Using the Growth Zone Model to limit the effect of mathematics anxiety on highly academic secondary students

John Thomas

University of Warwick

Mathematics anxiety is an "adverse emotional reaction to math or the prospect of doing math" (Maloney & Beilock, 2012, p.404) that negatively impacts individuals' experience of and progress in mathematics. There are studies examining the impact of mathematics anxiety on highly academic people (e.g. Beilock & Carr, 2005) but fewer large-scale studies of interventions in schools (Carey et al., 2019). The Growth Zone Model (Lee & Johnston-Wilder, 2017) helps students recognise and overcome negative emotions related to mathematics anxiety. I describe a pilot study into the benefits of introducing the Growth Zone Model to students in years 11 and 13 in a highly academic, selective school. Year 11 students were preparing for higher tier GCSE Mathematics and year 13 students IB Higher Level Mathematics. Time was allocated to discussion of students' emotional reactions, using the Growth Zone Model and associated tools (Johnston-Wilder et al., 2020) to moderate negative responses to difficult mathematics problems. Data is presented indicating the degree to which mathematics anxiety is an issue for these students and responses to a questionnaire about the efficacy of the Growth Zone Model are analysed. A case study examining one student's response to the intervention is presented, highlighting the potential for the intervention to make a positive change.

Keywords: mathematics anxiety; growth zone model; interventions.

Introduction

Mathematics anxiety (MA) is experienced as an "adverse emotional reaction […] to the prospect of doing math" (Maloney & Beilock, 2012). The international PISA study of 15-year-olds indicated that 30% of respondents report feelings of anxiety or panic when asked to work on mathematics problems (OECD, 2013). Students experiencing MA often mask their anxiety by attempting to avoid mathematics (Ashcraft, 2002).

While the efficacy of mindset interventions in general is contentious (e.g. Foliano et al., 2019; Yue Li & Bates, 2017), the impact of MA on working memory has been reported in various contexts (e.g., Beilock & Carr, 2005; Wilson, 1999). Johnston-Wilder et al. (2020) propose a three-piece toolkit for teachers designed to provide means by which learners can regulate the negative emotional responses linked to MA. The Hand Model of the Brain (HMB; Siegel, 2010) provides an easy to understand visualisation of the impact when the threat response is triggered. In the model, a closed fist represents the structure of the brain with the fingers representing the cortex, and the thumb the amygdala and hippocampus. When a stress or threat response is triggered, the fingers in the model open representing the instinct to avoid perceived threat taking over and mathematical thinking going 'off-line'.

The Relaxation Response (RR; Benson, 2000) provides a method by which learners can regulate their natural reaction to threat; in terms of the HMB this is represented by the fist closing, allowing recovery to occur. By introducing the domain-specific construct of Mathematical Resilience (Lee & Johnston-Wilder, 2017) and the Growth Zone Model (GZM; Johnston-Wilder et al., 2020), students are encouraged to further visualise the threat response in terms of zones. The green zone represents comfort, in other words students feel able to work without stress or worry. The red, or threat zone, is entered when the threat response is triggered. In this zone, students are more likely to implement various avoidance strategies which could include avoiding completing work set, displaying high levels of helplessness, or poor behaviour (Turner et al., 2002). In recognising that they have entered the threat zone learners may be able to move from the red zone into the amber, or growth, zone where challenges are effectively managed and learning can take place.

Mackrell & Johnston-Wilder, (2020) argue that Self-Determination Theory (Deci & Ryan, 2000) may offer further grounding for the concepts outlined in the Mathematical Resilience construct, particularly in terms of self-regulation. Providing students with the tools needed to regulate negative emotions and anxieties in mathematics has the potential to allow students to develop the autonomy needed to be successful, resilient learners (Lyons & Beilock, 2012). This pilot study offers an indication of the efficacy of the MA Toolkit (Johnston-Wilder et al., 2020) in achieving this aim.

School context

The setting for this pilot study is a boys' grammar school with a highly academic intake. While students must demonstrate the ability to do well in mathematics in order to gain a place at the school, there remains a minority who do not achieve expected progress. In the sixth form, Higher Level mathematics is a particularly demanding course. Introducing additional support that addresses students' maths-specific emotional well-being to ensure high levels of progress is therefore an important consideration. In year 11, student data identified a minority who were in danger of not attaining grade 5 or better in their final examination. In year 13, students in danger of not attaining grade 5 in terminal examinations were identified via performance data generated from high-stakes, timed assessments.

The incidence of MA in academically able secondary students is not well documented. To gain an understanding of the degree to which MA was an issue for the intervention groups, and to provide baseline data for the pilot study, students were given a questionnaire, completed in class, based on the modified Abbreviated Mathematics Anxiety Scale, mAMAS (Carey et al., 2017). A 3-point Likert scale was chosen to gain a broad understanding of how students responded emotionally to mathematics. Students were asked to indicate the degree of anxiety caused by the situations in each of the questions, as shown in Table 1. There is a high level of agreement between year groups with a clear tendency for students to feel more anxious in a test situation but less anxious during routine teaching and learning activities. This is not necessarily surprising given the high-stakes external assessments learners were preparing to take but since the interventions were aimed at improving examination performance, these results fully justify the approach to safeguarding taken during the intervention.

	Year 11			Year 13		
	Very	**A little**	**Not at all**	**Very**	**A little**	**Not at all**
Having to complete a worksheet by yourself	8	75	17	6	75	19
Thinking about a maths test the day before you take it	42	17	42	63	25	13
Watching the teacher work out a maths problem on the board	25	50	25	19	50	31
Taking a maths test	42	42	17	69	31	0
Being given maths homework with lots of difficult questions that you have to hand in the next day	33	58	8	56	19	25
Listening to the teacher talk for a long time in maths	17	0	83	19	38	44
Listening to another student in your class explain a maths problem	17	58	25	25	19	56
Finding out that you are going to have a surprise maths test when you start your maths lesson	67	25	8	81	19	0
Starting a new topic in maths	8	42	50	6	50	44

Table 1: Students' responses to questions in the mAMAS

Specific interventions – HMB and GZM

During the first lesson, the HMB was introduced as a method for students to understand the impact of any feelings of anxiety; students were then introduced to the RR (Benson, 2000) to be used if they identified a situation where feelings of anxiety were beginning to surface. In particular, students were encouraged to use a simple breathing exercise to regain control over the stress response, enabling them to refocus on identifying key aspects of each question before working towards a solution.

The GZM was introduced and a discussion about the meaning of each zone took place. The red zone was explicitly linked to the HMB concept of "flipping your lid" and students were encouraged to discuss occasions where they had experienced feelings of high anxiety, particularly in a mathematical context. Having agreed that this is a common experience, the discussion turned to methods that allow learners to make progress and adopt a growth mindset approach. These ranged from the simplistic ("just try to do it") to more refined approach such as: use the RR to recover; identify the topic; summarise key information about the topic as part of initial working; attempt to select appropriate methods from key information. The aim was to encourage students to begin to see the construction of solutions in mathematics as an iterative process rather than assuming that not "seeing" an answer immediately meant they lack ability to think and write mathematically. Since the intervention was aimed at improving examination performance, students were encouraged to see these strategies as a way to be awarded process or method marks, even if they were unable to then go on to produce a complete solution.

Evaluation

An approach based on practitioner research (Menter et al., 2011) was adopted to balance the tension between the need to develop meaningful conclusions while still delivering lessons to a high standard. Observations of student behaviours and responses to the HMB, RR and GZM were used to develop an understanding of the efficacy of the intervention. In addition, students were asked to complete a survey exploring two ideas underpinning the intervention. Further to this, one student's

response to the intervention was particularly noticeable and it is this student that became the subject of the case study presented below.

Open responses to survey questions

Questions exploring resilience and responses to the GZM were included in a more general survey to determine the overall effectiveness of the intervention lessons. Responses fell into two broad categories: use as a cognitive tool and adoption of the GZM as a way to regulate emotional responses before implementing strategies for answering questions. Typical responses related to cognition included:

> Yes, because I've realised no question is impossible, you just have to follow a process (year 11 student)
>
> Yes – I can actually approach difficult questions in a rational way, so it's possible I can reach a close answer (year 13 student)

Responses indicating a focus on regulating negative emotional responses were less common but included comments similar to:

> Useful because recognising where you struggle is the first step to improvement (year 11 student)
>
> It helps me think about the topics involved in the question and whether they are actually manageable instead of just panicking at first glance (year 13 student)

It is encouraging that the programme allowed all students to gain a degree of autonomy and apply the concepts to their learning experiences. This indicates that there is potential in developing students' awareness of their emotional responses to mathematics, to regulate negative responses, and become more resilient learners.

Case study

GT is a student whose attainment data indicated that he was in danger of not meeting his challenging target grade, consistently attaining no higher than grade 4. His answers demonstrated that, while he could produce reasonable solutions to more straightforward questions, he struggled to come to terms with more complex multi-step questions where little scaffolding is provided.

GT had been recognised by the school's SEND department as being predisposed to general anxiety. Observations of GT's body language and approach to challenging work, both in the intervention lesson and his regular lessons, indicated that the HMB and GZM were concepts that he engaged with positively. He was able to describe his emotional response to high levels of challenge clearly and could demonstrate effective implementation of the strategies presented in the intervention lessons.

Mid-way through the intervention process, students completed a spring mock examination. GT achieved high grade 6, an outstanding improvement given his previous tendency to avoid questions that caused anxiety. An example of one of his answers is presented in figure 1. Key aspects of this solution are:

- GT highlighted that the question placed him into the red zone and labelled the question as such. In discussions following the assessment, he was able to explain that he understood that he needed to withdraw, recover and then think carefully about a strategy that could lead to a correct solution.
- Once he had achieved clarity, he was able to start summarising key facts within the question.

- Not only that, he was able to write in a structured way that allowed him to get to the heart of the problem and produce a clear and correct answer.

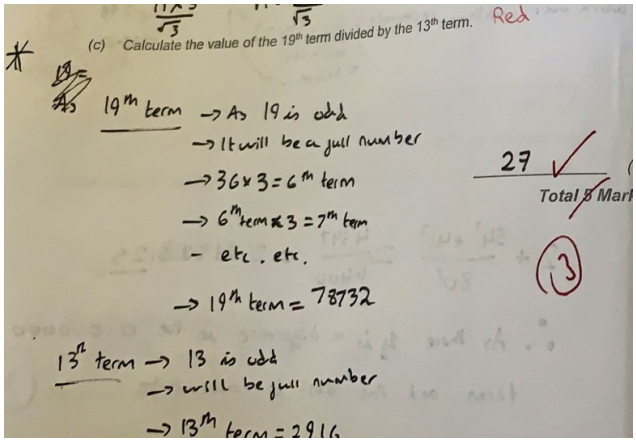

Fig 1: Example of a solution written by GT in the Spring mock examinations

While this case study involves only one student, it offers some compelling evidence that the potential exists for interventions of this type to offer self-regulation strategies to at least some students.

Further research

While there are signs that interventions of the type described in this paper offer students some cognitive and self-regulation strategies, there remains the question when they are best introduced. There is a need to investigate further the prevalence of mathematics anxiety in each school, even where students are expected to be academically able. Additionally, would this be more effective presented as an intervention when students are clearly experiencing anxiety or would an earlier introduction to self-regulation and the GZM be more effective? There have been significant strides forward in pedagogy and teachers' understanding of the role of questioning and feedback in the classroom in recent years, but much less attention given to incorporating effective affective interventions into routine teaching practices.

Further to this, the question of how students prepare for examinations needs to be asked. At which stage in the year is it reasonable to expect that students' revision is at a sufficiently detailed level that they feel ready to be assessed on their knowledge and understanding at short notice? In terms of self-determination theory (Deci & Ryan, 2000), are the students developing traits related to autonomous motivation? The intervention considered in this pilot offers a simple, time-efficient method for introducing awareness of how MA can have a negative impact on students' experience of doing mathematics and enabling some students to gain autonomy in their learning and improve progress.

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