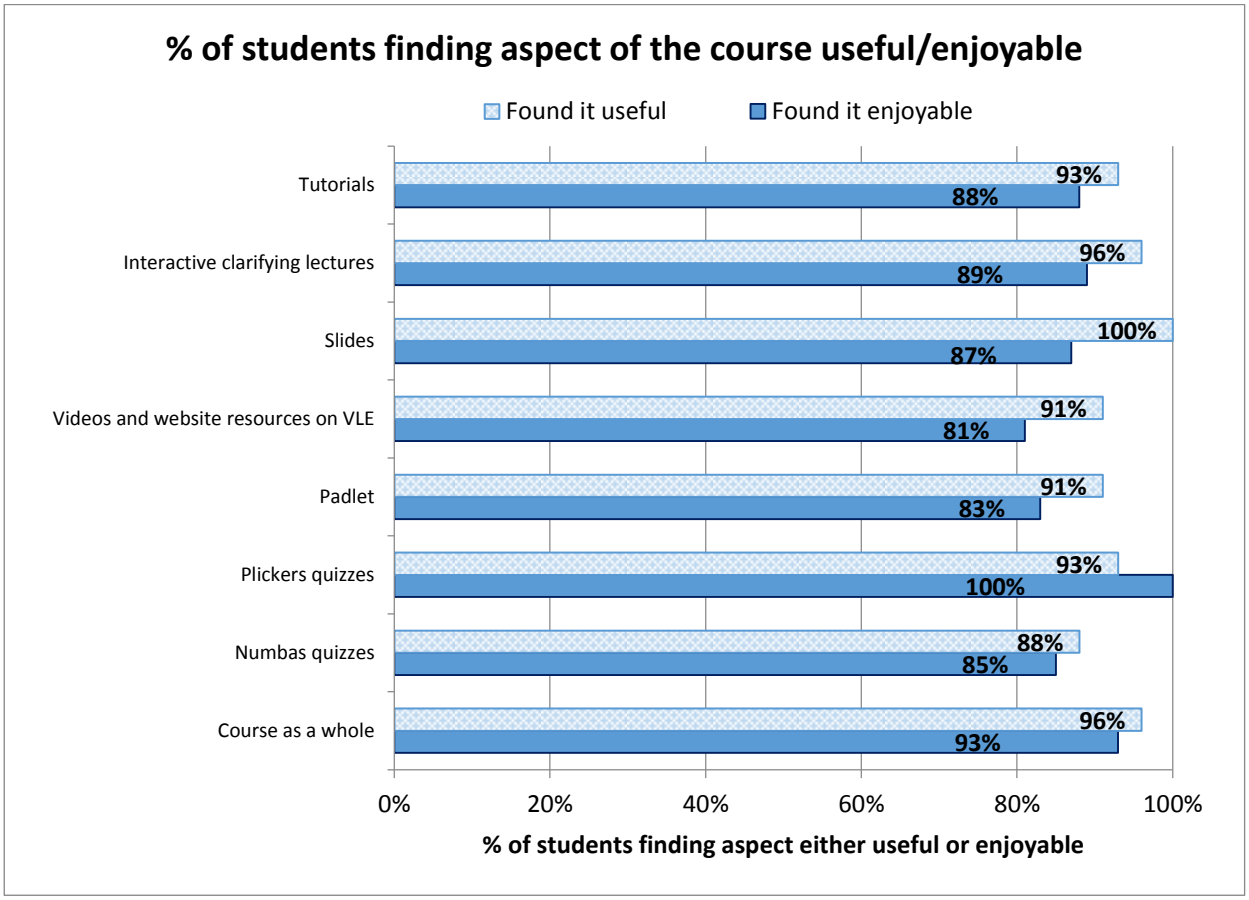

Figure 2: Summary of informal questionnaire feedback showing the percentages of students who found the various aspects of the course enjoyable or useful.

Based on the feedback, it is clear that students found the various resources available both useful and enjoyable. It is interesting to note that, with the exception of the Plickers quizzes, students recognised that the resources were very useful even if they didn't find them enjoyable. There was still a high percentage of students who enjoyed each aspect of the course, which has helped to reduce their anxiety levels, as evident from some of the free-text comments:

"The sessions are helpful and fun and have helped to lessen my Maths anxiety substantially. I like the Plickers quizzes for the quick thinking aspect and to cement what we have learned from the weekly materials."

The comments also indicate that the students found the learning environment presented by the tutor to be positive and encouraging.

"...you are taught in an academic manner, but are made to feel as though you can ask any question without feeling silly. Explanations are given clearly. The weekly materials are posted 2 weeks in advance which is helpful to me as it allows me to prioritise my time. The tutorials are helpful in that we can stay to ask questions if we are struggling but if we feel we are okay we can reflect on our answers in our own time."

"*Since attending my Foundation course I have come to realise that maths is actually quite fun, and that if you get the base right, the rest can follow. I've learned to be a lot calmer an approach what it is that I'm doing more positively."*

More detailed feedback on which aspects students found most helpful and which helped reduce their anxieties will be collected and reported later in the semester.

5. Conclusion

Maths anxiety is an issue impacting on many students' mathematical understanding in the Department for Lifelong Learning, and a number of strategies were trialled to address the issue. This paper demonstrates that implementing awareness, behavioral and formative test strategies are useful for addressing maths anxiety within the curriculum. The collaborative approach employed in this project has benefited the staff and students involved, and from the very first week of teaching, encourages students to use the various methods of support to succeed with their course. Whilst the initial preparation of the flipped learning approach and creation of formative online tests is quite time consuming, the benefits to the students are clear. Through the research carried out by the team, we hope to demonstrate to other academics that by embedding approaches that reduce anxiety within the curriculum, and encouraging the use of additional university teaching services, all students can reach their full potential.

6. References

Ashcraft, M.H. and Krause, J.A., 2007. Working memory, math performance, and math anxiety. *Psychon. Bull. Rev.,* 14(2).

Charles-Ogan, G. and Williams, C., 2015. Flipped classroom versus a conventional classroom in the learning of mathematics. *British Journal of Education,* 3(6), pp.71-77.

Foster, B., Perfect, C., and Youd, A., 2012. A completely client-side approach to e-assessment and e-learning of mathematics and statistics. *International Journal of e-Assessment*, 2(2).

Friedman, H., 1987. Repeat examinations in introductory statistics. *Teaching of Psychology,* 14(1)*,* pp. 2623.

Hunt, T. E., Clark-Carter, D., and Sheffield, D., 2011. The development and part validation of a UK scale for mathematics anxiety. *Journal of Psychoeducational Assessment,* 29(5)*, 455–466.*

Jackson, E., 2008. Mathematics Anxiety in Student Teachers. *Practitioner Research in Higher Education,* 2(1), pp. 36-42.

Juhler, S. M., Rech, J. F., From, S. G., and Brogan, M. M., 1998. The effect of optional retesting on college students' achievement in an individualized algebra course. *Journal of Experimental Education*, 66(2), pp. 125–137.

Lyons, I. M., and Beilock, S. L., 2012. When math hurts: math anxiety predicts pain network activation in anticipation of doing math. *PloS One*, 7(10), e48076.

Marshall, E.M., Wilson, D.A., and Mann, V.E., 2016. Attitudes and anxiousness about maths. In *Brave New World*: *Proceedings of the CETL MSOR Conference 2016*, (pp. 66–74). Loughborough.

Marshall, E.M., Wilson, D.A., and Mann, V.E. (under review Feb 2017). Evaluating the effectiveness of maths anxiety awareness workshops. *Journal for Research in Mathematics Education.*

Martinez, J. G. R. and Martinez, N. C., 1996. Math without fear. Needham Heights, MA: Allyn and Bacon.

McCabe, D.P. and Castel, A.D., 2007. Seeing is believing: The effect of brain images on judgements of scientific reasoning. *Cognition,* 10(7), pp. 343–352.

Núñez-Peña, M. I., Bono, R., and Suárez-Pellicioni, M., 2015. Feedback on students' performance: A possible way of reducing the negative effect of math anxiety in higher education. *International Journal of Educational Research*, 70, pp. 80–87.

Uusimaki, L. S. and Kidman, G. C., 2004. Reducing maths-anxiety: Results from an online anxiety survey. *Presented at the AARE Annual Conference, Melbourne, Australia: Australian Association for Research in Education.*

Richardson, F. C., and Suinn, R. M., 1972. The Mathematics Anxiety Rating Scale: Psychometric data. *Journal of Counseling Psychology,* 19(6), pp. 551.

Simzar, R. M., Martinez, M., Rutherford. T., Doina, T., and Conley, A.M., 2015. Raising the stakes: How students' motivation for mathematics associates with high-and low-stakes test achievement. *Learning and individual differences,* 39, pp. 49-63.

Spicer, J., 2004. Resources to combat math anxiety. *Eisenhower National Clearinghouse Focus,* 12(12).

Woodard, T., 2004. The Effects of Math Anxiety on Post-Secondary Developmental Students as Related to Achievement, Gender, and Age. *Inquiry: A Journal of Medical Care Organization, Provision and Financing*, 9(1), n1.

Young, C. B., Wu, S. S., and Menon, V., 2012. The neurodevelopmental basis of math anxiety. *Psychological Science,* 23(5), pp. 492–501.