Action Research Proposal

Interventions for Negative Mathematical Self-Perception in School Communities

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Mathematics anxiety and negative attitudes towards mathematics are problems that have been well documented in Western societies (Ashcraft, 2002; Dweck, 2008, National Numeracy, 2020). However, the extent and specific effects of these problems on international school communities, whose demographics tend to be unique in that they are both diverse and generally high-income families, are not yet well studied. Moreover, although the phenomenon of mathematics anxiety and its associated negative consequences are generally well-known in educational contexts, what might be a surprising finding for most is that it can even cause physical pain (Samuel and Warner, 2021, p. 205). After several years of teaching non-elective mathematics courses to high school age students in international schools, I accumulated significant anecdotal evidence of widespread mathematics anxiety and low mathematics self-efficacy (defined as a person's belief in their own ability to learn and do mathematics; Cribbs et al., 2021) in these populations. A recent study by Samuel and Warner (2021) suggested that a growth mindset intervention significantly reduced mathematics anxiety in first-year community college students, and so it would seem reasonable to hypothesise that a similar intervention would be effective for high school students (in this paper I will define a growth mindset as "the belief that intellectual abilities can be cultivated and developed through application and instruction"; Dweck, 2008, p. 1). Thus, because of the potential to both alleviate suffering and gain insights into the effects of mathematics anxiety in a different population, this action research proposal will suggest an intervention to improve mathematical self-perception and reduce mathematics anxiety in an international school setting.

Problem Statement

The problem is widespread negative perceptions about mathematical ability and associated mathematics anxiety within an international school community. The background of the problem comes from my experiences teaching "bottom set" mathematics cohorts in international schools over the last few years, and in particular the research that I did in writing the blog post "Mathematics Education Rebooted for the 21st Century" (Wallace, 2022). I discovered that my anecdotal experience of many students having convinced themselves that they're "just not a maths person" and of parents reinforcing that belief was similar to that of other mathematics educators (Stanford, 2012; Strauss, 2016). The research also supported my intuition that negative mathematical self-perception, mathematics anxiety, mathematics avoidance and convincing oneself that mathematics isn't worth studying all form part of a vicious cycle that can have far reaching consequences for students' life trajectories (Ashcraft, 2002). The population impacted by the problem that this action research study intends to implement interventions for is several cohorts of high school students studying compulsory mathematics courses as part of the International Baccalaureate curriculum.

Purpose of the Study

The purpose of this action research study will be to determine how the integration of regular growth mindset development activities into mathematics units at the school in question will improve mathematical self-perception and reduce mathematics anxiety. Growth mindset development was first chosen as an intervention strategy because it is one of the key pillars of mathematical resilience (National Numeracy, 2020). It is hoped that regular exposure to growth mindset ideas will help students to break the vicious cycle mentioned above and ultimately result

in improved attitudes towards mathematics in the school community. A possible side benefit is that a growth mindset can be transferred to other areas of students' lives.

Research Questions

According to Dweck (2008), students tend to have a disproportionately fixed mindset towards mathematics ability in comparison with other academic areas and intellectual skills. For this reason, growth mindset development activities can be confirmed as the intervention likely to have the largest impact on mathematical self-perception and mathematics anxiety, and hence the research questions will focus on the impact of this intervention. Thus, the following research questions will guide the literature review of the action research study:

1. Will the integration of regular growth mindset development activities into mathematics units improve mathematical self-perception and reduce mathematics anxiety in an international school community?
2. Why would the integration of regular growth mindset development activities into mathematics units impact mathematical self-perception and reduce mathematics anxiety in an international school community?
3. How will the integration of regular growth mindset development activities into mathematics units improve mathematical self-perception and reduce mathematics anxiety in an international school community?

Alignment

The problem statement, purpose statement and research questions will now be summarised in Table 1 below to demonstrate their alignment:

Table 1

Problem Statement, Purpose Statement and Research Questions Alignment

Problem Statement	Purpose Statement	Research Questions
The problem is widespread negative perceptions about mathematical ability and associated mathematics anxiety in an international school community.	The purpose of this action research study is to determine how the integration of regular growth mindset development activities into mathematics units will improve mathematical self-perception and reduce mathematics anxiety in an international school community.	1. Will the integration of regular growth mindset development activities into mathematics units improve mathematical self-perception and reduce mathematics anxiety in an international school community? 2. Why would the integration of regular growth mindset development activities into mathematics units impact mathematical self-perception and reduce mathematics anxiety in an international school community? 3. How will the integration of regular growth mindset development activities into mathematics units improve mathematical self-perception and reduce mathematics anxiety in an international school community?

Literature Review

A search for relevant literature was conducted using the terms “mathematics anxiety and growth mindset” (the alternative phrases “maths anxiety” and “math anxiety” were also checked for different results). An initial review of these results suggested that the phrase “mathematics self-efficacy” is in more common usage than “mathematical self-perception”, and thus a second search was conducted using the terms “mathematics self-efficacy and growth mindset (both searches contained the term “growth mindset” since it is the proposed causal factor). A whole-class growth mindset development activity that can be easily and regularly implemented at the beginning of lessons in a variety of secondary mathematics classroom settings was identified as

the best practice intervention most suitable for use in this study. A thematic review of the literature that most closely matched the search terms mentioned above will now follow, along with a summary of all relevant best practice interventions for reducing mathematics anxiety that were considered, and any identified gaps in the literature.

Discussion of Common Themes

Common themes found included the pervasive nature of mathematics anxiety, that it begins in early elementary grades and often persists into adulthood, and that adults suffering from mathematics anxiety can pass it on to children in a self-perpetuating cycle. Mathematics anxiety is associated with low mathematical self-efficacy, lack of agency, failure avoidance and a fixed mindset. On the other hand, working to adopt a growth mindset seems to be an effective way to reverse or improve these traits and break the negative cycle. Since the element that all studies had in common was mathematics anxiety (as opposed to mathematics self-efficacy or growth mindset), the discussion of the themes that follows has been organised in terms of the characteristics of mathematics anxiety that appear to be universally acknowledged.

Begins in elementary school and continues into adulthood

Multiple studies cited seminal research showing that mathematics anxiety begins during elementary school (Klee et al., 2022; Schubert, 2019; Lee et al., 2022). While it peaks sometime during secondary school (Schubert, 2019, p. 16), it does not appear to resolve as people mature (Samuel and Warner, 2021; Klee et al., 2022). Of particular concern is that elementary school teachers have been found to have some of the highest levels of mathematics anxiety among the general adult population (Pair et al., 2019, p.3).

Negatively correlated with mathematical performance and self-efficacy

It is well documented that mathematics anxiety leads to a decreased ability to perform mathematical tasks (Klee et al., 2022; Pair et al., 2019). Multiple studies have also shown that high levels of mathematics anxiety can lead to reduced mathematics self-efficacy, and vice versa (Cribbs et al., 2021). However, it is less certain whether reduced mathematical self-efficacy leads to increased mathematics anxiety (Cribbs et al., 2021, p. 276). In general, though, it would seem reasonable to assume that interventions that reduce mathematics anxiety will also improve self-efficacy.

Leads to mathematics avoidance and a vicious cycle

Students with high levels of mathematics anxiety tend to avoid mathematics, both in the long-term sense of not choosing career pathways that require them to study mathematics courses (Cribbs et al., 2021) and in the short-term sense of avoiding mathematics homework and test preparation (Schubert, 2019). According to Schubert, the latter tends to lead to a "self-defeating, self-perpetuating cycle" (p. 16) whereby lack of practice and preparation leads to poor results, which reinforces anxiety and negative self-beliefs. Often, teachers and/or parents contribute to the cycle, making it even more difficult to disrupt (Pair et al., 2019, Schubert, 2019).

Associated with a perceived lack of control or agency

Allowing students to feel in control of their own learning outcomes and environment can reduce anxiety, and vice versa (Klee et al., 2022). This increased sense of agency is correlated with increased mathematics self-efficacy (Samuel and Warner, 2021), which as discussed above is associated with reduced mathematics anxiety. However, providing students who are not yet accustomed to it with too much autonomy can have the opposite effect, and thus instructors must provide autonomy support at a level appropriate for the cohort (Klee et al., 2022).

Alleviated by mastery-seeking goals, aggravated by performance-avoidance goals

All studies analysed in this literature review either directly or indirectly discussed the distinction between mastery-oriented and performance-oriented learning goals. In a mastery-oriented mathematics classroom, achievement is criteria-based and not "bell curved", the learning process (and learning from mistakes) is valued over the outcome, and students and teachers are striving towards conceptual understanding rather than rote use of procedures.

Also important is the *direction* of the goal – in other words, *approaching* mastery as opposed to *avoiding* failure and social comparison, with the latter tending to lead to an increase in anxiety (Klee et al., 2022). As Schubert puts it: "When teachers employ best practices for teaching math, students understand and learn math, and anxiety is reduced" (2019, p. 19).

Alleviated by a growth mindset, aggravated by a fixed mindset

Again, all studies either directly or indirectly referred to the positive effect of a growth mindset on mathematics learning and achievement in general. With regards to the specific effect of a growth mindset on mathematics anxiety, Cribbs et al. (2021) demonstrated that a positive mathematics mindset leads to direct improvements in mathematics identity (which they also showed was strongly correlated with mathematics self-efficacy, and as discussed earlier, this likely leads to reductions in mathematics anxiety). Samuel and Warner (2021) reported a significant reduction in mathematics anxiety following a growth mindset intervention; however, the study simultaneously measured the increase in mathematics self-efficacy, and the growth mindset intervention was combined with a mindfulness intervention.

Can also be alleviated by explicit affective (non-academic) interventions

A final theme that emerged from the studies in this review was that although best practice, progressive mathematics teaching methods can go a long way towards alleviating mathematics anxiety, that alone may not be enough, or be effective for all students. Explicitly

naming, discussing, and confronting mathematics anxiety and/or fixed mindsets has also been shown to be effective in reducing mathematics anxiety (Klee et al., 2022; Pair et al., 2019). However, Lee et al. (2022) caution that when such interventions are employed with younger children, they should exclusively focus on the positive aspects of developing a growth mindset, so as not to expose children to negative ideas and emotions.

Best Practice Interventions

Based on the above themes, the following list of best practice interventions for reducing mathematics anxiety has been distilled from the literature:

- Adopt language that emphasises thinking and learning rather than results.
- Reframe assessments as opportunities for students to show what they can do.
- Allow students to participate in and give feedback on how they are assessed.
- Give students opportunities to be mindful of and discuss their anxiety.
- Praise students for effort and good strategy selection, not results or intelligence.
- Discuss findings related to growth mindset and the brain explicitly with students.
- Reframe mistakes as learning opportunities using positive language such as “not yet”.
- Allow students time to demystify approaches by exploring *why* they do/do not work.
- Emphasise the benefits of persevering through difficult challenges.
- Support parents with developing a positive attitude towards mathematics learning.

Gaps in the Literature

The negative correlation between mathematics anxiety and mathematics self-efficacy has been well-established, but the direct impact of a growth mindset intervention on mathematics anxiety alone does not seem to have been documented. Samuel and Warner (2021) studied the effect of a combined growth mindset and mindfulness intervention on the mathematics anxiety

levels *and* mathematics self-efficacy levels of first year community college students in the USA, while Lee et al. (2022) studied the effect of a combined growth mindset and gender-fair belief intervention on the mathematics self-efficacy levels (only) of fourth-grade students in Korea. Thus, the effect of a purely growth mindset intervention on the mathematics anxiety levels of an ethnically diverse group of high school students in an international school community would seem to be a potential new area of study.

Literature Review Summary and Conclusions

After a review of the literature revealed the potential redundancy of studying both mathematics anxiety and mathematics self-efficacy (originally worded as "mathematical self-perception") as responding variables, and given the gaps in the literature identified above, the purpose of this action research study can thus be refined as "to determine how the integration of regular growth mindset development activities into mathematics units will reduce mathematics anxiety in an international school community". A regular growth mindset development activity was chosen as the best practice intervention because it can be implemented in a diverse range of secondary mathematics classroom settings without requiring unit-specific mathematics pedagogy to be adapted by multiple teachers. Multiple reliable measures of mathematics anxiety already in existence (Cribbs et al., 2021; Samuel and Warner, 2021) can be used for the study, but further research is required to find or develop an age-appropriate and growth mindset-only version of Samuel and Warner's 2021 growth mindset and mindfulness intervention for community college students. In summary, mathematics anxiety and its associated loss of mathematical self-efficacy is a vicious cycle that can be interrupted at any age by targeted growth mindset development interventions alongside student agency-supporting, mastery goals-oriented pedagogy.

Methodology and Design

Since a review of the literature revealed that mathematics anxiety and mathematics self-efficacy were tightly (and negatively) correlated (Cribbs et al., 2021; Lee et al., 2022), the focus of the investigation can be narrowed to the effect of a growth mindset intervention on mathematics anxiety only. Thus, the following research question will guide the study design: how will the integration of regular growth mindset development activities into mathematics units reduce mathematics anxiety in an international school community? The methodology that will be used for this action research study is mixed methods, and the specific mixed method strategy that will be used is "concurrent mixed methods" (Creswell, 2009, p. 14). This is because of the desire to triangulate qualitative data with quantitative data and obtain a more comprehensive picture of the problem, and because of the mixed method strategy's generally acknowledged appropriateness for educational research (Creswell, 2009). The quantitative design aspect of the mixed methods methodology will be a survey that produces numerical data. An experimental design was not chosen because of ethical and practical issues involved in assigning participants to a control group; however, a simple pre-test/post-test design (Duesbery and Twyman, 2020) can be employed to test whether a significant improvement in the survey scores has occurred. Thus, two identical cross-sectional surveys (Creswell, 2009, p. 146) will be given; one will be pre-intervention and the other will be post-intervention. The qualitative design aspect of the mixed methods methodology will be ethnography; specifically, interviews and observations, because these are typical forms of data collected during ethnographic research (Creswell, 2013, p. 149), and can be used to validate any survey findings.

Population, Sample and Professional Practice Setting

The population most affected by the problem that this action research study will attempt to address is high school students taking compulsory mathematics courses. The professional

practice setting will be a mathematics classroom in an international school where instruction for an international curriculum, compulsory high school mathematics course takes place. Because participants are not able to be randomly sampled, and to facilitate data collection based around timetabling constraints, a non-random, purposive sampling approach (Duesbery and Twyman, 2020, p. 69) will be used. Mathematics anxiety is well known to affect performance in mathematics courses and lead to students avoiding further study of mathematics and STEM majors (Cribbs et al., 2021). Thus, this action research study has the potential to positively impact the futures of many high school students suffering from mathematics anxiety.

Data Collection Plan

The survey instrument chosen for the collection of quantitative data will be a modified version of the Mathematics Anxiety Rating Scale (MARS) proposed by Tamal et al. (2021). This modified version was shown to have higher reliability across a wider age range of students while using fewer survey questions (Tamal et al., 2021, p. 27). Post-intervention interviews, as used by Samuel and Warner in their 2021 study of mathematics anxiety in first-year community college students, will be triangulated with classroom observations of the interventions, as using a single qualitative method is unreliable (Duesbery and Twyman, 2020, p. 78).

Data Source 1 – modified MARS scores

The modified MARS score described above will be measured pre- and post-intervention. The intervention (an age-appropriate growth mindset development activity similar to the one described by Samuel and Warner (2021)) will be delivered over the course of a unit of study that culminates in a summative assessment. An online t-test calculator for two dependent means (Stangroom, 2023) will be used to determine whether there has been a significant reduction in the mean modified MARS score (post-intervention vs pre-intervention).

Data Source 2 – semi-structured interview notes

Semi-structured interviews will be conducted post-intervention with all participants who respond to an invitation. An interview protocol similar to that suggested by Creswell (2013, p. 165) will be used to record notes, and common themes in the participants' responses will be synthesised and reported. The interview questions will be focused on determining participant's opinions on the effectiveness of the growth mindset intervention activities in alleviating their mathematics anxiety, thus providing further validation of the approach.

Data Source 3 – participant as observer notes

Participants as observers (Creswell, 2013, p. 166) will be invited to observe the growth mindset intervention activity at several points throughout the unit. The participant as observer model was chosen to allow the observer to gain insights into how the growth mindset activity might alleviate mathematics anxiety. To mitigate the problem of the observer needing to record notes while participating in the activity, an observation protocol (Creswell, 2013, p. 169) that helps the observer collect relevant thoughts and insights immediately after the activity will be used. By using the same observation protocol but inviting different observers and at different stages in the unit of study, further data triangulation can be achieved.

Data Analysis Plan

The mean and standard deviation modified MARS scores (Tamal et al., 2021) for the sample pre- and post-intervention will be calculated and entered into Stangroom's online t-test calculator for two dependent means (2023), with the significance level set to $p = 0.05$. The t-test will be one-tailed, since we are looking to confirm the alternative hypothesis that the mean difference between post- and pre-intervention modified MARS scores is negative (meaning, there has been a significant reduction in modified MARS scores). The data analysis model used

for the qualitative data (interview and observation protocol notes) will be the "Data Analysis Spiral" described by Creswell (2013, p. 183). Creswell's "lean coding" method (2013, p. 184) will be applied by starting with the common themes identified in the literature review as prefigured codes that form a classification scheme, and then adding "in vivo" codes (2013, p. 185) and emergent themes as they arise during data processing. Themes and codes can then be represented using a hierarchical tree diagram or a concept map as appropriate.

Implementation Action Plan

An action plan has been drafted to specify in detail the steps required to successfully implement the chosen best practice (growth mindset) intervention and collect and analyse the quantitative and qualitative data described above. In constructing the detailed action steps, it became evident that significant input will be required prior to the commencement of the unit and intervention for the development of interview and observation protocols and preparation of the survey instrument. Additionally, significant coordination with students and colleagues will be necessary to facilitate collection of a meaningful amount of observation and interview data. The Proposed Implementation Action Plan can be found in Appendix A.

Communication Plan

According to Mills (2007), the main audience for action research findings is the participants themselves as well as any other relevant stakeholders associated with the professional setting. In the context of this action research study, other relevant stakeholders could include other high school students in the school community who also suffer from mathematics anxiety (self-assessed), any interested teachers whose course plans require their students to use and understand mathematics, and any interested parents, administrators and learning support teachers. Given this audience, it is also reasonable to use a somewhat less

formal format than a traditional research report, such as a presentation evening. Details of the data collected and the data analysis carried out could be made available to those interested. The findings and results of this action research study will benefit all stakeholders by demonstrating a pathway to mathematics anxiety relief (the explicit development of a growth mindset) that does not require the implementation of specialist mathematical pedagogies.

Reliability, Validity and Ethics

Reliability of the quantitative survey data is achieved by using a survey instrument that has already been shown to be reliable (as demonstrated by Tamal et al. (2021)). Validity of the quantitative survey data can be achieved by ensuring that the participants' survey scores are approximately normally distributed and do not contain outliers (Statistics Solutions, 2022). If necessary, the sample size can be increased (by expanding the survey and intervention to other sections) to achieve an approximately normal distribution, and outliers are unlikely, due to the nature of the survey scales and weightings used (Tamal et al., 2021, p. 24). As discussed by Mayer (2015), triangulation of qualitative data (in this study observation and interview notes) can both validate results and promote different perspectives on the issue being studied. Also, confirmability in this study is supported by the use of multiple observers.

Ethical considerations for this study will be based on the three basic ethical principles of *The Belmont Report* – respect for persons, beneficence and justice (National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 1979). As high school students can be considered autonomous agents, respect for persons simply requires that they be given the option to not participate in the surveys and interviews and are aware of how the data will be used. Beneficence can be assured by using evidence-based growth mindset interventions taken from recent positive psychology literature, and the principle of justice is satisfied because

the participants will be the direct beneficiaries of the research. Finally, to protect the privacy and social and emotional wellbeing of participants, all survey results and interview transcripts will be anonymised before being shared with other stakeholders.

Conclusion and Reflection

Anecdotal evidence in international school settings suggests that students in these settings experience similar mathematics anxiety and negative mathematical self-perception issues to students in Western countries. Mathematics anxiety can have adverse effects on young people's futures, but it can also be alleviated with appropriate interventions. Because students tend to have disproportionately fixed mindsets towards mathematics learning, focusing on developing a growth mindset should lead to significant improvements in their self-perceived mathematical ability and thus reduced mathematics anxiety. Moreover, although multiple best practice interventions for reducing mathematics anxiety can be found in the literature, a growth mindset intervention was chosen for its ease of implementation by non-mathematics specialists. By using a mixed methods approach, numerical survey scores can be combined with interviews and observations to gain further insights into *how* the proposed growth mindset intervention can reduce mathematics anxiety. Data collection via different instruments, by different people and at different stages throughout the study can provide validation and triangulation of results.

The anticipated outcome of this action research proposal and action plan is that teachers, students, and parents in the international school community in which the study is conducted will be introduced to an easily applicable, general-purpose intervention that can alleviate mathematics anxiety. Finally, the knowledge gained in the process of writing this action research proposal can be transferred to future action research into other aspects of integrated STEM education, and will no doubt be invaluable as I embark on my capstone project journey.

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Appendix A

Proposed Implementation Action Plan

Problem: widespread negative perceptions about mathematical ability and associated mathematics anxiety within an international school community.			**Research Question:** how will the integration of regular growth mindset development activities into mathematics units reduce mathematics anxiety in an international school community?		
Intervention Strategy: A whole-class growth mindset development activity that can be easily and regularly implemented at the beginning of lessons in a variety of secondary mathematics classroom settings.			**Goal:** To achieve a significant reduction in post-intervention modified Mathematics Anxiety Rating Scale (MARS) survey scores as compared with pre-intervention baseline scores.		
Target Population: high school students taking compulsory mathematics courses.			**Sample Population:** To be completed post-implementation.		
Action Steps	**Person(s) Responsible**	**Timeline**	**Resources**	**Evaluation criterion or data collected**	**Outcomes:** To be completed post-implementation.
Find or develop an age-appropriate and growth mindset-only version of Samuel and Warner's growth mindset and mindfulness intervention for community college students.	Author	During unit planning	Growth mindset literature	Intervention activity is evidence-based	
Write to modified MARS authors for permission to use survey instrument and digitise it.	Author	During unit planning	Google Suite for Education	Digital version of survey instrument checked by head of department	
Develop observation and interview protocols	Author	During unit planning	Examples from literature	Protocols checked by head of department	

Administer baseline modified MARS survey to willing participants	Author	Beginning of unit	Google Forms	All participants have submitted complete surveys.	
Deliver growth mindset intervention activity	Author	Throughout unit	Pending Step 1	Evidence in lesson plans and resources of regular delivery of intervention	
Invite and schedule participant observers	Author	Throughout unit	Observation protocol, timetable or calendar tool	Schedule of observations, completed observation protocols	
Administer post-intervention modified MARS survey	Author	End of unit	Google Forms	All participants have submitted complete surveys.	
Conduct interviews with volunteer students	Author and volunteer observers	End of unit	Interview protocol	Completed interview protocols	
Export and process survey data	Author	End of unit	Google Forms, Google Sheets, t-test calculator	Results table with standard deviations, p-values and means	
Analyse qualitative data using “data analysis spiral” and create graphic	Author	End of unit	Interview and observation protocols, Canva or similar	Qualitative data grouped into themes and codes, hierarchical tree diagram or concept map produced	
Reflection: To be completed post-implementation.					