Maths Anxiety: Theory to Practice

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February 11, 2019

Abstract

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1 Literature Review (/1100 words)

Prevalence

Maths anxiety is hugely prevalent, and consequently the literature describing research around it is extensive. The Organisation for Economic Co-operation and Development (OECD) (2013) 2012 Programme for International Student Assessment (PISA) report states that across OECD countries, over 30% of 15 year old students "get very nervous doing mathematics problems", and over 60% of students "worry about getting poor grades in mathematics".

Why is Maths Anxiety Important?

As teachers our foremost concern should be for the wellbeing of our students. It has been shown that students with a high level of maths anxiety often literally experience the anticipation of a maths task as visceral pain (Lyons & Beilock, 2012b). This helps to emphasise the clear and overwhelming moral imperative (and ethical duty of care) on us to do everything in our power to protect students in our care from maths anxiety.

Even if the wellbeing issue was not enough, there is also a clear maths anxiety-performance connection, and a complex web of stakeholders surrounding a students academic success in maths. One example of this is highlighted by Foley et al. (2017) who juxtaposes the internationally rising demand for Science, Technology, Engineering and Mathematics (STEM) professionals with the negative correlation between maths anxiety and performance shown in the 2012 PISA (OECD, 2013) report to highlight the relevance of addressing maths anxiety in filling this demand. This relationship between maths anxiety and maths-qualified professionals in the workforce is supported throughout the literature: when a student has low self-concept (correlated with high maths anxiety), they will tend not to enroll in maths beyond the minimum requirements for graduation (Ashcraft, Krause, & Hopko, 2007), and students affect towards maths can predict their university major

(LeFevre, Kulak, & Heymans, 1992). Beyond this example, the list of stakeholders in a students academic success in maths goes on and on: parents; the student's themselves; schools (which are often funded based on the results of standardised testing such as National Assessment Program — Literacy and Numeracy (NAPLAN)), and teachers amongst them.

Students success in maths, as well as their wellbeing, is important to many parties for many reasons. The one thing all the stakeholders agree on is that addressing maths anxiety is important, what nobody can agree on is exactly what maths anxiety is, how to measure it, and how to intervene and address it.

Frameworks for Understanding the Maths Anxiety-Performance Link

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Due to the importance of the maths anxiety-performance link, the bulk of the literature is focused on it. Only a few studies focus on maths anxiety itself (primarily functional magnetic resonance imaging (fMRI) studies such as those of Young, Wu, and Menon (2012) or Lyons and Beilock (2012b)). There are good reasons for focusing on the maths anxiety-performance link rather than maths anxiety in isolation, as discussed above. In terms of understanding this link however, there seem to be two distinct theories being pursued amongst the academy and I will adopt the terminology of Ramirez, Shaw, and Maloney (2018) to describe them: the "Disruption Account" and the "Reduced Competency Account". Ramirez et al. (2018) go on to make a convincing argument that although these two theories might seem to compete, they are not actually mutually exclusive and instead quite compatible with each other. Ramirez et al. (2018) suggests a third "Interpretation Account" which encapsulates observations made by both lines of research, see Figure 1. This seems to be a fairly new idea, and one we will aim to test in this study.

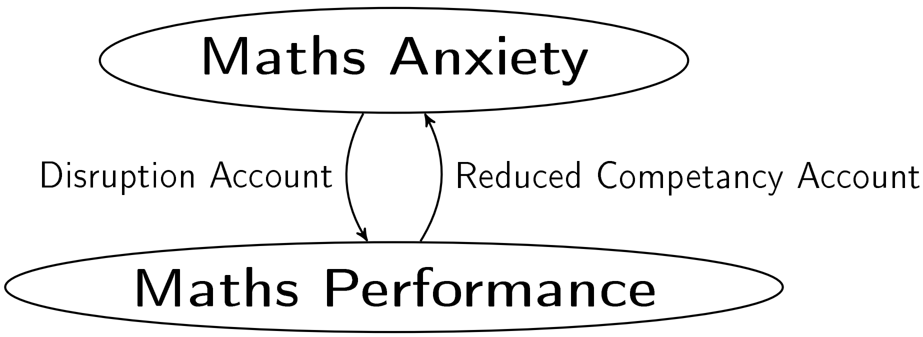

Figure 1: The Interpretation Account of Ramirez et al. (2018) for the maths anxiety-performance link showing how the Disruption Account and the Reduced Competency Account can be compatible.

First, a little more detail on the existing theories. The "Disruption Account" is currently considered as the dominant theory, seemingly spearheaded by the work of Ashcraft et al. and is based on a body of work centered around the concept of working memory (Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007). Specifically, the thought is that maths anxiety takes up students working memory, which prevents them from using that working memory to complete maths tasks and hence impacts performance. The "Reduced Competency Account", which seems to be less popular in recent times, claims that lower ability in maths leads to negative experiences associated to maths, and that these negative experiences cause maths anxiety to develop. There is also a significant body of work to support this hypothesis, including the meta-analysis of Hembree (1990) discussed above and more recent follow-up work such as the large longitudinal study of Ma and Xu (2004) which found that although past maths anxiety was correlated with future maths performance it was a small effect, while past maths performance had a strong effect on future maths anxiety.

Complexities in Finding Effective Interventions

These theoretical views are of course broad oversimplifications of what is an incredibly complex and interconnected topic. They also imply very different approaches for intervention. The "Reduced Competency Account" would imply interventions to boost maths performance and hence allow students to experience success in math should also help to reduce maths anxiety. The results of Supekar, Iuculano, Chen, and Menon (2015) seem to support this hypothesis as when students are given an intensive 8-week tutoring program to boost their maths skills, this is associated to a reduction in maths anxiety. The earlier work by Faust (1996) further supports this by demonstrating an anxiety-complexity effect in which low and high maths anxiety groups performed similarly on low complexity problems, but in high complexity problems the high anxiety groups performance was impacted. On the other hand, Jansen et al. (2013) showed that it is not neccessarily that simple, by showing that when students experience more success they attempt more problems and perform better. However their improved performance is almost completely predicted by the number of problems they attempted, not their experience of success, and their level of maths anxiety was not affected in a significant way. Which raises an important moral question: if we have interventions that improve students performance, but not their maths anxiety

On the other side of attempted interventions are those in line with the "Disruption Account", in which the maths anxiety itself is addressed in the hopes that will free up extra working memory and hence boost students performance. One fairly direct and successful attempt at this is that of Park, Ramirez, and Beilock (2014), in which they used expressive writing exercises to help guide students self-perceived narratives about their maths experiences and thereby reduce their maths anxiety. Notably the approach of Park et al. (2014) is in line with successful treatments for clinical anxiety disorders (see McNally (2007); Becker, Darius, and Schaumberg (2007); Foa et al. (2005)). Another approach that has shown success in this vein does not attempt to directly reduce the anxiety experienced, but rather reappraise it's symptoms (Jamieson, Peters, Greenwood, & Altose, 2016). This is another technique from clinical psycology in which stress is reconceptualised as a coping tool, an evolutionary method for heightening performance in response to a challenge to be overcome, instead of a symptom of exposure to something to be feared and avoided. This change in the perspective students have of stress is also very much in line with the "Interpretation Account" of Ramirez et al. (2018).

The work of Wang et al. (2015) showed the role that intrinsic motivation has mediating the relationship between maths anxiety and performance, and suggested the importance of a mindset centred on viewing the process of learning maths as one of "productive struggle". This reconceptualisation to a 'productive struggle' model is supported by other literature as well, Lin-Siegler, Ahn, Chen, Fang, and Luna-Lucero (2016) exposes students in a classroom to struggles experienced by famous scientists in order to help normalise the concept of productive struggle, and Hiebert and Grouws (2007) discuss the importance of this same concept in a maths context.

One of the implications of the "Interpretation Account" not predicted by either of the two major theories out there right now is that after an intervention the other, untreated, direction will re-establish the cycle shown in Figure 1 and that in the longterm the intervention will be relatively ineffective even if it has shortterm results. Several authors have mentioned the need for more longitudinal research surrounding interventions for maths anxiety (Suárez-Pellicioni, Núñez-Peña, & Colomé, 2016; Chang & Beilock, 2016). Notably the there is the study of Ma and Xu (2004) mentioned above, but otherwise there are very few such longitudinal studies, and those that exist have shown mixed results. My hypothesis is that with a multi-faceted approach targetted multiple causation pathways interlinking maths anxiety and performance, the entire cycle can be disrupted and result in a more positive long-term effects than individual interventions alone.

2 Research Proposal (/700 words)

I propose a multi-pronged intervention in which multiple links in the cycle (see Figure 1 are attacked simultaneously to disrupt the maths anxiety-performance link, and I hypothesise that this approach will result in a longer term sustained effect on both students wellbeing, reducing their negative affect towards maths and their maths anxiety, but also an improvement in maths performance. The four interventions I suggest are:

- An intensive tutoring program to boost students math abilities, along the same lines as that of Supekar et al. (2015).
- Coaching around reappraisal of physiological signs of stress (increased heart rate, sweaty palms, etc.) such as that of Jamieson et al. (2016) to interpret these signs as an evolutionary trait that increases fitness and performance in response to a challenge, instead of interpreting them as signs of danger to run from and avoid.
- Guided expressive writing, such as the approach of Park et al. (2014), inline with existing exposure therapy approaches from clinical psychology.
- Coaching around perceiving the process of learning maths as one of "productive struggle".

Instruments for Measuring Maths Anxiety

In order to track the effectiveness of these interventions, we will be collating assessment results as a measure of performance, but will also want to measure maths anxiety and maths affect/ self-concept.

Significant work has been done over the years to develop psychometrics to measure maths anxiety, almost exclusively consisting of self-reporting surveys (with the exception of some more modern fMRI work, such as that of Lyons and Beilock

(2012a)). One of the earliest instruments for measuring maths anxiety was the Maths Anxiety Rating Scale (MARS) 98-item 5-point Likert scale of Richardson and Suinn (1972). Since then, many different groups have split off and created various revised versions of a number of offshoots of this original idea, but all rely on a self-reporting survey. One of the more recently developed scales is the Maths Anxiety Scale — Revised (MAS-R) of Bai, Wang, Pan, and Frey (2009), which has been shown to be remarkably self consistent by incorporating both positive and negative affect items (Bai, 2011), and due to this property as well as the fact that it is short and easy to imlement is the one we will use to measure maths anxiety.

Jansen et al. (2013) modified the Perceived Competence Scale for Children (Harter, 1982) to measure "Math Competance". Although this extended scale doesn't seem to have comparative consistency studies done on it, the internal checks Jansen et al. (2013) were quite rigorous and so we will use their instrument to measure maths self-concept, although in English.

Methodology and Timeline

This research is predicated on collaborating with a school and the maths faculty therein. There will be three key components to the study: an intensive tutoring program for the students, a professional development program for the teachers, and guest lecturers. This professionsal development program for teachers will help the teachers, with the occasional help of guest speakers, to modify their teaching to:

- Incorporate examples of productive struggle into the classrooms, and coach students to adopt a productive struggle mindset.

- Coach students on how to reappraise physiological signs of stress as a response to a challenge to be overcome.

- Deliver expressive writing tasks to help guide students naratives about their math abilities.

Throughout there will be 5 primary forms of data collection:

- During school holidays there will be social teacher debrefiing sessions in which the teachers will be asked to provide feedback on their perspectives on the effects of the interventions.

- Assessment results for students academic performance will be collated for an entire three year period including a year prior to the interventions and a year afterwards.

- Students will complete self-surveys on both maths anxiety, and maths self-concept/ efficacy the year prior, during, and the year after the interventions.

- The expressive writing tasks will yield written work from each student describing their narative view of their journey learning maths, which can also be used to assess their self-concept/ efficacy in a deeper way.

3 Ethics Issues (/100 words)

Key ethical considerations include:

- All stakeholders (Teacher and student participants as well as parents and school leadership) will be given the full experimental details prior to commencement of the study.

- All published results will be fully anonymised.

- Students and parents will be made aware of their option to opt-out well in advance of the experiment commencing, and can choose to withdraw from

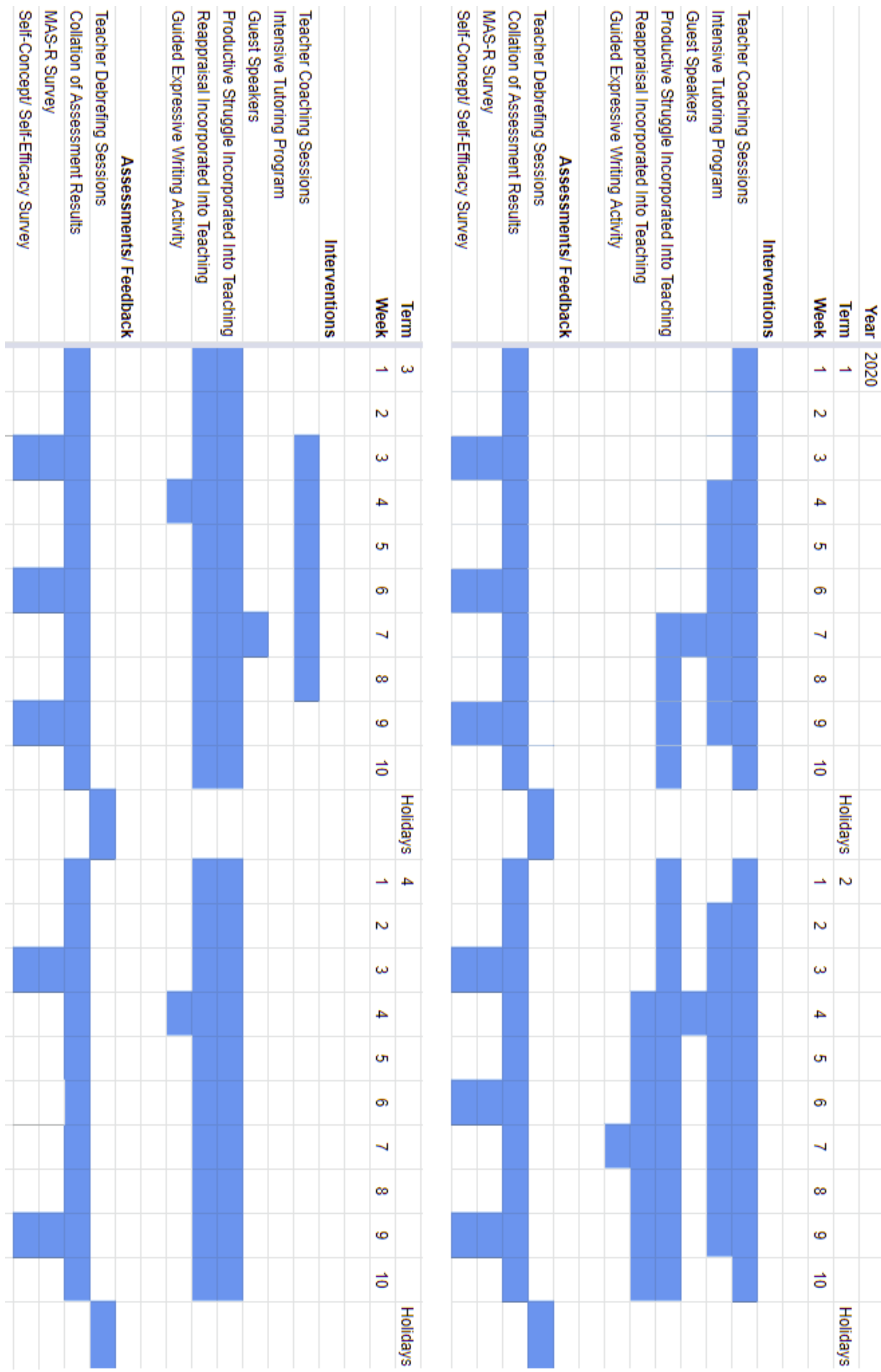

Figure 2: Gantt Chart

	Unit Cost	Units	Sub Total
Development Costs			
Teacher Coaching Sessions	$180.00	26	$4,680.00
Guided Expressive Writing Excercises	$300.00	3	$900.00
MAS-R Survey	$2,400.00	1	$2,400.00
Self-Concept/ Self-Efficacy Survey	$2,400.00	1	$2,400.00
Staff Wages for Interventions			
Teacher Coaching Sessions	$120.00	26	$3,120.00
Intensive Tutoring Program (per hour per student)	$60.00	600	$36,000.00
Guest Speakers (per session)	$300.00	5	$1,500.00
Running Costs/ Admin			
Printing and Stationary (per student)	$50.00	30	$1,500.00
Teacher Debrefing Sessions	$500.00	4	$2,000.00
Data Analysis and Project Management			
PI wages (per week)	$2,280.00	60	$136,800.00
Data Collation (per week)	$2,280.00	8	$18,240.00
Data Analysis (per week)	$2,280.00	10	$22,800.00
			Total
			$232,340.00

Table 1: Budget

the study at any point. Any student that wishes to be withdrawn during the study will be moved to a class not participating in the study. Withdrawn data will be ommitted from all analyses, it's only inclusion as a note of the total number of students that withdrew during the study.

- At all times teachers will still have complete autonomy running their classes, and will have the ability to stop the study at any time should they beleive it to be causing any harm (emotional, or academic) to the students. This judgement will be left to the discretion of the teachers involved in consultation with the leadership team at the school.

- As the study involves discussing and surveying students on sensitive topics including anxiety, all such content will include appropriate trigger warnings, a school councillor will be on-hand at all times should a student find themselves in distress, and a "cooling off space" will be available should students want to make use of it.

4 Executive Summary (/100-150 words)

Glossary

fMRI functional magnetic resonance imaging. 2–4

MARS Maths Anxiety Rating Scale. 3

MAS-R Maths Anxiety Scale — Revised. 4

OECD Organisation for Economic Co-operation and Development. 2, 16

PISA Programme for International Student Assessment. 2, 16

PTSD Post-Traumatic Stress Disorder. 6

STEM Science, Technology, Engineering and Mathematics. 2

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