The Proceedings of the 4th International Conference on Developing Mathematical Resilience 2024

4th International Conference on the Opportunities and Challenges of Building Mathematical Resilience

At University of Warwick and on-line

6th JULY 2024

This conference showcased work on Mathematical Resilience from researchers, teachers and others across the world. Mathematical resilience enables people to overcome mathematics anxiety and protect their well-being. The conference offered an innovative and friendly environment for participants to showcase and discuss their research or emerging practice. The day included the launch of the forthcoming Mathematical Resilience Book.

The day was opened by Clare Lee and Sue Johnston-Wilder who welcomed delegates in person and across the globe who joined on-line. They celebrated the work going on in so many different countries and environments to work against the prevalence of mathematical anxiety and for developing mathematical resilience. The papers that follow in these proceeding show the opportunities that are being taken up but also the challenges that must be overcome if learners are to progress their mathematical learning without the hindrance of anxiety and ill-being.

The recently published Mathematical Resilience Book (Routledge, 2024) was presented at this conference and was positively reviewed and welcomed by Dave Bowman who runs the YesU can website and runs CPD sessions in schools. Dr Telma Pará who has authored chapters within the book also presented at the conference, encouraging the use of the ideas within the book.

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Introduction to the Proceedings

The Fourth International Conference on Developing Mathematical Resilience features papers from researchers, academics and, importantly, from those who work with people of any age who are learning mathematics. Alongside people working in academia or working as consultants, in these proceedings you will find papers from teachers and others working with parents and learners in the classroom and in other learning environments.

Having mathematical resilience enables people to overcome the barriers that learning mathematics presents. Many papers in these proceedings deal with overcoming mathematics anxiety which is prevalent globally and helping learners know how to protect their well-being and still learn mathematics.

All the papers in these proceedings are research-based. They present research dealing with the affective domain in its broadest sense and how mathematical resilience is making an impact in learning environments from higher education to school and in homes, in countries across the world. The conference offered an innovative, inclusive and friendly environment for participants to showcase their research and emerging practice. These proceedings aim to do the same.

Clare Lee and Telma Pará (Joint Editors)

Contents

Mathematics Anxiety: Foundation Phase Student Teachers' Experience

Folake Modupe Adelabu

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Abstract: This study aims to ascertain the level of mathematics anxiety among student teachers in the foundation phase. A quantitative research methodology was applied in this study. A closed answer questionnaire was used to gather data for the study. Forty-five (45) student mathematics teachers participated in the study. The sample for the investigation was chosen using purposeful sampling. Self-determination theory is the theoretical basis for this study. The findings reveal that many students worry about making mistakes when practicing mathematics, and half of the respondents constantly worry that they do not know enough mathematics to succeed in subsequent mathematics classes. Furthermore, half of the respondents become tense and anxious when preparing for and writing a mathematics exam. Therefore, the study recommends introducing mathematics interventions, such as the Growth Zone Model, Relaxations, and GeoGebra or Math Lab software, which can assist and inspire students to learn mathematics.

Keywords: Mathematics anxiety; mathematics performance; foundation phase student teachers.

Introduction

Despite how quickly technology is developing today, many students are choosing careers in fields unrelated to mathematics and computing. This may be due to the prevalence of mathematics anxiety. A strong negative sentiment toward mathematics or a sense of stress, worry, or fear that affects one's ability to do mathematical operations is known as mathematics anxiety (Bjälkebring 2019; Skagerlund et al., 2019). Students who are anxious about mathematics exhibit unpleasant physiological responses such as increased heart rate or sweating. Mathematics anxiety leads to cognitive changes that affect memory and concentration, as well as negative thoughts and fears. Behavioral changes also occur, such as a lack of interest in mathematics classes and aversion to employment and careers that include mathematics (Beilock & Maloney, 2015; Patkin & Greenstein, 2020; Vukovic et al., 2013). This study examines the experience of foundation phase student teachers with regard to mathematics anxiety.

There are not enough students qualified to enroll in universities and pursue STEM fields of study (Mji & Makgato 2004), which can be attributed to the low mathematics and scientific literacy status in the South African curriculum. The students' current performance in mathematics has not improved to the desired levels in South Africa. South Africa's learners have come into the international spotlight since it started participating in the Trends in International Mathematics and Science Study (TIMSS) for grades 4 and 8 mathematics. TIMSS has eight benchmark assessment systems administered to participating countries every four years. South Africa participated with grade 4 and 8 learners in 1999 and 2003 and with grade 4 and 9 learners from 2011 to 2019. (Harmon et al., 1997; Martin et al., 2012; Martin et al., 2000).

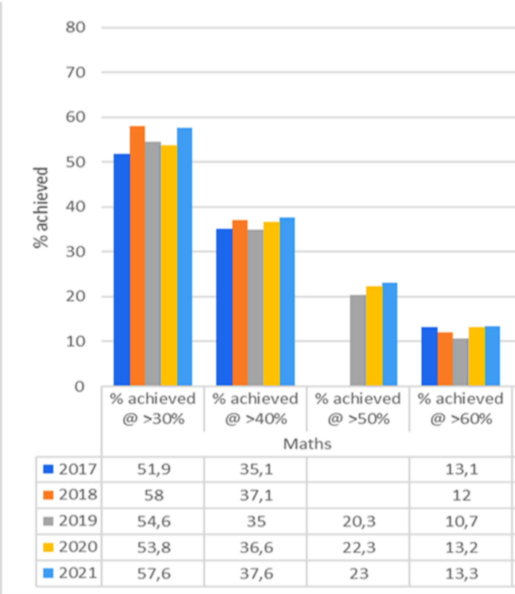

Figure 1: National Statistics for Grade 12% achievements from 2017 to 2021 (DBE, 2019 and 2021)

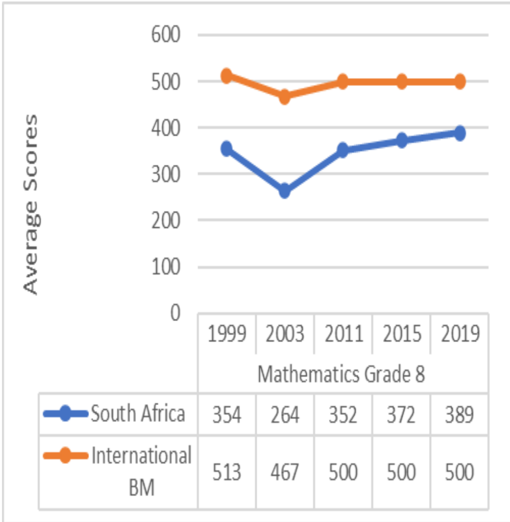

Figure 2: SA average performance vs international average benchmark - 1999 to 2019 TIMSS Mathematics Results

South Africa's performance, although improving slightly, remained well below the TIMSS average benchmark score in 2019. The result of percentage scores of student confidence in Mathematics is also low according to TIMSS. South Africa has the third lowest student confidence in mathematics compared to its international counterparts (Mullis et al., 2004; Mullis et al., 2016; Mullis et al., 2020). Anxieties in mathematics are significant predictors of low performance in teachers and learners. There is a need to address these anxieties to improve learners' performance in mathematics. Hence, this study has examined the view of Foundation phase mathematics students regarding mathematics anxiety, and ascertained the level of mathematics anxiety among student teachers in the foundation phase. The research question for this study is as follows: *What is the experience of foundation phase mathematics student teachers on mathematics anxiety?*

Theoretical framework

The theoretical framework that guides this study is Self-Determination Theory SDT) (Deci & Ryan, 2000; Kaplan & Madjar, 2017; Ryan and Deci, 2017). Three key components that psychologists state learners require serve as the theoretical basis for this study. These three components are **Autonomy, Relatedness, and Competence.**

Autonomy, which involves self-initiating and self-regulating one's behaviour, is the capacity to feel in control of one's behaviour and destiny
Relatedness (need to have close, affectionate relationships). Being related is being able to experience both a connection to and a sense of community with other individuals. Feelings of intimacy and social group membership are components of relatedness.
Competence (need to be effective in dealing with the environment). A person is said to be competent if they possess the qualities necessary to carry out a particular task or is competent in the sense of having adequate intelligence, judgment, skill, and/or strength.

Self-determination is more difficult to attain without connections since the person cannot access support and assistance. When people feel valued, cared for, and a part of an inclusive atmosphere, they are more likely to have a sense of relatedness. On the other hand, competing with others, being in a clique, and receiving criticism from others, diminish relatedness sentiments (Lopez-Garrido, 2021).

Methodology

A quantitative research methodology was applied to this study. A closed-question questionnaire was used to gather data for the study. In the study, 45 student mathematics teachers took part who were currently in the foundation phase. The student teachers enrolled in the foundation phase of the Teaching Bachelor of Education programme are predominantly from rural secondary schools. Purposive sampling was used to select the participants for the study. Upon completion of the degree program, the student teachers will be eligible to teach mathematics in primary schools in South Africa. All participants were given a questionnaire to which they had to respond on a 5-point Likert scale, ranging from *strongly disagree* to *strongly agree*. The questionnaire consisted of eight items which related to mathematics anxiety scales adapted from Betz (1978). All ethical conditions were met, and the student teachers consented to participate in the study (Ethical Clearance Number: FEDSRECC014-03-23).

Results

To determine the anxiety levels of the foundation phase mathematics student teachers, a Likert-type scale questionnaire was used to collect the data. The results of the analysis were presented.

Item	Description	Frequency					Mean		Standard Deviation	Skewness
		SD	D	U	A	SA				
		1	2	3	4	5				
1	Mathematics makes me feel uncomfortable and nervous	6	27	4	8	2	2.43		1.058	0.894
2	I have usually been at ease during mathematics lesson	3	17	14	12	1	2.81		0.970	0.104
3	I have usually been at ease during mathematics test	4	24	7	10	2	2.62		1.054	0.608
4	My mind goes blank, and I am unable to think clearly when doing mathematics	1	10	7	23	6	3.49		1.040	-0.516
5	I get really uptight during mathematics test	3	17	12	15	0	2.83		0.963	-0.102
6	I usually do not worry about my ability to solve mathematics problems	12	27	2	4	2	2.09		1.018	1.374
7	I get a sinking feeling when I think of trying hard mathematics problems	2	14	7	22	2	3.17		1.049	-0.356
8	I get nervous about making a mistake in math	6	16	6	14	5	2.91		1.265	0.099
	Overall						2.48		0.511	

Table 1: Descriptive statistics of student teachers on mathematics anxiety

Table 1 shows the frequency, mean, and standard deviation of the student teachers' responses to each questionnaire item. The highest mean score of the response is (M) = 3.49 with a standard deviation of (SD) = 1.040, which is the fourth item in the questionnaire and stated, "My mind goes blank, and I am unable to think clearly when doing mathematics."

This indicates that many of the participants are unable to think accurately during mathematics tests or when they are solving problems in mathematics. Item seven of the questionnaire, "I get a sinking feeling when I think of trying hard mathematics problems," also recorded a high mean score of (M) = 3.17 and SD = 1.049. The result indicates that several student teachers always feel discouraged when getting low marks in mathematics after they have done their best to have high marks. The lowest mean score is (m) = 2.09 and SD = 1.018; it is the sixth item of the questionnaire, "I usually do not worry about my ability to solve mathematics problems." This indicates that few of the student teachers are not anxious about mathematics. The overall mean score of the questionnaire is 2.48, according to Table 2. This shows that only a small number of the student teachers are not afraid of mathematics, and many of the student teachers still need encouragement. A few are totally discouraged about mathematics. Therefore, intervention is required for those students to be able to attain a high performance in mathematics.

Discussion and Conclusion

These findings show that student teachers have varying degrees of mathematics anxiety, which affects their performance in mathematics and creates barriers to studying mathematics. Researchers have discovered that when teacher educators foster a culture of autonomy in the classroom, students demonstrate an increased intrinsic motivation to learn (Niemiec & Ryan, 2009; Wang, Liu, Kee, & Chian, 2019). The self-determination theory will support student teachers to demonstrate increased intrinsic determination to learn mathematics when teacher educators foster a culture of autonomy in the classroom.

Furthermore, teacher educators will provide feedback and extend and challenge the student teachers to encourage a sense of competence in the student teachers for mathematics learning.

In addition, self-determination theory will help student teachers to feel good when there is high achievement in mathematics performance.

Recommendation

This study recommends the introduction of mathematics interventions, such as **Growth Zone Model, Relaxations, and GeoGebra or Math Lab** software for learning mathematics, which can support and inspire the students to learn mathematics. When teacher educators are encouraged to investigate, take responsibility for, find, and implement answers to their difficulties, students become more autonomous. This software is designed to be a precursor to developing resilience, thereby addressing the specific challenges of mathematics anxiety among student teachers.

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Exploring Mathematical Resilience as a Coping Mechanism for Anxiety in Statistics among Kenyan Postgraduate Students

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Mathematical resilience is the ability to overcome challenges in learning mathematics. This study explores the role of mathematical resilience in helping Kenyan postgraduate students manage anxiety related to learning statistics. Using Bandura's Social Cognitive Theory (SCT), the research examines levels of statistical anxiety, the connection between resilience and coping ability, and the factors that contribute to resilience among these students. A mixed-methods approach was used, including quantitative surveys and focus group discussions, with a sample of 385 students drawn from a population of 50,000. The pilot study identified academic support systems, self-efficacy beliefs, and prior mathematical experiences as key contributors to resilience. The findings highlight the importance of fostering mathematical resilience to improve student well-being and academic performance. The study offers practical recommendations for educational institutions and policymakers to enhance support for students struggling with statistical anxiety, contributing valuable insights to literature on student well-being in higher education.

Keywords: mathematical resilience; statistical anxiety; public universities; postgraduate students

Introduction and Problem Statement

Resilience is the ability of a student to cope with academic demands, stress, and school-related learning pressures, manifested by internal and external factors (Mwangi, et al, 2015). Resilience can also be defined as a person's ability to face obstacles, pressure, and other difficult situations in overcoming academic problems which significantly affects student learning outcomes. A number of studies have shown that resilience significantly affects school and student life, as well as learning outcomes (Chen, et al., 2022). A students' level of resilience can affect their ability to think creatively, leading to improved learning outcomes in the classroom (Ramandani & Muhandaz, 2021).

Mathematical resilience refers to the ability of individuals to persist and overcome challenges in mathematical problem-solving or learning. Iman and Firmansyah (2019) argue that higher levels of mathematical resilience lead to improved academic performance. They add that the key components of mathematical resilience include: persistence and perseverance, flexible thinking, positive mindset, metacognitive skills, problem solving skills, supportive learning environment, real-world connections, among others.

In Kenya, statistics education usually starts at the tertiary level, where it is incorporated as a common unit across most degree programs both at undergraduate and postgraduate levels depending on the curriculum (Onwuegbuzie & Wilson, 2003). It is important to note that the Kenya Universities & Colleges Placement Services (KUCCPS) admissions often attract fewer applicants for STEM programs and are skewed towards education and social sciences (CUE Report 2017/2018).

The mastery of statistical concepts is crucial for academic success and professional competence. This is due to the increasing demand for data-driven decision making in various fields which has heightened the significance of statistical knowledge, particularly among postgraduate students. However, many students experience significant anxiety when engaging with statistics, which can impede their learning and academic performance. A study conducted in Bayelsa State, Nigeria, (Oribhabor & Akpomemiyere, 2023) found that enhancing mathematical resilience can significantly improve academic outcomes.

Understanding the challenges posed by statistics and the associated anxiety among postgraduate students has been a topic of growing interest in educational research. Statistical anxiety, defined as the fear or apprehension experienced when dealing with statistical concepts, has been recognized as a significant barrier to learning and academic success (Onwuegbuzie & Wilson, 2003). This anxiety can manifest in various forms, including avoidance behaviours, decreased confidence, and negative attitudes towards statistics (Baloglu & Koçak, 2006). For postgraduate students, who often encounter advanced statistical concepts in their research and coursework, managing this anxiety is crucial for their academic progression and overall well-being.

In recent years, the concept of mathematical resilience as a potential factor in statistical anxiety among students has been explored. Mathematical resilience is defined by Mandinach & Gummer (2016) as the capacity to persist and adapt when confronted with mathematical challenges. While resilience has traditionally been studied in the context of broader academic challenges, its relevance to the specific domain of statistics remains relatively understudied. The present study seeks to address this gap by investigating the role of mathematical resilience in statistical anxiety among Kenyan postgraduate students. Building upon existing literature on resilience in education, the research aims to uncover the factors contributing to statistical resilience in this population by looking at the following objectives: assess the level of anxiety experienced by Kenyan postgraduate students when dealing with statistics; examine the relationship between mathematical resilience and the ability to cope with statistical anxiety; identify factors contributing to mathematical resilience among Kenyan postgraduate students; explore strategies and interventions that promote mathematical resilience to reduce anxiety in statistics; establish strategies employed by students to overcome statistical anxiety.

Literature Review: Theoretical Review

The study applies Bandura's Social Cognitive Theory (SCT) to examine how self-efficacy, behaviour, and environmental factors influence mathematical resilience and reduce statistical anxiety in Kenyan postgraduate students. Social Cognitive Theory provides a framework for interventions, emphasizing the role of self-efficacy in improving performance and addressing anxiety, which impedes academic success.

Levels of Statistical Anxiety: Statistical anxiety refers to the fear and anxiety individuals experience when dealing with statistical concepts and courses, driven by emotional and cognitive responses like apprehension, lack of confidence in mathematics abilities, and previous negative experiences with statistics (Onwuegbuzie & Wilson, 2003). Onwuegbuzie (2004) describes statistical anxiety as a specific type of anxiety that students feel when engaging with statistical concepts, characterized by tension, fear, and apprehension. It can manifest through cognitive, emotional, and physiological responses, hindering learning and performance in statistics courses.

Relationship between Mathematical Resilience and Statistical Anxiety: The relationship between mathematical resilience and statistical anxiety is significant in educational research. Mathematical resilience protects against statistical anxiety by helping students view challenges as growth opportunities, reducing anxiety, and enhancing performance (Lee & Johnston-Wilder, 2017). Studies show that higher mathematical resilience correlates with lower statistical anxiety. Zakariya (2020) found a negative correlation between the two, suggesting that fostering mathematical resilience can effectively reduce anxiety and improve students' learning.

Factors Contributing to Mathematical Resilience: According to Komala (2017) students with strong resilience are likely to develop the necessary mathematics skills and demonstrate a readiness to apply them in everyday situations. In addition, Johnston-Wilder, Lee, & Mackrell (2021) found that students who demonstrate resilience in mathematics are better equipped to focus and become aware of their physical and mental needs. Students' positive responses to learning mathematics are influenced by their mathematical resilience, which varies with their cognitive processes, as shown by Hutauruk et al. (2019) research. Other studies have also confirmed the beneficial effect of mathematical resilience on problem-solving strategies (Fitriani et al., 2023). Non-cognitive abilities and factors such as mathematics resilience and achievement of goals are linked to university students' performance in mathematics (Vergara, 2021).

Research highlights key factors contributing to mathematical resilience, such as self-efficacy beliefs, prior mathematical experiences, and academic support systems like effective teaching and supportive environments. These elements collectively help students build resilience, enabling them to cope with mathematical challenges and succeed academically (Bandura, 1997; Johnston-Wilder et al., 2017). Several studies have explored the components and benefits of mathematical resilience. For instance, Lee and Johnston-Wilder (2017) emphasize the role of supportive learning environments and positive teacher-student relationships in fostering resilience. They argue that resilience is not an innate trait but can be developed through targeted interventions and supportive educational practices.

The reviewed literature identifies factors contributing to statistical anxiety to include students' negative attitudes from past experiences, perceived difficulty of statistical concepts, and inadequate preparation and support. These factors can overwhelm students, leading to heightened anxiety and impacting their ability to succeed in statistics (Onwuegbuzie, 2004).

***Academic support systems*:** Allen's (2024) study explores how teachers in rural Kenya build resilience in students amid challenges like poverty and domestic violence. Interviews with secondary school teachers in West Laikipia reveal the importance of student-teacher relationships, extracurricular activities, and practical support. Despite limited professional development, fostering resilience improves academic performance, social-emotional well-being, and student empowerment.

***Self-efficacy beliefs*:** Clarke's (2021) study examined how mathematics anxiety and self-efficacy impact the mathematics performance of High School Equivalence (HSE) students. Using stepwise multiple regression analysis, the study found a significant positive relationship between mathematics self-efficacy and performance. Interestingly, no significant differences in mathematics anxiety or self-efficacy were found across age, gender, or race/ethnicity, suggesting broad applicability for confidence-building interventions.

Previous Mathematical Experiences: Rodgers et al., (2020) examined how classroom relationships influence academic resilience and hope amid rising loneliness and dropout rates. They found that peer support, rather than instructor relationships, was crucial for fostering resilience. The study advocates for creating a strong classroom community and teaching social support behaviours, using semi-structured interviews for data collection.

Methodology

The study employed a mixed methods approach which combined quantitative surveys and qualitative (focus group discussions). The target population was 50,000 postgraduate students (CUE 2017/2018), with a sample size of 384 obtained through Fisher formula for populations above 10,000. A sample of 38 respondents was picked for the pilot study. Google forms was used to circulate the questionnaires and google meet used to hold focus group discussions.

Findings

The findings presented in this section are results from the pilot study carried out in the Faculty of Education where the researcher works. It is important to note that I interact with the postgraduate students at a personal level unlike supervisors who interact with students at the cognitive level. This allowed the respondents to openly and passionately express their feelings towards statistical anxiety. For objectives 1–4, I used the Statistical Anxiety Rating Scale (STARS) which was found to be particularly relevant, as it is specifically designed to measure anxiety related to statistics. The components include items that assess six dimensions of anxiety: worth of statistics, interpretation anxiety, test and class anxiety, computational self-concept, fear of asking for help, and fear of the statistics teacher (Cruise et al., 1985). The likert scale key: SD = 5, D = 4, N l = 3, A = 2; SA = 1 was used.

Objective 1: Assessing the level of anxiety experienced by Kenyan postgraduate students when dealing with statistics. The results generated an average mean of 2.247 – an indication that high levels of anxiety are common, with significant concerns about failing courses and feeling overwhelmed by content. Based on the findings, it is concluded that the majority of the postgraduate students are in the red zone of the growth zone model.

Objective 2: Examining the relationship between mathematical resilience and the ability to cope with anxiety in statistics. The results generated an average mean of 2.178. This result implies a relatively strong consensus that mathematical resilience positively influences the ability to cope with anxiety in statistics, with only a small variation in the level of agreement.

Objective 3: Factors Contributing to Mathematical Resilience among Kenyan P**ostgraduate Students.** The results were categorized as follows:

Academic support systems: Access to tutors, study groups, supportive instructors, and peers generated an average mean of 3.754. The mean of 3.754 suggests that, while the overall sentiment is not strongly disagreeable, there is a tendency towards disagreement rather than agreement or neutrality among the respondents.

Self-efficacy beliefs: Confidence in one's ability to succeed despite challenges generated an average mean of 3.018. The mean of 3.018 suggests that while the overall mood is generally neutral, there is a tendency towards an unfavourable attitude.

Previous mathematical experiences: Both positive and negative experiences influence resilience and generated an average mean of 2.930. Respondents are almost evenly split between being neutral and agree, with a slight tilt towards agree.

Objective 4: Strategies and interventions that promote mathematical resilience and reduce anxiety in statistics. The findings generated an average mean of 1.210 – an indication that the majority of the respondents strongly agreed that workshops on resilience-building, peer study groups, breaking down complex problems, regular feedback from instructors, and fostering a positive mind-set would promote mathematical resilience and reduce anxiety in statistics.

Objective 5: Strategies used by students to overcome statistical anxiety

The results of the focus group discussions showed that the respondents used the following strategies to pass statistics examinations: Positive: group discussions, reviewing previous exam papers, asking for help, consulting lecturers, staying calm and confident. Negative: over-reliance on memorization (cramming), avoidance, dependence on others, isolation, substance abuse, cheating (*degree ni harambee*). Negative strategies were justified by work-life balance issues as the majority of students were employed and studying part-time. The majority said that they study statistics mainly to pass exams, and perceived limited applicability in their current/future jobs. This highlights a certain gap between academic learning and practical application in different professional contexts.

Implications for Policy and Practice

The findings offer valuable insights into the role of mathematical resilience in mitigating statistical anxiety. **Recommendations:** Higher education institutions should prioritize understanding and addressing the factors that influence both resilience and anxiety to foster more inclusive, supportive, and effective learning environments. This could involve integrating resilience-building strategies into curriculum design, offering targeted support services, and promoting a culture that normalizes seeking help with statistical challenges. **Future Impact:** The study highlights the need for a more comprehensive investigation into coping mechanisms, particularly among students in STEM-focused institutions, where statistical competencies are crucial for academic success. **Way forwards:** Drawing from the researcher's experiences as advisors to postgraduate students, it is evident that many students face significant struggles with statistical components of their research, often resulting in delays in completing their studies. A more extensive study could provide deeper insights into these challenges, enabling the development of tailored interventions that enhance student resilience and improve overall research outcomes.

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Exploring Project Based Learning to develop mathematical resilience of ESOL learners

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The objective of this paper is to explore the benefits of Project Based Learning (PBL) in the context of ESOL. It studies how PBL can enhance learners' wider skills, particularly their mathematical skills. The paper will attempt to investigate whether developing mathematical and wider skills of ESOL learners in a further education college can help them become more mathematically resilient by strengthening their self-efficacy and self-confidence. A description of the project with stages and learning outcomes is discussed so that other practitioners can also benefit from it. Qualitative as well as quantitative data – pre and post diagnostic assessments; peer and self-evaluation; feedback from the audience; group and individual semi-structured interviews and video recordings of the presentations – are analysed to determine whether PBL contributes to growth of mathematical and wider skills of ESOL learners leading to an increased level of self-efficacy which, as a result, supports learners to develop mathematical resilience.

Keywords: Project Based Learning (PBL); ESOL; further education; mathematical resilience; wider skills.

Introduction

Project-Based Learning (PBL) is a dynamic and effective instructional approach in mathematics lessons as well as English language teaching classrooms, offering a range of benefits that extend beyond completing boring mathematics worksheets (Liu Sun, 2019) and traditional language acquisition methods. Researchers such as Beckett (2006) and Thomas (2000) have highlighted how PBL fosters deeper linguistic understanding by immersing students in meaningful, real-world tasks that require active use of the target language and mathematics skills. By engaging in hands-on projects, students develop problem-solving skills, collaboration, and the ability to communicate mathematical ideas effectively. According to Johnston-Wilder and Lee (2010), project-based learning in mathematics helps students build resilience and confidence in their abilities, while also enhancing their conceptual understanding. This approach not only reinforces mathematical skills but also cultivates a more positive attitude toward mathematics through hands-on and meaningful activities (Finkle & Monk, 2008). Additionally, it supports the development of higher-order thinking skills, making mathematics more relevant and engaging for student (Bransford, Brown, & Cocking, 2000). This article explores the multifaceted advantages of PBL in ESOL settings, emphasising its role in accelerating language and mathematics learning while fostering wider skills such as critical thinking, collaboration, and problem-solving skills. Additionally, it highlights how PBL builds mathematical resilience among learners, equipping them to navigate challenges both within and beyond the classroom.

Research Context

A substantial proportion of ESOL learners migrating to the UK through various routes often lack foundational linguistic knowledge and essential mathematics skills necessary for securing improved employment opportunities and integrating effectively into the community. A significant number of these learners have no prior formal education and may, therefore, be illiterate in their first language. Among those with educational backgrounds, exposure to the English language is frequently minimal or non-existent. Hence, they might be quite good at mathematics in their first language but struggle in mathematics in English. As a result solving mathematical problems presented in English can induce significant emotional distress among some learners. The unfamiliar contexts often embedded in Functional Skills Mathematics assessments may exacerbate this response, contributing to heightened levels of apprehension and discomfort.

Transitioning into productive members of society necessitates the acquisition of essential knowledge and skills in both English and mathematics. (PBL) offers a promising and efficient approach to accelerate this process. As this article will demonstrate, PBL not only expedites the learning of language but also fosters the development of mathematical and broader skills.

Literature Review

In EFL (English as a Foreign Language) classrooms, studies have demonstrated that PBL enhances learners' communicative competence by providing authentic, real-world tasks that simulate language use outside the classroom (Beckett & Slater, 2005). In ESL (English as a Second Language) settings, research emphasises its role in bridging classroom learning with everyday experiences, fostering critical thinking, problem-solving, and collaboration (Stoller, 2006). Studies in blended and online language environments indicate that PBL enhances learner engagement and autonomy through digital tools that increase students’ ability to self-regulate their learning and facilitate collaboration and project management while enhancing communication and technological proficiency (Thomas, 2000 and Stoller, 2006).

Beckett and Slater (2005) found that PBL activities, which require learners to collaborate on tasks such as creating presentations or conducting research, significantly improved teamwork and problem-solving skills. These projects also encouraged learners to take responsibility for their learning, fostering greater autonomy and motivation. Furthermore, a study by Simpson (2011) highlighted that PBL leads to faster learning as it engages students in real-world tasks that mirror authentic language use, making learning more relevant and memorable. The process of planning, executing, and presenting projects requires learners to repeatedly practise key skills, consolidating their knowledge and transferring it to long-term memory.

PBL has been widely studied for its impact on mathematics education, demonstrating several key benefits. Research has revealed that secondary students participating in PBL exhibited not only higher assessment scores, but also demonstrated increased intrinsic motivation, critical thinking skills, and appreciation for peer learning (Holmes and Hwang, 2016). PBL in mathematics classrooms has led to enhanced collaboration, problem-solving abilities, critical thinking, and a more positive attitude toward mathematics (Rehman et al, 2024). Rijken and Fraser (2024) demonstrated that PBL improved classroom learning environments and student outcomes, including enjoyment, academic efficacy, and achievement.

These findings collectively demonstrate that PBL creates an immersive and dynamic learning environment where students not only foster a deeper understanding of language and mathematical concepts but also develop the competencies needed for academic, professional, and social success. Although there are numerous studies that show the effectiveness of PBL, none of these studies focus on developing resilience of ESOL students by developing their English language, mathematics and wider skills.

PBL has a profound capacity to build resilience in learners by fostering self-efficacy, defined as the belief in one’s ability to accomplish specific tasks (Bandura, 1997). Resilience, which Masten (2001) describes as “ordinary magic” that enables individuals to adapt and thrive amidst challenges, is essential in ESOL settings where learners often face linguistic and cultural barriers. Johnston-Wilder and Lee (2010) emphasise the role of a safe and supportive learning environment in nurturing resilience, noting that when learners are encouraged to embrace mistakes as opportunities for growth, they develop the perseverance needed to overcome setbacks. PBL supports this process by engaging students in meaningful, real-world tasks that require persistence, creativity, and adaptability.

Learning together builds and fosters not only the acquisition of knowledge but also the ability to collectively navigate and overcome challenges. The social interactions inherent in PBL encourage learners to rely on peers for support, reinforcing their ability to navigate difficulties with confidence. Krajcik and Blumenfeld (2006) further argue that the iterative nature of PBL – where students plan, test, and revise their work – mirrors real-life problem-solving, strengthening resilience through repeated cycles of effort and improvement.

Teaching Models and PBL

PBL involves learners in extended, real-world projects that integrate language acquisition with broader skills such as collaboration, creativity, and problem-solving. PBL focuses on learners solving complex, real-world problems in small groups which helps them develop analytical and problem-solving skills alongside language acquisition. Where students work on projects that require mathematical reasoning, PBL encourages engagement, application of mathematics to life (Thomas, 2000).

The role of an ESOL teacher extends beyond delivering language lessons and developing mathematics skills; it encompasses the responsibility of equipping learners with the knowledge, skills, and behaviours necessary for effective communication and integration into society. An expert teacher creates opportunities for learners to use their acquired knowledge in authentic situations, enabling the transition from short-term memory to long-term retention (Ellis, 2003). By scaffolding learning through clear instructions, guided practice, and feedback, teachers build learners’ confidence and motivation, ensuring they are prepared to progress to the next level. Additionally, teachers instil behaviours such as active participation, perseverance, and resilience, which are essential for academic success and lifelong learning.

PBL offers a comprehensive and immersive approach to addressing the multifaceted duties of an ESOL teacher and the diverse needs of learners. This method fosters confidence and motivation, as students see tangible outcomes from their efforts, and it promotes autonomy by encouraging learners to take ownership of their learning (Thomas, 2000). Additionally, the immersive nature of PBL creates ample opportunities for learners to stretch and challenge themselves, supported by scaffolding ensuring they consolidate learning effectively while progressing rapidly. PBL aligns seamlessly with the goal of equipping learners to progress to the next level and beyond. The iterative process of planning, executing, and reflecting inherent in PBL mirrors the scaffolding and consolidation practices which nurture resilience and adaptability, preparing learners for challenges outside the classroom.

While there is a wealth of research supporting the efficacy of PBL in broader ESL/EFL contexts, studies focusing on ESOL are sparse or non-existent. It appears that no significant studies have been conducted specifically on the benefits of PBL within the ESOL further education sector.

Stages of the Summer Holiday Project

The Summer Holiday Project conducted for this research starts with making groups and group leaders developing leadership skills. Learners are asked to read about four different places developing their reading skills and then decide, as a group, which place they would like to visit, how far it is from London and in which direction. Learners round up/down the distances and decide which date they will depart and return. Learners are then directed to www.nationarail.com and www.nationalexpress.co.uk to compare costs, journey duration and departure and arrival times. They are then asked to use www.booking.com, to find two hotels and compare their prices and facilities. Learners are given special offers and are asked to calculate the discounted prices using fractions and percentages. Using the reading texts, learners decide on a total of five - either places to visit or activities to do - during their stay. They take notes of all the information about travel, accommodation and excursions. After this, learners design PowerPoint presentations and make final formal presentations to a real audience.

In this way, PBL is implemented within a supportive and safe learning environment, (Johnston-Wilder and Lee, 2010) where students are encouraged to stay in growth zone (ibid). As learners navigate and succeed in these tasks, they experience a sense of mastery that contributes to the development of self-efficacy.

Research Methods and Data Collection

A variety of data collection tools were employed in this research project to collect quantitative and qualitative data. Students completed a speaking and a writing assessment both before and after taking part in the project. The speaking assessments were recorded on Teams and the writing assessments were stored in hard copies. Students were assessed on designing the PowerPoint presentations as well as presenting their project using the target language. The audience, which included the principal, a director and teachers, filled in a questionnaire (Likert Scale 1-10) to give their perception of students' performances. At the end of the project, students completed a questionnaire (Likert Scale 1-10) to evaluate their own progress. I, as a teacher and facilitator, directly observed my learners develop knowledge, behaviour and skills. Informal group interviews were conducted during and after the project. The learners seemed quite comfortable with sharing their thoughts and experiences.

Date Analysis and Findings

To measure the effectiveness of PBL, Hattie's effect size (2009) was used to analyse the speaking and writing assessment scores. A high average effect size of 1.36 was recorded in the writing assessments and a significantly high effect size of 1.88 in the speaking assessments. Both effect sizes are much higher than 0.40 – the hinge point (ibid). The mean score was calculated for the questionnaires (Likert Scale 1-10) completed by the students and the audience. A high effect size in both writing (1.36) and speaking (1.88) assessment scores provides evidence that Project Based Learning helps learners make a speedy progress in a short period of time. The results of the questionnaires showed an average score (9.12 out of 10). Most learners stated that they liked working in groups and they improved their mathematics, reading, presentation and English skills because of the holiday project.

The qualitative data was analysed using thematic text analysis (Braun and Clarke, 2006). Themes were derived inductively, emerging from recurring patterns within the data and presented as cohesive narratives that illuminate and expand upon the underlying meaning within the data (ibid).

Theme 1 – Meeting High Expectations and Beyond: Learners successfully met high academic expectations. The audience were all 'impressed and amazed' by the performance of the learners. Not only were the presentations 'amazing' and 'excellent', they exceeded by far the expected standard for Entry 1 level students. The director said they were 'better than Functional Skills English students.'

Theme 2 – Effectiveness of PBL: Students were able to 'correctly' use 'a variety of grammar' and they gave 'excellent responses to varied questions' asked by the audience. These questions included mathematics. All students 'participated' and 'supported each other'. Students 'enjoyed presenting' as they had practised. Students were 'engaged', 'busy' and 'challenged' during the project and they 'managed their behaviour' well. Students improved their English, learnt new words and found the mathematics in the project comparatively easier.

Theme 3 – Wider Skills: The skills learned included critical thinking, collaboration, communication, and problem-solving, all of which are essential for real-world contexts. Students had the opportunity to use 'many different skills simultaneously' and this gave them a lot of 'confidence'. There was evidence of students developing 'teamwork' and 'presentation' as well as mathematical skills. They showcased these skills during presentations. They were 'not shy' and 'not scared' when they 'talked in front of people'. One teacher from the audience noticed that 'cross-curricular application was really effective' and learners took responsibility and ownership of their 'own learning and performance skills'. Learners 'made mistakes, corrected themselves,' and showed great respect whilst they 'listened to the presentations' of their classmates.

Theme 4 – Pedagogical Benefits: One of the benefits was 'contextualised mathematics' which enabled learners to see mathematics as not difficult to learn. All lessons were 'clearly staged and planned' with 'a clear link from one lesson to the next one' making it easy for the leaners to 'recall things more easily and accurately'. There was evidence of 'recycling and consolidation and extension' as well as 'obvious differentiation' allowing learners to achieve with the support they needed.

Theme 5 – Aspirational, Mastery Experience & Resilience: The presentations were 'excellent, professional and inspiring'. Although preparing for and presenting the final presentations was 'nerve-racking task' and 'challenging' for learners, especially 'without notes', 'they rose to it' and proved their resilience. They were 'pushed and challenged' but they did not give up and believed in themselves gaining mastery experience and developing the resilience they need to develop further skills.

Conclusion and Recommendations

In conclusion, PBL has the power to accelerate the acquisition of knowledge, skills, and positive behaviour in students. As Dewey (1938) emphasised, learning through doing fosters deeper engagement and understanding, enabling students to actively apply concepts in real-world contexts. The completion of challenging tasks enhances students' self-efficacy and resilience, aligning with Bandura's (1997) theory of self-belief. These projects engage, motivate and stretch students to meet complex challenges leading to self-efficacy and resilience. Students should complete at least one project a year to foster growth in both cognitive and emotional capacities and supporting emotional well-being, helping to reduce anxiety. Additionally, teachers, especially those working with ESOL students, should receive specialised training.

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Performing 1-1 intervention to address Mathematics Anxiety based on Mathematical Resilience Toolkit

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Mathematics Anxiety is well-researched, but solutions are few. This study introduces an intervention developed by Baker (2021) based on the Mathematical Resilience Toolkit (MRT), which involves 1:1 sessions where participants share their mathematics learning experiences, learn about the MRT, and reframe past negative experiences. The toolkit includes the hand model of the brain, the growth zone model, and the relaxation response. The study sought to answer: In what ways did the Mathematical Resilience Toolkit affect the participants? The interventions involved Brazilian volunteers living in England with high levels of mathematics anxiety. The qualitative data were analysed using deductive thematic analysis and the Mathematical Resilience Framework. The data indicated a positive impact of the intervention. The participants reported new perspectives about themselves in relation to mathematics. The study adds the evidence that all mathematics learners and adults with mathematics anxiety would benefit from learning about the Mathematical Resilience toolkit.

Keywords: Mathematics anxiety; Mathematical resilience; Growth zone model; Mathematics.

Mathematics anxiety (MA) is described as a feeling of tension that disrupts mathematical problem-solving in both everyday and academic contexts. In Brazil, MA has been further defined by Carmo et al. (2019) as involving physiological, cognitive, and behavioural reactions. Physiological symptoms include sweating and increased heart rate, cognitive reactions involve forgetting algorithms and developing negative beliefs about mathematics, and behavioural responses include avoidance and freezing. Despite global efforts to boost STEM education, MA remains a significant barrier to achieving success in mathematics and pursuing STEM careers. Studies indicate that women experience higher levels of MA than men, a disparity influenced by societal stereotypes and reduced encouragement. A related construct called Mathematical Resilience (MR) can be defined as “a learner’s stance towards mathematics that enables pupils to continue learning despite finding setbacks and challenges in their mathematical learning journey” (Johnston-Wilder & Lee, 2010, p. 38). In this study, we introduce the use of the mathematical resilience framework to address mathematics anxiety and build mathematical resilience in three Brazilian women.

One-to-One Interventions

In this study, we implemented one-on-one interventions based on the mathematical resilience framework, integrating psychological and coaching techniques such as reframing and psychoeducation. A key contribution of this work is demonstrating how educators can effectively conduct these interventions. Reframing involves altering participants' perceptions to offer new insights and solutions by shifting the focus from self-blame to understanding past experiences. Psychoeducation aims to enhance participants' knowledge and strategies for maintaining mathematical well-being by providing information on mental health and coping mechanisms. While not therapists, educators can use coaching techniques to support learners by addressing their concerns and experiences, ultimately empowering them to take an active role in their mathematical resilience and well-being.

Mathematical Resilience Toolkit

The Growth Zone Model (GZM)

The Growth Zone Model (Lugalia et al., 2013) helps learners identify and express their feelings about learning mathematics into three zones: the "comfort zone," where there is safety but no growth; the "growth zone," where challenges are met with courage and offer opportunities for development; and the "anxiety zone," which should be avoided due to its overwhelming nature. The model emphasizes that mathematical resilience involves moving from the comfort zone to the growth zone and managing anxiety when it arises.

The Hand Model of the Brain (HMB)

The Hand Model of the Brain, developed by Siegel (2010), uses a hand analogy to explain some biological responses from the brain. In this model, the curled fingers represent the cerebral cortex, responsible for complex thoughts, while the thumb symbolizes the limbic system, which handles primary emotions and alertness. When facing threats, the cortex is "turned off," triggering fight, flight, or freeze responses. This simple model helps individuals with mathematics anxiety understand that their reactions are not due to a permanent lack of ability but are temporary responses to stress. By recognizing these brain activities, participants learn that they need to manage their panic and relaxation responses in stressful mathematics situations.

Relaxation Response (RR)

The Relaxation Response should not be confused with simple relaxation. The RR is a nervous system response that reduces stress effects by slowing heart rate, lowering metabolism, and decreasing breathing rate. This response is triggered by following specific instructions, which include repeating a sound, word, phrase, thought, or prayer, and adopting a passive attitude (Benson, 1975). Everyone can learn to trigger this response through breathing or attention techniques, but they have to train. A 2013 study found that breathing exercises helped mathematics-anxious students feel calmer and perform better on tests, suggesting that focused breathing can effectively mitigate mathematics anxiety (Brunyé et al., 2013).

The Study

The study aimed to assess the effectiveness of interventions on participants with mathematics anxiety by addressing two main questions: 1) Did the Mathematical Resilience Toolkit benefit the participants, and if so, how? 2) What was the overall impact of the intervention on Brazilian participants?

The project also sought to train Brazilian colleagues in 1:1 interventions for implementation in Brazil. Ten Brazilian residents in the UK showed interest and participated in Portuguese. Participants' mathematics anxiety levels were measured using the Betz scale before the intervention, recruiting those with moderate to high anxiety. Scores were categorized as: 10-27 low, 28-32 moderate, and 33-42 high, with extreme levels (over 42).

Eight members of a chat group completed the pre-questionnaire, with 2 scoring low, 3 high (Tania, Amanda, Rita), and 3 extremely high in mathematics anxiety. Individual interventions were conducted for those with high scores, consisting of two 45-minute sessions each.

The study received ethical approval from the University of Warwick HSSREC committee, and informed consent was obtained from participants. Data collection included session recordings, narrative records, and questionnaires, all transcribed via Teams. The intervention, originally developed for children and adapted for adults, was tailored for the Brazilian context and language. One cultural adaptation was needed, but overall, the tools were effective.

The first session focused on discussing mathematics experiences and introducing the Hand Model of the Brain (HMB), the Growth Zone Model (GZM), and the Relaxation Response (RR). The second session reinforced these tools and emphasized moving from the Anxiety Zone to the Growth Zone and not to hide in the Comfort Zone. Participants shared their experiences with the intervention, and data were anonymized with thematic analysis planned for qualitative data.

Results

First session

In the first part of the session, the three participants shared their mathematics experiences. Tania felt nervous during tests, Amanda hated studying and felt incapable, and Rita experienced insecurity and anxiety. None had heard of mathematics anxiety before, underscoring the term's educational value. Their stories illustrate the deep emotional impact of their previous mathematical experiences. In the second part of the session, the discussion focused on the fear of making mistakes, a common issue for individuals with mathematics anxiety. Amanda recounted her father’s negative reactions to her mistakes, and Rita described her excessive anxiety and meticulous preparation to avoid errors. This part aimed to shift their perspective on mistakes by explaining concepts like neuroplasticity and framing errors as part of the learning process rather than failures.

In the third part of the session the toolkit was introduced. The Growth Zone Model (GZM), the Hand Model of the Brain (HMB) and the Relaxation Response (RR) helped participants understand their mathematics anxiety and develop strategies for managing it. Participants had positive reactions. Amanda liked knowing about the anxiety zone and growth zone, Tania used breathing techniques to recover from the anxiety zone, while Rita found music helpful.

Second session

At the beginning of the second session, participants recalled key aspects from the first session. Tania remembered the HMB, noting their relevance to her mathematics experiences and identifying her past mathematics test as being in the "red zone." Amanda specifically recalled the GZM and its impact on her understanding of anxiety. Rita reflected on applying the Growth Zone concept beyond mathematics, noting that it helped her manage anxiety and stay calm when anticipating mathematics-related situations.

In the second part of the session, strategies for managing mathematics anxiety were discussed. The participants shared their methods for handling anxiety, such as Tania's use of breathing techniques and Amanda's slow breathing. Rita used music and task-switching as strategies and sought support from colleagues to manage anxiety. To assess their responses to mathematics, participants were shown a mathematics question to gauge their reactions. Tania showed avoidance, Amanda expressed willingness to try, and Rita displayed a pragmatic approach despite her anxiety.

The session also focused on persevering in the Growth Zone, with participants reflecting on their strategies and growth. Tania acknowledged some trauma but showed a growth mindset, Amanda expressed encouragement from learning new things, and Rita highlighted the overall positive impact of the intervention. Participants found the theoretical concepts, the Hand Model of the Brain and the Growth Zone Model, particularly useful in managing both mathematics anxiety and broader life challenges.

Discussion

In this study, reframing adverse experiences with mathematics was used to challenge the belief that mathematics anxiety reflects intrinsic inability. The aim was to change participants' perspectives, demonstrating that past mathematics struggles are not indicative of their capabilities but rather a result of previous negative experiences. The study employed the Mathematical Resilience Framework, which included identifying signs of mathematics anxiety, using the Mathematical Resilience Toolkit (HMB, GZM, RR), and fostering psychological safety and growth mindset.

Each participant engaged with the toolkit differently: Tania found the HMB impactful, Amanda focused on understanding the GZM, and Rita applied the techniques effectively, showing significant behavioural changes. Despite these variations, all participants gained insight into their mathematics anxiety, realizing it was not a reflection of their intelligence.

The study highlights that while individuals with high mathematics anxiety may respond differently to interventions and some may require more time, reframing and understanding the tools can significantly enhance mathematical resilience. Key elements for developing this resilience include reframing negative experiences, recognizing and managing anxiety, understanding the Growth Zone, and applying strategies to persist and learn. The study underscores the importance of personalized approaches and active listening in supporting individuals with mathematics anxiety.

The complete paper is available in the references session (Alves et al., 2024)

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From Mathematics and Science Anxiety to Mastery: A Tenth Grader's Journey with the Growth Zone Model in Mathematics and Physical Sciences

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Abstract

In the South African Education system, the transition from ninth to tenth grade is the time when learners choose their academic trajectories. Mathematics anxiety is known to make many apprehensive about continuing with mathematics and science subjects. This study delves into the anxieties of a tenth-grade learner, investigating her journey from anxious mathematics/science learner to building resilience. The study is part of a longitudinal action research (AR) project. The findings indicate that several factors influence learners' attitudes towards mathematics and science, such as a fear of academic failure and lack of interest. The account reveals initial difficulty in understanding basic concepts which progressively worsened. However, once her teachers used the Growth Zone Model intervention, she began managing her anxiety and building confidence in these subjects. The study suggests addressing the root causes of learners' fears and implementing coping strategies help learners build resilience in mathematics and physical sciences.

Keywords: Anxiety, mathematics, ninth graders, physical sciences, resilience tenth graders

Introduction

Mathematics and physical sciences are foundational for cultivating analytical reasoning and problem-solving skills. However, a considerable number of students suffer from mathematics/science anxiety, which can significantly impede their academic progress. Mathematics anxiety can induce sensations of anxiety, unease, and dread that disrupt their performance in these disciplines (Zuo & Wang, 2023). Mathematics anxiety has been extensively studied and is known to result in the avoidance of mathematics-related tasks, constraining students' potential (Zhang & Zhou, 2024). Nonetheless, the existing literature lacks effective interventions that specifically target the fundamental psychological challenges that contribute to this anxiety, despite the common emphasis on remediation and assistance for struggling students in traditional teaching approaches (Rubinsten et al., 2018). The growth zone model and the hand model of the brain serve as impactful educational tools designed to alleviate anxieties, particularly in subjects like mathematics and science, while fostering resilience among learners. The growth zone model elucidates the zones in which individuals operate: the comfort, growth, and panic zones. This model illustrates how stepping beyond comfort can lead to growth, although such transitions may evoke anxiety ((Pará & Johnston-Wilder, 2023) effectively. By promoting an understanding of these zones, educators can help students reframe anxiety from a debilitating emotional state to a potential catalyst for learning and resilience. Pará and Johnston-Wilder (2023) effectively utilized this model in a high school setting to address mathematical anxiety; through participatory action research, students could identify moments of growth amidst challenging scenarios in mathematics, mitigating fears associated with failure (Pará & Johnston-Wilder, 2023). The hand model of the brain reinforces this understanding by connecting students' emotional responses to specific brain functions. This model explains the workings of the brain's limbic system, which governs emotions, and the prefrontal cortex, which is responsible for rational thinking and decision-making. The hand model gives students a relatable representation of this complexity, enabling them to visualize their emotional state and how thoughts influence anxiety levels. Educational literature indicates that employing such relatable models has shown promising outcomes in reducing anxiety and enhancing confidence in learners as they navigate challenging subjects like mathematics and science (Johnston-Wilder et al., 2021; Pará & Johnston-Wilder, 2023). Both models encourage students to frame their struggles as part of the learning process rather than as indicators of their abilities. (Johnston-Wilder et al., 2020; Johnston-Wilder et al., 2021). This study aims to address anxiety by examining the implementation of the GZM in an educational environment, specifically tracking the progress of a tenth grader in mathematics and physical sciences subjects.

The following research question guides this study:

1. How does the Growth Zone Model influence a tenth grader's progression from anxiety to mastery in Mathematics and Physical Sciences subjects?

Literature Review

The Growth Mindset Theory (Dweck, 2006) suggests that people who believe that their talents may be enhanced by commitment and exertion (growth mindset) are more inclined to attain success than those who perceive their abilities as unchangeable. This theory emphasises the need to embrace challenges and derive lessons from failures as a means to achieve personal development (Dweck, 2006). Research has demonstrated that cultivating a growth mindset can augment motivation, resilience, and academic achievement.

Literature has extensively examined the phenomenon of mathematics and science anxiety among students, specifically with a focus on understanding the correlation between anxiety levels and academic achievement in these fields. Ramirez et al. (2013) emphasised the negative impact of early mathematics anxiety on students' attitudes, motivation, and cognitive functioning, ultimately resulting in decreased mathematical proficiency. Research has demonstrated that interventions employing the Growth Zone Model, in conjunction with instruments such as the hand model of the brain, have effectively addressed anxiety and fostered mathematical resilience in students (Heshmati et al., 2020). In addition, interventions targeting parents with high levels of mathematics anxiety, interactive mathematics applications, mindset shifts from fixed to growth mindsets, and mindfulness practices have been effective in reducing students' mathematics anxiety (Shafiq et al., 2021). These strategies emphasise the need to promptly identify and address mathematics/science anxiety to prevent enduring consequences on academic achievement. Implementing these techniques in educational settings enables teachers to establish conducive conditions that facilitate students in effectively coping with their anxiety and enhancing their academic achievements in mathematics and science (Falco, 2016).

An intervention study conducted by Para and Johnston-Wilder (2023) used the Growth Zone Model (GZM) and the hand model of the brain (HMB) to address mathematical anxiety and promote the development of Mathematical Resilience in high school students in Brazil. Cooper et al. (2018) present the influence of active learning practices on student anxiety in large-enrolment college science classrooms. The study demonstrates that implementing active learning can elicit increased and reduced student anxiety levels in science.

Methodology

This study employed a design-based action research framework. The research was conducted in a rural public educational institution in the Eastern Province of South Africa. The primary component of the study incorporates a comprehensive intervention for a whole grade 10 class, during which teachers developed coping mechanisms to alleviate students' mathematics and science anxiety within the classroom setting. Initially, the teachers in the school were trained in using the GZM in mathematics/science classrooms. The teachers implemented the tool in the classrooms for the entire school year by establishing a nurturing environment where students feel empowered to accept challenges enthusiastically.

A 16-year-old girl volunteered for this phase of the study. She was selected according to the following criteria: (a) possessing the highest initial score on the mathematics and science anxiety scale, (b) currently in grade 10, and (c) willing to disclose the extent of her progress with the tool to the researcher. The study employed an interview method for data collection, supplemented by classroom observations. An informed consent form outlining the interview procedures and ensuring the participant's autonomy to engage in the interview was signed by the participant.

The data analysis procedure employed was thematic analysis, initially proposed by Braun and Clarke (2006). The narrative thematic analysis procedure I employed comprised five stages: (a) data organisation and preparation, (b) acquiring a comprehensive understanding of the information, (c) coding, (d) categorisation or determination of themes, and (e) data interpretation. The data preparation phase commenced by transcribing audio data after the interview. During the transcription, any basic patterns or themes were recorded in the margins of the transcript. A single document was created by combining the two transcripts from classroom observation and interviews.

Results

Lusanda is a 16-year-old girl in grade 10, majoring in mathematics, physical sciences, and another 5 subjects. Lusanda had consistently performed below average in both subjects and firmly believed that she was "not good at mathematics or science," a belief reinforced by repeated negative experiences. This mindset made it difficult for her to engage fully with the learning process, as she was often overwhelmed by a sense of inadequacy and hopelessness.

The Growth Zone Model (GZM) was introduced to Lusanda as part of a school-wide initiative to nurture resilience and a growth mindset among high school learners. This model emphasizes the importance of stepping out of one's comfort zone (where learning is minimal) and entering the "growth zone," where challenges are faced, and skills are developed. However, it also warns against the "panic zone," where the level of challenge becomes too overwhelming, leading to heightened anxiety and shutdown. Lusanda initially resisted using or thinking about the Growth Zone Model, viewing it as just another strategy that would not address her issue of an inability to grasp complex concepts. Despite this resistance, the model was gradually integrated into Lusanda's daily learning routine by her two teachers who also encouraged her to view mistakes as opportunities for learning rather than evidence of failure. The emphasis was on incremental progress rather than perfection, a shift Lusanda found challenging to accept.

Over time, Lusanda noticed slight changes in her approach to learning. With consistent encouragement and support from teachers and peers, Lusanda started to engage more with challenging problems. For instance, during a particularly difficult unit on analytical geometry, Lusanda initially struggled but was encouraged to remain in the growth zone, where the challenge was neither too easy nor overwhelming. Through guided practice and positive reinforcement, Lusanda experienced moments of understanding and mastery, slowly starting to chip away at her anxiety.

The turning point in Lusanda’s journey came during a project on Newton's laws of motion. Initially daunted by the complexity of the concepts, Lusanda applied the Growth Zone Model by breaking down the problem into manageable parts and working through each step methodically. The sense of accomplishment after completing the project marked a significant reduction in Lusanda's anxiety levels.

As the year progressed, Lusanda's confidence continued to grow. Regular reflection sessions revealed that Lusanda was increasingly comfortable with ambiguity and uncertainty in learning. The anxiety that once paralyzed her transformed into a healthy respect for the challenges posed by Mathematics and Physical Sciences.

Lusanda’s teachers used the Growth Zone Model to provide feedback that effectively bridges the gap between her current understanding and the challenging concepts she must master. For instance, Lusanda indicated that her teachers offered constructive guidance on mathematics tasks rather than just praising her correct solutions to Euclidean geometry, breaking the process into manageable steps and providing extra resources for practice. In science class, Lusanda indicated that electromagnetic waves were particularly challenging and struggled with the different types of electromagnetic waves and their properties. Lusanda indicated that her science teacher would say, you have a good understanding of basic wave concepts which she indicated did not address her difficulties with the new material. However, the science teacher provided additional resources, including interactive simulations and videos, to help her understand the properties and applications of each type of electromagnetic wave. The interactive resources made learning engaging and reinforced her understanding.

Discussion

Introducing the Growth Zone Model to Lusanda's learning environment represents a strategic intervention to foster resilience and a growth mindset. This model encourages students to step out of their comfort zones and embrace challenges while avoiding overwhelming situations that could trigger anxiety. This framework is particularly relevant to Lusanda's journey, as her initial resistance to the model reflects a common reaction among students who have previously encountered failure in challenging subjects. Lusanda's gradual shift in perspective, as she began to engage more with challenging problems, highlights the importance of supportive teaching practices in promoting a growth mindset. The literature emphasizes that teachers play a crucial role in shaping students' attitudes towards learning by providing constructive feedback and encouraging a focus on incremental progress rather than perfection (Hughes et al., 2019). Ramirez et al. (2013) highlight that early mathematics anxiety can lead to negative attitudes, decreased motivation, and impaired cognitive processing, ultimately resulting in reduced competence in mathematics (Zuo & Wang, 2023). This aligns with Lusanda's initial struggles, where her fear of failure and belief that she was "not good at mathematics or science" significantly hindered her engagement with these subjects. The literature further suggests that addressing such anxiety early on is crucial to preventing long-term academic consequences (Zuo & Wang, 2023). ln Lusanda's case, her teachers' encouragement to view mistakes as learning opportunities was pivotal in her journey. This aligns with findings from Shafiq et al. (2021), which suggest that interventions incorporating a growth mindset can significantly reduce mathematics anxiety and improve students' attitudes towards mathematics. The gradual changes in Lusanda's approach to learning, particularly during challenging units like analytical geometry, illustrates the effectiveness of this supportive framework. The turning point in Lusanda's journey, marked by her successful project on Newton's laws of motion, exemplifies the transformative potential of the GZM.

The sense of accomplishment that Lusanda felt after completing her project reflects the positive outcomes associated with sustained effort and the application of effective learning strategies. As Lusanda's confidence grew throughout the academic year, her experience aligns with the broader literature on the relationship between a growth mindset and academic success. Studies indicate that students with a growth mindset are more likely to exhibit persistence and adaptability when faced with challenges, leading to improved performance in mathematics and science.

Conclusion and Recommendations

In conclusion, Lusanda's journey with the Growth Zone Model highlights the potential for targeted interventions to transform students' experiences in Mathematics and Physical Sciences. Teachers can effectively address mathematics and science anxiety and promote mastery in these critical subjects by encouraging a growth mindset, creating supportive learning environments, involving parents, and continuously assessing educational practices.

Therefore, teachers must recognize these patterns early and implement effective interventions to support students like Lusanda. Considering Lusanda's transformative experience, several recommendations can be made for teachers and policymakers aiming to address mathematics and science anxiety in educational settings. First, it is essential to implement early interventions that focus on building a growth mindset among students. This can be achieved through professional development programs that equip teachers with the skills to create supportive learning environments and provide constructive feedback that emphasizes effort and progress rather than perfection. Moreover, integrating mindfulness practices into the curriculum may help students manage anxiety and improve their overall emotional well- being. Teachers should regularly evaluate the effectiveness of interventions and be open to them. This iterative process fosters a culture of continuous improvement and empowers students to take ownership of their learning journey.

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The impact of an intervention programme on reducing math anxiety among elementary school students in Brazil

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This study investigated the reduction of mathematics anxiety (MA) -following an intervention programme with primary school students. Two students responded to MathAS, P1 with high and P2 with extreme MA. The intervention programme consisted of ten weekly sessions. The sessions included techniques for emotional self-regulation, shaping study habits, and social skills. To assess the programme effects, participants completed questionnaires on study habits and MathAS, before and after the intervention. The follow-up was carried out two months later. The post-test results showed a significant reduction in MA (P1 from high to low MA; P2 from extreme to moderate MA). Furthermore, both students showed low MA at follow-up. There was also a significant improvement in attitudes towards mathematics. These findings suggest that educational interventions that combine emotional regulation and the shaping of study habits may be effective in reducing mathematics anxiety and changing attitudes towards mathematics and may promote mathematical resilience.

Keywords: Mathematical Resilience, Mathematics Anxiety, Educational Intervention, Building Resilience, Elementary Schoolers.

Introduction and Literature Review

Understanding the multiple determinants of mathematics anxiety (MA) is essential for conducting studies and proposing intervention programmes for students with MA, both to prevent and reverse MA. Promoting the removal of barriers related to learning and progress in the discipline is essential for a society driven by innovation and technology, showing a present need for STEM (science, technology, engineering, and mathematics) professionals (Hurst & Cordes, 2017).

Helleum-Alexander (2010) conducted a literature review that focused on effective teaching methods for the treatment of mathematics anxiety. Many of the characteristics of a supportive teacher, such as cooperative learning, positive mood, and teacher expectation that students will succeed, were found in the successful treatment methods. Creating a supportive and stimulating learning environment allowed a positive relationship to be established between the student and the content, thereby reducing mathematics anxiety.

Colombini *et al.* (2012) investigated the effect of developing study habits on MA in a 16-year-old student. The intervention was conducted by an analytical-behavioural therapist, who had already established a therapeutic bond with the participant. Acting within the participant's natural environment, the therapist promoted the generalization of repertoires, academic autonomy, study organization, and anxiety management. Specific strategies included teaching the use of an agenda to appropriately record mathematical tasks, supporting the completion of these tasks for at least two hours per session, and providing positive reinforcement for each problem-solving attempt. The intervention resulted in improvements in the quality and organization of study habits, reductions in avoidance and anxiety related to mathematical situations, and increases in mathematics performance.

A meta-analysis conducted by Sammallahti *et al*. (2023) indicates that longer interventions (lasting three weeks or more) promote a greater reductions in mathematics anxiety, but the effects of longer interventions in MA were not significantly different from the effects of interventions considered to be of medium duration (more than one day and less than three weeks). Short interventions did not show significant effects, but no structured intervention programme has yet been established as a gold standard.

The present study proposes an intervention programme based on Carmo and Henklain (2022), including educational and cognitive-behavioural strategies to reduce mathematics anxiety (MA). The programme consisted of four stages: 1. Application of the MAthAS and brainstorming to identify students with high MA. 2. Explaining MA and the intervention to teachers, including a meeting to discuss results and select participants. 3. Communicate with parents and teachers to obtain permission and instructions for behaviour recording. 4. Follow-up with selected students through weekly sessions over two semesters, focusing on techniques such as breathing exercises, relaxation, social skills, and study habit management. Progress is assessed through brainstorming and questionnaires such as the Mathematics Study Habits Inventory (MSHI) and related checklists.

Method

Participants: Forty-four 6th-grade students from a public primary school completed the MAthAS. Two female students (P1 with high and P2 with extreme MA) received parental consent to participate.

Setting: The research was conducted at the school during students' free-time.

Instruments and Techniques

a) Mathematics Anxiety Scale - MathAS (Carmo, 2008)

The MAthAS is a five-point Likert scale with 25 scenarios describing mathematics class situations. Participants indicate their level of anxiety as none, low, moderate, high, or extreme. The total score reflects the predominant level of anxiety: 0-25 points for no anxiety, 26-53 for low, 54-77 for moderate, 78-101 for high, and 102-125 for extreme anxiety.

b) Brainstorming

This technique involves writing down the participants' immediate thoughts about the word "mathematics" on a piece of paper to understand their ideas about the subject.

c) Mathematics Study Habits Inventory (Carmo, 2013a)

The Mathematics Study Habits Inventory (MSHI) includes 34 items about study behaviour, scored from 0 (never) to 3 (almost always). The scores ranged from 0 to 103 and are classified as follows: Poor (0-70), Regular (71-79), Good (80-89), and Excellent (90-103).

d) Supplementary Questionnaire on Study Habits (Carmo, 2013a);

The Supplementary Questionnaire on Study Habits has seven questions (five multiple choice and two open-ended) to examine students' mathematics study behaviours at home and in the classroom.

e) Mathematics Study Habits Checklist (Carmo, 2013b).

The checklist provides instructions for effective study habits in five categories: classroom participation, content review, post-class actions, mathematics book handling, and memory aids. Students adopt daily actions to improve their study habits.

f) Techniques

Diaphragmatic breathing is a relaxation technique that consists of slower and deeper inhalations and exhalations. Jacobson's progressive relaxation aims at physical and mental relaxation by tensing and relaxing 16 muscle groups, with participants following verbal instructions.

g) Semi-structured interviews

Semi-structured interviews were conducted with participants, parents, and teachers to obtain feedback on the intervention.

Procedures

MAthAS was administered to all 6th grade students with parental consent to identify those with high or extreme mathematics anxiety. Results were reviewed, and students with high mathematics anxiety were invited to participate in an intervention programme. The families of two students agreed to participate, and informed consent was obtained. Parents were asked to support their daughters' study behaviour, while teachers observed and responded to classroom behaviour.

Pre-test

Before the intervention, the programme was explained to students, detailing their selection, session content, frequency, and engagement expectations. The first session included brainstorming and the application of the Mathematics Study Habits Inventory, Supplementary Questionnaire, and Mathematics Study Habits Checklist.

Intervention sessions

The programme consisted of ten weekly sessions, of approximately 45 minutes each. The sessions focused on strengthening study habits, teaching emotional self-control, and developing social skills. Each session ended with a weekly practice suggestion for students to use at home and in the classroom. Student progress was monitored, and occasional meetings were held with parents and the teacher for updates and additional guidance.

Post-test

After the intervention, participants resat the initial instruments to assess progress and provided feedback through semi-structured interviews. Parents and the teacher also shared their observations via interviews.

Follow-up

Two months after the intervention, the participants responded once more to the initial instruments. The final application assessed whether the post-test results were maintained and evaluated the effectiveness of the programme in reducing mathematics anxiety.

Results and Discussion

The application of MathAS at the beginning and at the end of the intervention (pre-test, post-test, follow-up) showed behavioural changes in the participants' MA. In the pre-test, P1 scored 93 (high anxiety) and P2 scored 102 (extreme anxiety). In the post-test, P1 scored 45 (low anxiety) and P2, 52 (moderate anxiety). In the follow-up, P1 scored 38 and P2, 49, both indicating low anxiety.

On the Study Habits Inventory, P1 initially scored 63, and P2, 74. In the post-test, the scores increased: P1 scored 85 (good study skills) and P2, 90 (excellent study skills). Both maintained excellent skills at follow-up. The supplementary questionnaire on mathematics study habits showed an increased in study frequency. P1 went from rarely studying to studying two hours a day, and P2 from short periods to more than two hours of study a day after the intervention.

The results of the intervention, including the reduction in MA and improved study habits, suggest a positive impact. The engagement of the students, parents, and the teacher was significant. The teacher observed that both students continued to use effective study habits, including note-taking, asking questions, doing homework, and managing test time.

The participants' mothers reported in interviews that after the intervention, P1 became very organized in her studies, completed her homework, and asked questions in class. P2 showed less anxiety, complained less about mathematics, and had better study habits. These reports indicate that mathematics anxiety is closely related to study habits and that enhancing these habits effectively reduces MA, which is consistent with previous research (Carmo & Simionato, 2012).

No improvement in mathematics grades was observed before and after the intervention, which took place in the last bimester of the year. The final grade reflected only a two-month period, and the complexity of the content at the end of the year may have influenced the results. These findings raise questions about the need for a longer intervention or starting it earlier in the school year to improve mathematics achievement.

Conclusion

Given the impact of mathematics anxiety on individuals and career choices, research into its reduction should be expanded and scaled up. This study highlights key intervention components, including systematic desensitisation, relaxation, diaphragmatic breathing, and improved study habits. However, the programme needs to be applied to a larger group to test consistency and replicability of the findings.

The OECD (2013) reports found that, in Brazil, at least 45% of students feel helpless when solving a maths problem. This means that when faced with a problem a person may believe that outcome is independent of their efforts (Maier & Seligman, 1976). Another way to address the problem is for teachers to work explicitly on developing “mathematical resilience”. This pathway consists of strategies for teaching mathematics in a way that does not lead to negative consequences. In this case, the focus is on attitudes and beliefs that enable learners to approach mathematics positively, resulting in a students' willingness to make the effort to learn and solve mathematical problems to overcome any barriers to mathematical growth (Lee, 2017). Future experimental research on mathematical resilience will demonstrate the plausibility of the construct and its potential application on a large scale.

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Neurodiversity, mathematical resilience, and learning.

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Learning mathematics is not something that should be taken for granted, and in countries like Argentina, 7 of 10 children living in poverty are in danger of not learning mathematics at all. In educational and clinical settings, acknowledging that neurodiversity is a fact and learning results from the relationship between individual and environmental factors is imperative. Facing the need to promote mathematics learning in children, either because individual or environmental risk factors are present, adults could learn from and reflect on mathematical resilience, scaffolding, and feedback. All of them are protective factors for learning in any context. Some strategies used in clinical and educational settings can help children learn mathematics (and any subject) and reading and learning about them can help adults promote child development.

Keywords: learning mathematics, mathematical resilience, scaffolding, feedback.

Where are we starting from regarding the situation in Argentina?

Argentina is a large and diverse country at the bottom of South America, where 7 out of 10 children live in poverty. There are 8.6 million children under 18 years of age, who live in homes that do not reach the minimum monetary income floor or in environments of deprivation of rights (housing, health, education among others). Also

7 out of 10 students do not achieve basic levels in Mathematics. In 2018 they ranked 66 out of 81 participants (OECD 2019). By 2022 in Reading and Science, there were small improvements but in mathematics the current results show no progress (OECD 2023). Nistal et al., (2023) found that in Mathematics, 7 out of 10 (72.9%) students did not achieve a basic level. Therefore, as a country, we are facing a challenge in Mathematics education, and there is an urgency to develop new strategies to teach mathematics, which help the students learn mathematics. It seems that learning from other countries with better results than ours could be beneficial.

As a clinician, I often encounter children with difficulty learning mathematics, and face the challenge of helping them grow as learners and promote mathematics resilience and knowledge. In NeuroEduca, the company I work for, we have developed an intervention frame that uses evidence-based strategies from neuropsychology and teaching to help children with mathematics learning difficulties. In my work I help children, parents, and teachers to foster mathematics learning in clinical, domestic, and school settings, acknowledging that generalization is the key to building academic skills. One of the easiest ways of doing so is using scaffolding as a universal language to promote learning and open the learning zone (the growth zone in Lee and Johnston-Wilder´s words, 2018).

Neurodiversity: how universal brains become individual minds, understanding neurodiversity as the normal heterogeneity and becoming aware of the need to address this in the classroom

Neurodiversity is the fact that all humans vary in how their brains take in and process information. Thus, any group of people will have different experiences and behave in different ways. The neurodiversity paradigm is a position or perspective on the biological fact of human diversity (Alcorn et al., 2023).

Each of us builds a learning trajectory throughout their life, integrating genetic and environmental influences.

> Thus, armed with perceptive, cognitive, emotional, and behavioral tools (it is certainly necessary to say “among others” here), the person interacts with the environment from the moment he or she is conceived until the moment he or she dies, and develops an almost infinite sequence of learning that shapes his or her relationship with the world in which he or she lives, conditioning his or her way of responding to it and to the challenges it presents. In addition, learning allows us to “adjust the parameters of a mental model” (Dehaene 2019), with which we navigate the world and set goals and paths to achieve them. I like to call this sequence the learning trajectory, the tireless succession of experiences that are translated from the relationship between the person and his or her environment (with the combination of variables that this implies) and that allows us to build knowledge, memories, autobiography, ways of responding and the ability to establish goals that are our own and direct ourselves towards them (Figiacone, 2022, pp 9).

Parents, teachers, school resources, community characteristics, and geography all set boundaries for an individual's learning trajectory. This also helps to shape self-regulation, resilience, and learning skills (along with individual components such as DNA, temperament, and susceptibility to the environment, among others).

It is impossible to avoid considering environmental variables in fostering learning and resilience since “neurodivergent children and young people do not exist in a vacuum, but are strongly affected by the knowledge, beliefs, and choices of those around them” (Alcorn et al., 2023, pp 10). Through beliefs, expectations, verbal and non-verbal feedback, and behaviour, each adult around a child can influence the development of the child´s learning, resilience, and self-regulation. Adults are co-creators of this kind of neuropsychological resource. Learning mathematics is a challenge for every child from the early years, and adults' beliefs, expectations, and feedback regarding mathematics learning will directly impact mathematics learning and resilience development.

“Children with SLDs tend to experience increased stress as a result of the various factors related to their disability. For instance, in addition to academic challenges, higher rates of high school drop-out, behavioral disorders, and incarceration, individuals with SLDs frequently have high levels of anxiety, depression, poor mental health, lower self-esteem, and higher rates of suicidal ideation. Thus, it is important to foster resilience to support positive outcomes for these children.” (Stein et al, 2024 pp. 1)

Resilience is the ability to positively adapt to stress or adversity through a process involving both internal and external characteristics. Mathematical resilience allows us to cope with the stress and anxiety learning mathematics often generates. Internal characteristics are personal traits that resilient individuals possess. In contrast, external characteristics refer to other environmental variables supporting resilience, such as an individual’s family and community life (Stein et al., 2024). As teachers, parents, and professionals, fostering resilience to support positive outcomes for every child is important as we acknowledge adults are co-builders of self-regulation, learning, and resilience. Recent work views resilience as dynamic and able to be improved rather than innate and fixed (Stein et al., 2024). This makes it imperative to look for and implement strategies that foster resilience in general and mathematics resilience in particular.

"Taking a neurodiversity approach to SLD has the potential to alleviate these stigmatizing societal pressures by understanding SLD as a difference rather than only a deficit that needs to be fixed, removing the belief that there is an inherently negative impact given the disorder, and emphasizing each individuals' unique strengths" (Stein et al., 2024 pp.2).

So, considering that each child has his or her own learning trajectory and personal profile of strengths and weaknesses, if we consider that all children are expressions of diversity in equality (diversity as a person, equality as a human), then thiswill help us plan and establish ways of promoting resilience and learning for each child using, for example, scaffolding as a regular strategy.

Scaffolding is used to foster learning in the mathematics classroom and any classroom, as well as to conceptualize and classify different types of scaffolding.

Adults are responsible for orienting prognosis in children in any needs. When a child has, for example, a specific learning disorder (SLD), they will be subjected to more stress than children with no diagnosis, especially in school settings. Learning becomes more difficult, and the need for scaffolding becomes more urgent. For these children and for all children, adults are responsible for orienting what are called "resilience factors" to promote healthy school learning environments. Stein et al. (2024) summarize these "resilience-promoting factors" as productive in SLD children: parent support, friendship, regular school breaks, school-connectedness, motivation, supported reading strategies, problem-solving strategies, and shorter homework times. Good outcomes are achievable when adults work to reduce the stress children experience and promote resilience.

Scaffolding is one of many strategies used to reduce stress and promote resilience in academic settings and can also be used in domestic settings. Scaffolds are temporary, movable, and modifiable support systems or structures that allow a person to advance the course of any task (Frey et al., 2023). In NeuroEduca, we work with children with SLD and use the Growth Zone Model as a scaffold (Lee & Johnston Wilder, 2018) to help them *see*, in visible terms, where they are in each situation. The Growth Zone Model "*helps learners understand their feelings as they move from comfortable tried and tested ways of working in mathematics into learning, reasoning, connecting and developing more efficient ways of enjoying mathematical activity*" (Lee & Johnston–Wilder, 2018, no page). We identify the learning zone with the Zone of Proximal Development of Vygotsky, and we help them understand how scaffolding opens this zone where learning can happen.

Scaffolding linked to instruction arises from a process in which the teacher (or, in this case, the clinician) adds support to promote and enrich learning and assist in developing skills. It is used when the task is out of reach without support. It is also customizable, and it can be adjusted to individual needs. It is temporary and is used until the structure is no longer needed (Frey et al., 2023). According to Frey et al. (2023), the first purpose of scaffolding is to open a Zone of Proximal Development. As clinicians, we use the Growth Zone Model to help children identify if the scaffolding is useful and lets them enter the learning zone. We also use the concept of the Panic Zone to help them understand they sometimes need more or another kind of scaffolding. Helping them learn to be metacognitive about scaffolds is another way to promote resilience and relieve stress. In their book, Frey, Fisher, and Almarode (2023) state that among the purposes of scaffolding, are also orienting conceptualization, **promoting resilience development**, sustaining practice, and diminishing cognitive overload. Considering mathematics learning, scaffolding has, of course, the same objectives and functions, and some scaffolds may be more useful than others.

As teachers (parents, clinicians), we can (and must) use affective or emotional scaffolding. Emotional scaffolding is as crucial for learning as the other kinds. Emotions are a central dimension or component in learning, and taking care of students' emotions and having positive expectations are protective factors for academic achievement.

"Many learners experience strong negative emotions when they get stuck and may feel that they have been offered the chance to fail. Unless learners understand that all mathematicians struggle, get stuck and make mistakes, perhaps especially those mathematicians that work with really complex and difficult mathematics, and that many mathematicians like to collaborate with others so that they get ideas and encouragement in the difficult task of learning more mathematics, they may feel justified in concluding that they cannot do mathematics and they will not continue with the struggle" (Lee & Johnston–Wilder, 2018, no page).

Emotional scaffolding can take many forms. Being aware of how we use it helps promote learning and resilience. In mathematics classrooms, talking about mathematics learning and mathematics resilience is likely to be beneficial. One of the ways we can scaffold learning emotionally is by using proper feedback. "*The most valuable feedback focuses on helping the student improve*" (Hattie, 2018, p2). In other words, "*feedback is information about the task that fills a gap between what is understood and what is aimed to be understood*" (Hattie, 2019, p3). Therefore feedback can direct earners to the growth or learning zone. Hattie (2018), makes clear that where teachers open the Growth Zone for learners they use feedback to state the qualities of what has been done without comparing one child´s work with the work of another child; they say explicitly how the work can be improved, giving clear clues and state the improvements that the child has made recently.

Some examples of clear and emotionally inspiring feedback can be taken from teachers from Northern Hills School in Mar del Plata, Argentina:
"*I do not matter the order of solving the problems; what really matters is that you did not give up and handled it very well!"*
"Good strategies!! You showed confidence!"
"You did it very well!! I know some stuff was difficult, but you worked with effort, and you could manage. That is very important!"

"*There is now much evidence that leads us to believe that learners develop mathematical resilience in a supportive environment, where learning mathematics is, at least sometimes, a collective and collaborative endeavour*" (Lee & Johnston-Wilder, 2018 no page). Giving proper feedback is one way to build a supportive environment. It can help to give raise the belief that "*everyone can grow their understanding*" (Lee & Johnston-Wilder, 2018) something critical to work resiliently in mathematics and in any other subject. Although emotional feedback is crucial, we should know that "*feedback is most effective when goals are specific and challenging*" (Hattie, 2018). Communicating learning objectives and clarifying the relationship between tasks and learning goals is as important as emotional feedback to promote mathematics (or learning) resilience. Knowing where we are and where we are going are two keys to the visible learning framework, inspired by John Hattie and the work of many authors.

Building mathematics resilience in the classroom and clinical settings goes beyond feedback. We need one particular kind of task, tasks that invite play, thinking, and interaction freely with mathematics, and we need an emotional climate where mistakes are welcome. Boaler (2019) promotes what she calls *opening mathematics.* "Opening mathematics involves inviting students to see ideas differently, explore with ideas, and ask their own questions. Students can access the same mathematical ideas and methods through creativity and exploration that they can by being taught methods they practice" (Boaler, 2019, p8). These ideas help develop what Boaler calls a mathematical mindset (2022), the mindset that inspires positive struggle and welcomes mistakes as part of the journey.

These strategies help every child and facilitate the opening of the Growth Zone for SLD learners and all learners. To sum up, learning mathematics can be difficult and, in some countries, more difficult because of a lack of adequate teaching strategies or learning opportunities. Some learners need extra help not because they do not have enough opportunities but because they have some SLD. Both groups of children may feel overwhelmed by mathematics and develop fixed mindsets or avoidance strategies to cope with negative emotions. Adults can help these learners by fostering mathematics resilience and opening the learning zone with proper scaffolding. Some strategies, such as feedback, opening mathematics, and focusing on building a mathematical mindset, may help promote mathematics resilience and learning.

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Mathematical Resilience: Working in Initial Teacher Education with Pre-service Teachers

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Mathematical resilience is a positive approach to learning mathematics, characterised by a growth mindset, valuing mathematics and one's place in the learning community, accepting struggle as part of the process, and knowing how to seek effective support. Overcoming societal myths about mathematical ability is also crucial for developing mathematical resilience. This paper explores barriers and strategies in building mathematical resilience in pre-service teacher education, highlighting the advantages of an andragogical approach in Higher Education. Finally, the critical importance of integrating resilience-building techniques into Initial Teacher Education (ITE) programmes will be discussed.

Keywords: Mathematical resilience, Initial Teacher education, Andragogy

Introduction

Mathematical resilience is a positive stance towards learning mathematics, where individuals believe their mathematical abilities can grow through effort and support. This involves valuing mathematics personally and communally, accepting that learning requires struggle and perseverance, and actively seeking help when needed. Cultivating this resilience is vital for dispelling negative societal beliefs and promoting mathematics as an accessible and interconnected subject for everyone.

Fostering mathematical resilience in pre-service teachers seems crucial, necessitating tailored strategies that acknowledge their unique learning experiences and orientations. This paper will first differentiate between pedagogical approaches for adult learners versus children, highlighting distinct learning approaches suitable for pre-service teachers. The paper will then analyse the obstacles hindering the development of mathematical resilience, exploring effective strategies and the implications for Initial Teacher Education (ITE) providers working within this context.

Review of Literature

Comparing Andragogy with Pedagogy

The fundamental difference between pedagogy, the education of children, and andragogy, the teaching of adults, is how the learning experience is shaped. While various pedagogical strategies exist, contemporary mathematics classrooms often lean towards traditional, transmission-based, teacher-led approaches that position learners passively. In stark contrast, andragogy, with its established history, recognises the distinct characteristics of adult learners. Knowles (1998) posits that teaching adults differs fundamentally from teaching children, a view Smith (2002) considers largely relevant today. Drawing on Knowles' (1998) work, Smith (2002) highlights several key attributes of adult learners: their motivation to learn tends to intensify with age and accumulated experiences; they are self-directed and seek involvement in planning and evaluation and they possess life experience that serves as a foundation for learning, fostering a greater intrinsic motivation for learning compared to younger learners.

Furthermore, the adult learners' disposition towards education evolves significantly with maturity (Smith, 2002). Their readiness to learn is often heightened by life experiences that stress the necessity or desirability of acquiring new knowledge and skills. Unlike younger learners who may be directed by curricula or external pressures, adults are typically motivated by a perceived need or a personal goal, such as career advancement, personal enrichment, or problem-solving in their daily lives. This intrinsic motivation fosters a greater willingness to invest time and effort into learning endeavours that they deem relevant. Complementing this heightened readiness is a shift in their learning orientation. While younger learners may often view education as preparation for the future, adult learners tend to focus on the immediate applicability of what they are learning (Smith, 2002). This desire for immediate relevance means that learning activities and content that clearly demonstrate practical value are more likely to resonate and engage adult learners.

Barriers to Mathematical Resilience in Adult Mathematics Education

Mathematical resilience can be understood as the development of psychological resilience specifically within the context of mathematics learning. When learners face challenges in learning mathematics, mathematical resilience provides the drive to continue engaging. Johnston-Wilder and Lee (2010) proposed four dimensions crucial for fostering this resilience: a belief in the value of mathematics, an acceptance of struggle as a learning opportunity, the adoption of a growth mindset, and the availability of supportive resources.

A significant obstacle in adult mathematics education stems from the deeply ingrained belief, often expressed as "you're either good or bad at maths." This sentiment, as Dweck (2000) highlights, reflects a pervasive fixed mindset—the notion that mathematical ability is an innate, unchangeable trait. This belief discourages effort, as individuals may perceive it as futile, potentially leading to feelings of inadequacy. Consequently, adult learners may rationally choose to identify as mathematically inept and avoid meaningful engagement with the subject (Dowker et al., 2016). These fixed mindset beliefs profoundly impact self-efficacy, the conviction in one's ability to succeed in mathematical tasks. Bandura (1997) posits that self-efficacy, in turn, influences agency—the sense of control over one's environment and actions. When mathematical outcomes reinforce the fixed mindset, it can cultivate an "anti-resilient" approach to learning amongst adult learners.

Schoenfeld (2022) emphasises the enduring impact of prior school experiences on adult learners' beliefs about their mathematical potential. Individuals with lower past attainment are prone to interpret these results as confirmation of their inherent inability, leading to disengagement. Faced with a mathematical problem, they may quickly give up, as a fixed mindset can stifle perseverance and the exploration of alternative strategies. If someone is convinced, they "can't do maths," investing time in trying seems illogical. Furthermore, adults who believe school mathematics lacked real-world relevance may fail to recognise its applicability, dismissing it as unworthy of attention. An expectation that mathematics will not make sense can render effort and struggle meaningless, hindering the development of problem-solving and mathematical thinking skills, ultimately impeding the growth of mathematical resilience. The prevalence of a fixed mindset regarding mathematics, often rooted in past educational experiences (Dowker et al., 2016), constitutes a primary barrier to adult learners' confidence in their ability to learn, use, and understand the subject.

Schoenfeld (2022) highlights the particularly demanding nature of mathematics education, highlighting the necessity of both resilience and substantial time commitment from learners. This inherent demand amplifies the challenges posed by adult learners' often packed schedules, juggling work, family, and other responsibilities, which can severely restrict opportunities for meaningful mathematical engagement. Moreover, the time and effort needed to address gaps from prior schooling can lead to feelings of being overwhelmed and subsequent avoidance. Adding to these challenges is a reluctance to seek help, frequently stemming from negative past social and emotional experiences where adult learners perceive asking for support as a sign of personal or professional incompetence.

While school mathematics may have predominantly focused on developing procedural fluency for examinations (Nardi and Steward, 2003), efforts to connect mathematical ideas and concepts would have been more beneficial for adult learners who may have repeatedly struggled to "remember how to do it." A key challenge in adult mathematics education is fostering problem-solving and self-directed learning skills, underpinned by andragogical principles (Knowles, 1984), in a context where learners may believe mathematics is solely about rote memorisation. School curricula often emphasise systematic teaching, procedural practice, and memorising rules and formulas, without always making the real-world value of these ideas apparent (Nardi and Steward, 2003).

Literature identifies mathematics anxiety as a significant and persistent barrier to developing mathematical resilience in adult learners. This unease, which for many extends far beyond their school years, can continue to manifest in adult life when confronted with mathematical tasks such as managing finances or understanding data at work (Ashcraft, 2002). For mathematically anxious adults, these encounters can trigger panic and avoidance (Ashcraft, 2002), potentially leading to difficulties and disadvantages in both their personal and professional lives. Consequently, there is a clear need to specifically address mathematics anxiety and cultivate mathematical resilience in adults, employing strategies and approaches tailored to their unique experiences and learning preferences.

Building Mathematical Resilience in ITE

In my role as a mathematics teacher educator, I have dedicated recent years to strategies to enable beginning secondary maths teachers to not only survive but to thrive in their early careers. However, I am growing increasingly aware of a major stumbling block: insufficient mathematical resilience amongst pupils in mathematics classroom. This is a significant issue, especially considering the well-documented relationship between mathematical resilience and learners' engagement, which is crucial for maintaining high standards in the constantly changing and complex school environment (Johnston-Wilder and Lee, 2010).

Resilient pupils are more likely to persevere and persist when confronted with challenging mathematical tasks, making them less likely to abandon their efforts. Additionally, mathematical resilience is important in teaching for another reason: it is only realistic to expect pupils to be mathematically resilient if their teachers exhibit resilience themselves. Therefore, fostering mathematical resilience in Initial Teacher Education (ITE) programmes is crucial for several interconnected reasons. Firstly, it equips pre-service teachers with the personal capacity to navigate their own mathematical learning and potential anxieties. Many individuals entering teacher training may have had negative experiences with mathematics, leading to anxiety or a fixed mindset. Developing their own mathematical resilience helps them overcome these barriers, build self-efficacy, and model a positive stance towards mathematics for their pupils. Secondly, mathematically resilient pre-service teachers are better equipped to create supportive and effective learning environments for their pupils. Understanding that struggle and mistakes are integral to mathematical learning, they can design lessons and implement pedagogical approaches that encourage perseverance and a growth mindset in their pupils. By knowing how to seek and provide appropriate support, they can better guide their pupils through mathematical challenges and build their resilience. Finally, promoting mathematical resilience in ITE programmes helps to disrupt negative societal myths about mathematics. By experiencing a growth mindset and recognising the value and accessibility of mathematics themselves, pre-service teachers can actively challenge the elitist notion that only some people are "good at maths." They can create a learning environment where pupils believe that mathematical ability is developed through effort and where every individual is a valued member of the mathematics community, thereby fostering greater inclusivity and engagement in mathematics for all.

A foundational element of effective andragogy for educators working with pre-service teachers should be cultivating a positive attitude and a growth mindset. As my earlier work indicates, challenging fixed notions of intelligence and demonstrating the potential for mathematical growth through support can empower both teachers and pupils to re-engage with mathematics. Because the development of mathematical resilience is a gradual journey involving struggle and perseverance (Lee and Johnston-Wilder, 2017), which are experiences frequently perceived as indicators of failure by those with fixed mindsets, it is vital to provide pre-service teachers with learning environments where they can connect the experience of struggle with eventual mathematical success.

Mathematics problems often allow for multiple solution pathways, even with a single correct answer. This concept—that diverse methods are valid and preferred approaches can vary—can be a revelation for many learners. Valuing and exploring learners' unique mathematical approaches is crucial for cultivating their mathematical resilience. This is often overlooked in traditional mathematics instruction that prioritises teacher-led activities over learner engagement. Working effectively with pre-service teachers requires ITE educators to exercise patience and their own resilience, actively listen to novice teachers' perspectives, and engage in meaningful discussions about mathematical ideas. While this approach may differ significantly from their past educational experiences, it is essential for developing resilient pre-service teachers.

Another critical challenge for those supporting pre-service teachers is creating learning environments that foster not only knowledge, skills, and experiences but also a sense of autonomy and agency in their mathematical endeavours. Developing autonomy and agency empowers learners to move beyond simply replicating taught procedures to actively engaging in sense making (Schoenfeld, 2022). This necessitates employing alternative, productive teaching approaches, often grounded in socio-constructivist learning theories (Vygotsky, 1979), which emphasise collaborative learning and problem solving (Swan, 2006). Such problems and collaborative methods can motivate learners, enable them to connect concepts, and apply their understanding through discussion and sense making. The social dimension of learning, through interactions among learners and between teachers and learners, is central to mathematics andragogy (Smith, 2002). These approaches also encourage learners to re-evaluate their attitudes and beliefs about mathematical learning by articulating their ideas and explaining their reasoning (Swan, 2006), thereby building mathematical resilience.

Discussion and Conclusion

Initial Teacher Education (ITE) programmes strive to shape beginning teachers' understanding of effective mathematics pedagogy (Boz, 2008). However, pre-service teachers are frequently exposed to pedagogical models that diverge from established principles and strategies focused on building mathematical resilience. For instance, new teachers completing ITE programmes in secondary schools have noted a lack of focus on broader issues and barriers hindering the development of their pupils' mathematical resilience, often overshadowed by an emphasis on subject mastery.

Robust professional training within Initial Teacher Education (ITE) programmes can equip new teachers with the knowledge, skills, and experience to foster mathematical resilience. However, effectively cultivating this resilience in pupils within the limitations of the classroom requires significant changes to traditional teaching practices. To facilitate this shift, both pre-service and in-service teachers require relevant professional development, supported by appropriate resources. This training should prioritise pedagogical approaches that lead to meaningful and productive mathematical learning experiences for pupils, specifically focused on building their mathematical resilience.

The successful integration of pedagogical approaches designed to build mathematical resilience hinges on teachers possessing both robust mathematical subject knowledge and a deep understanding of pedagogical and andragogical principles. This dual expertise enables educators to tailor their instruction to the unique needs and learning needs of pupils, fostering environments where resilience can flourish. However, a significant impediment to this ideal is the prevalent issue of a high percentage of non-specialist mathematics teachers (Allen and Sims, 2018). This lack of deep subject knowledge can directly impact their confidence in implementing innovative and challenging tasks that promote resilience. Furthermore, non-specialist mathematics teachers are often more susceptible to mathematics anxiety themselves. This personal experience of anxiety can inadvertently shape their teaching practices, potentially leading to a reluctance to embrace pedagogical approaches that involve struggle and risk-taking – elements crucial for building mathematical resilience in their pupils. Consequently, the implementation of meaningful and authentic learning experiences, which are vital for developing resilience, can be significantly hindered in the short term due to this complex interplay of factors.

A clear correlation exists between teacher quality and their ability to empower pupils to develop mathematical resilience. Consequently, addressing challenges related to teacher quality remains crucial for effective mathematics education. One potential solution involves fostering collaborations between schools and ITE providers. These partnerships could facilitate discussions on the barriers to building mathematical resilience for both teachers and pupils, thereby identifying the specific learning needs of both groups. Such collaborations could also explore and develop effective pedagogical approaches for fostering mathematical resilience within the ITE context.

This paper has illuminated key issues and potential solutions surrounding mathematical resilience in the context of initial teacher education. However, further research and action are undoubtedly needed to fully address these complex challenges as successful implementation of relevant strategies requires a level of expertise significantly exceeding that required in traditional instructional settings.

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Developing Mathematical Resilience through Problem-Solving and Critical Thinking

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Abstract

Mathematical resilience is an important component that prepares students to cope with mathematics tasks in a positive and continuous manner. Focusing on the issue of mathematical resilience, this paper presents findings on the contribution of problem-solving and critical thinking processes to the construction of the required resilience. Thus, considering the data from prior research and, respectively, practical case studies, this paper aimed to reveal how exactly these cognitive processes can promote an effective mindset for overcoming mathematical challenges. The results revealed that when learners are empowered with adequate problem-solving abilities and cognitive reasoning, they are likely to exhibit success in mathematics. Finally, the implications of the paper are provided to educators regarding how these skills can be included in teaching pedagogies.

Keywords: *Mathematical Resilience; Problem-Solving; Critical Thinking; Mathematics Education*

Introduction

Mathematical resilience is the ability to not give up when faced with mathematical difficulties. It defines a learner's ability to persist while completing mathematics tasks (Johnston-Wilder & Lee, 2024). Globalization and the management of different problems caused by climate change or other issues in the present and in the future world means that the value of mathematical literacy increases. These factors stress the necessity to strengthen and build up the students' resilience in mathematics for both their academic performance and their ability to cope with problems in their futures. Nonetheless, far too many students experience stress and feelings of helplessness whenever they are presented with complex mathematical problems which in turn result in pessimism, which is counterproductive for students' advancement (Siaw et al., 2020).

Engagement in problem-solving and critical thinking has been claimed to be a strategy that may help in developing mathematics resilience (Scholar, 2024). Problem solving entails finding practical ways of applying existing knowledge in mathematics to new situations and this involves the student formulating ideas and demonstrating tenacity. Analysis and evaluation are critical thinking skills which the student must use to enable problems to be solved. The skills required include making judgments about what mathematics to use, which is important in making meaning from mathematical concepts (Facione, 1990). This paper suggests that incorporating problem-solving and critical thinking into mathematics instruction can have a positive impact on students' learning outcomes and improve their resilience whilst increasing mathematical learning.

Literature Review

Mathematical Resilience

Mathematical resilience is a concept, relatively new in educational psychology, which highlights students' ability to persist and sustain positive attitudes in the face of mathematical difficulties (Johnston-Wilder & Lee, 2024). Studies have indicated that learners who have mathematical resilience are well positioned to perform in mathematics examinations and are expected to be in a better position to solve problems in various facets of life (Agustin et al., 2022). Mathematical resilience in students is associated with instructional practices that promote an acceptance of errors, viewing them as tools for learning and students' ability to persist through difficulties (Johnston-Wilder, et al. 2015) seeking support as and when necessary.

Problem-Solving in Mathematics Education

Using the concepts learned in problem-solving is core in mathematics education and can be considered at the same time an outcome of mathematics learning and a process by which mathematics knowledge is developed (Schoenfeld, 1992). Teaching students using problem solving activities directs them towards learning how to solve the problems using a systematic approach and also to consider difficulties as being positive and not as a hindrance. Studies also show that if the student learns to solve these tasks more often, they are more likely to have a positive attitude to mathematics as they take time and learn from errors made (Siaw et al., 2020).

Critical Thinking and Mathematics

Another factor that is part of the development of mathematical resilience is critical thinking. This includes challenging reasoning, arguing, and making a decision, all of which may be considered vital when learning and applying mathematics (Facione, 2011). Research has also revealed that students who have learned to employ critical thinking are in a good position to solve mathematical problems, since their mind is more open and has less cognitive biases that may slow the students in problem solving. Some of the benefits of teaching critical thinking in mathematics have included enhancing the students' problem-solving skills as well as the tenacity to solve these problems in the event the problems are complex (Lipman, 1988).

Methodology

The research question of this paper is:

- Does teaching problem solving help students to develop mathematical resilience?

This qualitative paper reviews literature data and case studies to investigate relationships between problem solving, critical thinking, and mathematical resilience. Accordingly, the discussion uses multiple claims of educational theories and some empirical research, depicting cognitive and affective processes of resilience which seem to be the outcome of problem solving. Furthermore, selected case studies from various educational settings are presented in order to demonstrate how problem-solving and critical thinking have been implemented to address mathematics education for resilience.

Findings and Discussion

Problem-Solving as a Tool for Resilience

Doing more problem-solving activities prepares students for the kind of skills to solve any mathematics problems with hard work and flexibility. For instance, Siaw et al. (2020) noted that it is possible to change girls' attitudes from negative to positive by constantly assigning them, and supporting them in solving, open-ended problems. The traits they developed through solving open-ended problems comprise a significant part of mathematical success. These students differed from the others in their cohort in the sense that they approached challenging tasks mostly as learning opportunities not as threats. This is in accord with Schoenfeld (1992) who asserted that problem solving not only enhances the mathematical content knowledge of students on computations but also develops the students' coping power when problem-solving

Also, the type of approach characterized by cyclic problem solving where the students are almost always bound to make errors and take wrong turns before discovering the true solution, encourages determination by making failure an acceptable part of the activity. Researchers called problem solving a way of handling barriers and addressing problems in an orderly manner, finding ways to make corrections from one try to another. This initiates an iterative learning process, which can lead to a positive mindset orientation in the students if they are well supported by teachers and peers, as they progress through their learning process, plus it can increase their tenacity as they search for solutions.

Critical Thinking's Role in Resilience

Critical thinking works in conjunction with mathematical resilience as it allows students to approach problems with 'question-asking' skills. Facione (2011) noted that critical thinkers will spend considerable time in self-monitoring when thinking with an eye to questioning themselves in all aspects of their thinking. This self-awareness is especially important for building up resilience. It allows a true assessment of one's own assets and gaps in knowledge, and allows learners' to develop effective coping skills when faced with adversities.

Lipman (1988) opined that critical thinking should always form part of mathematics education since it makes students think beyond the conventional order to develop creative ways of solving problems. Thus, cultivating an investigative approach within the classroom will enable learners to be comfortable when facing different challenges and not give up when solutions are not easy to find.

Conclusion

Therefore, it can be concluded that problem solving can be a vehicle to be used in fostering mathematical resilience and can be a significant contribution to student's success in learning mathematics and other essential courses. Spending time on problem solving, educators will be in a position to support students' tenacity with their problem solving activities, until they come up with the appropriate solution to each mathematics problem. Likewise, teaching the idea of critical thinking enables the students to understand the reflective skills that they require in order to solve a problem confidently and innovatively.

Future studies should extend the investigation of these skills and their relationships with mathematical resilience in different learning environments. Furthermore, particular attention should be paid to the enhancement of these skills in terms of teaching skills so that the concept of mathematical resilience can be made more effective for all learners.

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Anxiety and Resilience Among Undergraduate Chemistry Education Students

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This study investigated the depth of anxiety levels in pre-service chemistry teachers, the impact of anxiety on their performance and teaching strategies that could be employed to develop resilience in undergraduate chemistry. A mixed research methodology was employed to collect data, using questionnaires and focus-group interviews. Descriptive statistics were used to analyse quantitative data, while thematic analysis was used to analyse qualitative data. Participants comprised of twenty-two (22) female and twenty-nine (29) male students. Mindset Theory (MT), or Implicit Theory of Intelligence, was employed as a theoretical framework to explain the findings. The results demonstrated that independent samples t-test indicates that t (51) = 2.374, p = (0.011 and 0.022 for both sides respectively). $p<0.05$ in both cases, conclude that genders differ in their levels of chemistry anxiety. Interviews revealed that the teaching of chemistry and student's fears of chemistry generated anxiety in some students.

Keywords: chemistry anxiety; chemistry-fear; pre-service

Introduction

Science concepts are considered by many students and scholars difficult to learn due to their abstraction. Chemistry is perceived to be the most challenging as it involves scientific concepts and mathematical skills (Ibrahim & Iksan, 2018). Furthermore, anxiety or chemo-phobia may be a factor contributing to students' failing and low numbers of students taking chemistry subjects. Scholars have identified science anxiety as an impediment to student learning (Ramli, 2020; Ibrahim & Iksan, 2018; Huey, 2013). Nevertheless, it differs from a general test or performance anxiety (Mallow, 2006). Test anxiety involves physiological and psychological components. "Worry, fear, apprehension, panic, and cognitive impairments" constitute the psychological aspects (Tabolt, 2016 citing Sarason, 1984, p. 931). Tests are generally stressful situations. It has been estimated that two to three students in any given classroom are highly anxious (Talbot, 2016). This ranges from primary to higher institutions of learning. These students are not performing at their highest capacity due to test anxiety. Nevertheless, individual differences can influence the harshness of the anxiety. Different levels of stress can dictate whether to motivate students to prepare for a test or debilitating (Talbot, 2016). Chemo-phobia disables the learning process by creating mental barriers to the absorption of knowledge. According to Eddy (2000), chemo-phobia is the fear of chemicals and chemistry courses. Examinations contribute to chemo-phobia as it is the main tool in assessing students' achievement. In my institution, general chemistry is a prerequisite for science, natural resources, medicine, mathematics, science education and engineering courses. However, there is a high dropout rate among first-year general chemistry students (SMNS Board of Studies, 2016, 2023). The huge dropout rates in general chemistry among first-year students seems to be focused on teaching and learning. Hence, in 2022, six, 2023, and 2024 five chemistry education students graduated respectively. In 2024, three chemistry education students enrolled.

The study interrogated the levels of anxiety exhibited by undergraduate chemistry education students in anticipation of building resilience. This study employed quantitative and qualitative research methods to gain a deep insight into the problem. Three research questions guided the study.

Research Questions

1. How deep are the anxiety levels in preservice teachers doing chemistry education subjects?
2. To what extent do anxieties in chemistry subjects affect preservice teachers' performance?
3. What teaching strategies can be used to develop preservice teachers' resilience in chemistry subjects?

Theoretical Framework

The Implicit Theory of Intelligence, a theory of mindset, serves as one of the theoretical frameworks for this study. According to Mindset Theory (MT), sometimes referred to as the Implicit Theory of Intelligence (Dweck & Legget, 1988), people have one of two attitudes concerning intelligence: a fixed or entity mindset, or a growth or incremental mindset. According to proponents of entity theory, intellect is a fixed quality that is predetermined by nature. Contrarily, proponents of incremental theory believe that intellect is a changeable, expandable trait that can be trained (Dweck, 2006; Dweck, 2012; Dweck & Legget, 1988). Implicit views about intelligence can have a significant impact on motivation to learn, according to mindset theorists who contend that ideas about intelligence affect motivation, attitude, and behaviour (Dweck, 2006).

Methodology

In this study, a mixed methods approach was employed. An action research(AR) methodology was used to develop anxiety-informed practices among mathematics and science education lecturers situated at Copper-belt University. Krause and Eilks (2019) highlight that AR thoroughly connects domain-specific Mathematics and Science education research to curriculum development and teaching practices.

Method and Data Collection Tools.

The study employed quantitative and qualitative research methods using questionnaires and focus-group interviews. Questionnaires were used to measure the students' pre-levels of chemistry anxieties. The questionnaire questions in this study were ten item questions that asked students to read the sentence and then mark the words that describe themselves and how they feel. Five items were positive and five were negative. Items "2, 3, 5, 6 and 9" were positive, whereas items "1, 4, 7, 8 and 10" were negative. They rated their level of anxiety on a degree scale, "strongly disagree", "disagree", "uncertain", "agree", or "strongly agree". The emphasis was on learning chemistry, doing chemistry, problem solving and taking a test (Belz, 2012). The questions used a 5-point Likert scale. Focus-group interviews were conducted to collect narratives about adverse prior experiences and to gauge students' perception of chemistry learning anxiety.

For the sample**.** I engaged those who are enrolled in chemistry education to complete the questionnaire and participate in focus-group interviews. Participants consisted of twenty-two females and twenty-nine male students. They signed consent forms prior to participating in the research. The participating students were in their first to fourth-year of a chemistry teacher education course.

Qualitative analysis was conducted using a thematic process to answer the research questions. Quantitative data were statistically analysed.

Results and Discussion

The anxiety level was categorized into three groups; 7.8 % of the students had results that were described as a low anxiety score, 70.6 % of the students had results that were described as a moderate anxiety score and 21.6 % of the students had results that were described as a moderately high anxiety score. Table 1 shows chemistry education students' anxiety levels. These results indicate that the majority of the students in the survey experienced significant anxiety with respect to learning chemistry.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	4	7.8	7.8	7.8
	Moderate Anxiety	36	70.6	70.6	78.4
	Moderately High Anxiety	11	21.6	21.6	100.0
	Total	51	100.0	100.0	

Table 1: Chemistry Students' Anxiety Levels

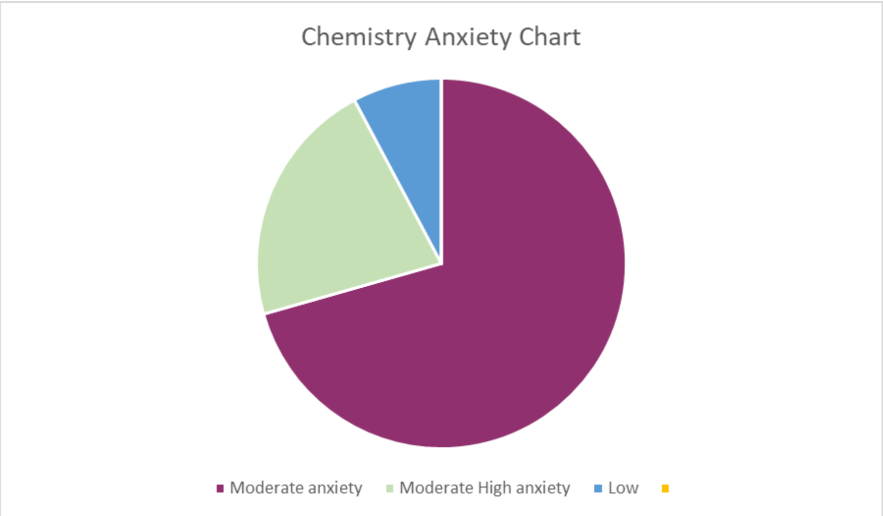

Figure 1: showing Students' Anxiety Levels in Percentage.

		Chemistry Anxiety Cat			Total
		Low	Moderate Anxiety	Moderately High Anxiety	
Gender	Female	0	14	8	22
	Male	4	22	3	29
Total		4	36	11	51

Table 2: showing Chemistry Anxiety Levels by Gender

The independent samples t-test indicates that t (51) = 2.374, p = (0.011 and 0.022 for one sided and two sided respectively). Since $p<0.05$ in both cases we reject the null hypothesis (there is no difference in levels of mathematics anxiety between females and males) and conclude that that there is a statistically significant difference between the means of the two groups (genders).in other words the genders actually differ in their levels of chemistry anxiety.

The t-statistic (2.374 and 2.469), which large indicates a significant difference. The mean difference (2.423) indicates that Group 1 has a higher mean than Group 2. In this study Females have a higher mean (31.18) in chemistry anxiety levels than males with a mean of (28.76). The study used a 95**% Confidence Interval [0.372, 4.474]:** This suggests that the research is 95% confident that the true difference in the means lies between 0.372 and 4.474.

Independent Samples Test											
		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	Df	Significance		Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Chem. Anxiety	Equal variances assumed	1.121	.295	2.374	49	.011	.022	2.423	1.021	.372	4.474
	Equal variances not assumed			2.469	48.998	.009	.017	2.423	.981	.451	4.395

Table 3: Depicting Independent Samples Test

In this study, the independent samples t-test demonstrated a significant difference in levels of chemistry anxiety between Females (M = 31.18, SD = 3.002) and Males (M = 28.76, SD = 4.006), t (51) = 2.374, p = 0.011, suggesting that females' higher anxiety in chemistry may be the reason why they are seen to be outperformed in chemistry. This is inconsistent with the study's null hypothesis that there is no significant difference in chemistry anxiety levels between the two genders. These findings are consistent with previous studies by Westerback and Primavera (1992) who also highlighted the differences between female and male students.

Findings from focus-group interviews.

Emerging themes from transcribed data from the interviews were found to be as follows: laboratory work, exposure, teaching approaches, secondary school experiences, lecturer's negative comments and performance in tests. I defined and named the themes into three overarching themes which are teaching strategies, fear of tests and proposed teaching approaches.

Female students in chemistry education had their best experience during laboratory work. They could put the theory into practice, analyse samples, and operate the equipment that they see in textbooks. On the contrary, two female students suffer anxiety when asked to use instruments and chemicals. Every time Bwalya is in the chemistry laboratory, she thinks she will break the apparatus, as happened in secondary school. She stated, "*I broke a conical flask during an experiment, and I was told to buy. So, I fear breaking the apparatus*". Similarly, Diniwe (pseudonym*) feared handling apparatus, working with chemicals and doing experiments that emanated from her secondary school laboratory lesson in which the teacher told them not to touch anything. Nevertheless, some members of her group fiddled with the fume cupboard during an experiment*. Diniwe explained that they "…*opened the fume cupboard and the laboratory was filled with a gas*". Such laboratory experiences in some students can create chemistry phobia and impede their learning.

Most of the teaching-learning were theoretical as we were told that the educators did more talking than demonstrations. Salifyanji (pseudonym) further stated that "*I tried to ask friends but I could not understand, so I ended to memorise [memorizing]".* The curriculum of chemistry was too large and detailed, and they are exposed to many ideas in a short time. Hence, Muntinta (pseudonym) exclaimed that *"focus on many things, many books, causing confusion, very stressful, and a lot of pressure".* Furthermore, Chela lamented that they studied very hard but could not understand thermochemistry and failed test 1. Despite failing test 1 they worked hard to pass test 2. Some students' failure demotivated them whereas to some it created affordances. They were inspired to work harder (Dweck, 2006). Those that believe that intelligence can be improved and developed via effort prepared for test 2 as Mulambia revealed "*I prepared very well but the time we started writing I started shivering, missed some questions, got those questions wrong, failed to answer questions that I had answered before*".

Conclusion

Findings from the questionnaires and interviews revealed that the teaching-learning of chemistry contributed to the anxiety experienced by the participants. The depth of anxiety levels was shown to differ between genders. Female students experienced high anxiety levels when it came to tests, fear of chemistry course, problem solving and chemicals. Male students experienced moderate anxiety levels. Field-trips and hands-on, mind-on teaching approaches were proposed because they connect chemistry ideas to real life situations.

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How can the learning relationships that work to develop Mathematical Resilience in mathematics classroom be characterised?

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I want to explore here a question that feels paramount to me in work to develop mathematical resilience. How can teaching and learning day-in, day-out which develops mathematical resilience be characterised? Working for mathematical resilience means developing a particular relationship in the classroom, one that cares about the students and one that cares about learning mathematics. I know that mathematical resilience is developed in environments where there is mutual warmth and respect, where learning is a shared endeavour, where learners are encouraged to express their ideas and where everyone listens attentively, especially the teacher. Recent research on the brain suggests that the social is a vital part of how the brain works and that removing the social removes a vital form of support and motivation in learning. A classroom that offers care in learning mathematics (Watson,2021), is a social classroom and one that prioritises the wellbeing of the students.

Keywords: Characteristics of learning and teaching; the social brain; care in teaching mathematics.

Introduction

In this paper I want to set out what is for me a research agenda. I feel that much is known about mathematical resilience, what the principles are for developing it and why work to develop it is necessary, indeed vital. What I feel is less known about is what the basic characteristics of a classroom in which mathematical resilience is developed are. Without a vision of such a classroom, how can teachers work towards practices that increase mathematical resilience?

I have been able to define the mathematically resilient classroom in terms of the characteristics that can be expected of those who are mathematically resilient (Lee and Johnston-Wilder, 2024a) and the principles that a classroom in which mathematical resilience is likely to be developed will adhere to (Lee and Johnston-Wilder 2024b). It has been established (e.g. Kooken et al., 2016, Hunt and Petronzi, 2024) that there are four factors to consider when teaching mathematics with the intention of building resilience: growth, value, struggle and support. We also know that teaching for mathematical resilience is a way of thinking or possibly a set of principles; it is not a 'to-do' list and certainly not a 'don't-do' list. Such teaching is certainly about ensuring the wellbeing of all actors in the classroom. As such, there are elements of social justice at play, no one should be excluded or left behind because they lack the previous experiences that have enabled their peers to progress in learning, appropriate support can and should be provided. It is also about recruitment and retention, it is about asking teachers to do what most teachers say they came into teaching to do, which is to care for their students and allow their understanding to grow. Such an attitude makes a difficult job much more rewarding than the 'teach to the test' attitude that currently seems to be prevalent. Teaching for mathematical resilience is not about test results, although resilient learners see examinations as another barrier to think their way through. It is about enabling students to approach mathematical ideas with positivity and to be able to continue to willingly engage with mathematical ideas, thinking and reasoning beyond school.

Teaching for mathematical resilience is about teaching mathematics without creating anxiety, and care for the learning of mathematics must be at its core. This means that as well as caring for students, mathematics teachers must also care about the mathematics they teach. The two must be intertwined. Such teachers must help learners to understand that learning mathematics can, by its very nature, present barriers while at the same time inducting them into the complexities, intricacies and joys of mathematical thinking and reasoning.

It is not easy or straightforward to implement such teaching in ordinary classrooms, but it is possible. I am aware of teachers working in schools who enable their pupils to enjoy thinking mathematically and overcoming the barriers that learning mathematics presents. They enable their pupils to become resilient learners of mathematics. What I do not know is exactly what should be happening in a classroom day-in and day-out if the learners in that classroom are developing and growing mathematical resilience alongside learning and growing mathematical understanding. It seems to me that what is important is not which tools to use to overcome anxiety but rather how mathematical learning can be presented so that learners grow their understanding in an atmosphere of support and care for each individual's learning and well-being.

Care and compassion and mathematical resilience

I have been considering the place of care and compassion within mathematics education for some time. It became clear to me that relationships within the classroom were of vital importance when I was reading the literature included in my publication with John Morgan (Lee and Morgan, 2024). The teachers that the participants talked about in this study did not have good relationships in their classrooms. Their teachers reacted to the participants' lack of understanding of the mathematics being offered with a lack of comprehension of how anyone could not understand. If the teachers had cared for these participants surely their reaction would have been one of curiosity: what is it that is preventing you from understanding? The participants led us to understand that this lack of care from the teachers for the learners in their classes may have been due to a lack of understanding of how to help. Several participants felt that their teachers had no idea what to do if their first explanation was ineffective. So, the care that they should have been able to show their learners was inhibited because the teachers themselves did not know how to show care for mathematical understanding. It seems to me therefore that teachers who want their pupils to grow mathematical resilience alongside mathematical understanding need to care for their pupils, as well as care for the mathematics they teach. Neither can take precedence.

Care for teaching mathematics

Anne Watson has written persuasively about what it means to care when teaching mathematics, pointing out that "care for the students and care for the subject matter must be intertwined" (Watson, 2021, 83). She goes on to say:

> This view posits mathematics as a shared task in which teacher and student focus together sometimes as equals; sometimes as expert-apprentice. In her image, the shared task is overtly mathematical, the ideas, methods and meanings are in the classroom mathematical culture, the goal is mathematics learning and the actions are those of mutually caring about the mathematics." (Watson, 2021, 84).

She sees the pedagogical relationship as happening between people, learning is not seen as transferred from one person to another, learning occurs in the shared focus the teacher and the student have on the object, in this case, the mathematics. Therefore, learning mathematics requires an intertwining of the skills of caring for the student and caring for mathematics. Only in this way can the teacher offer and encourage this shared focus on the mathematics to be learned and care for the learners' minds.

Caring for learners' minds requires teachers who listen, to try to understand what learners say and how they think, and above all take concerns and successes seriously. Talking about mathematics with a more competent peer offers not only an introduction into the technical language of mathematics and instruction in concepts and processes but also offers ways of visualising and manipulating representations. The shared conversations allow the monitoring of concept images as they are being constructed, allowing appropriate adaptation of further conversations and tasks accordingly. "Language and listening in the midst of mathematical opportunities are the mechanisms by which care for mathematics and care for learning are fused into care for the learning of mathematics." (Watson, 2021, 200).

Enabling learners to develop the language to express their mathematical ideas must therefore be part of the classroom that cares for mathematical learning (Lee, 2006). Listening skills are also needed by both parties if the learning is to be a shared endeavour, but most importantly what is needed are tasks that provide worthwhile mathematical learning opportunities and classrooms set up to exploit those opportunities.

The social brain

Talking about caring relationships in the classroom in this way brings me to another important aspect of the relationship required for teaching for mathematical resilience, that is it acknowledges the social brain (Lieberman, 2015). Studies have found that mathematics is seen as an isolated endeavour (see for example Nardi and Steward, 2003 and Lee and Morgan, 2024) to the extent that they may see working with others as 'cheating'. Baumeister and Leary (1995), among others, have shown that humans have a great need to belong and will react badly to the feelings of exclusion that many learners experience when in a mathematics learning environment. The craving to belong is at its strongest during the teenage years, just when the isolationist pedagogies seem to be most prevalent in schools. In previous publications (Lee, 2006) I have suggested that working in a social way in the classroom allows students to support each other as they engage in learning mathematics. Lieberman makes clear that working together on a task engages a very different part of the brain, one that is a vital part of being human, which he calls the social brain. Instead of gradually finding mathematics more off-putting and feeling more excluded from mathematics lessons, young people could engage their social brains in suitable mathematics learning opportunities, something that cognitive science sees as intrinsically inclusive and motivating. Engaging in collective problem solving or in peer tutoring activates the social brain. In peer tutoring a student could be asked to learn something in order to help out someone else, which Lieberman (2015) explains works with the natural tendencies of the students' brains. Furthermore, most concepts that are learned in school are learned and then forgotten, which is less true when these ideas are learned in order to contribute to a social situation; "when we encode information socially, the social brain manages the encoding and leads to better retention of the information than the traditional memory system" (Lieberman, 2015: 288).

Caring schools

Caring compassionate relationships are being seen as the answer to the recent crisis in the number of children who are excluded from school (Wheale, 2024). It seems to me that this is particularly true in mathematics education. Teachers who continue to teach in ways that generate mathematics anxiety, by, for example, imprudently using competitions, demanding that students 'memorise this' when they are seeking understanding and isolating students 'because otherwise they will not concentrate', are causing damage to students' relationship with school as a whole, not just with mathematics. Teachers who work to develop mathematical resilience, on the other hand support and include all learners and increase their motivation, which can help in other subjects.

Can all teachers create appropriate relationships?

One question I struggle with is ‘can all teachers create the ethos in a mathematics classroom that develops mathematical resilience?’ In a system that has for so long continued to generate mathematics anxiety in its learners, it is likely that most teachers of mathematics have some lingering anxieties about mathematics. Quantitative studies have established that there is a strong relationship between teachers’ negative attitudes towards mathematics and their students’ mathematics achievement (Mensah, Okyere, & Kuranchi, 2013). It has also been found that teachers who have mathematics anxiety may transfer this anxiety onto their students (Bekdemir, 2010). Real or perceived deficiencies in mathematics knowledge or knowledge of how to teach mathematics will affect how a teacher presents the subject (Hadley & Dorward 2011). Any lack of self-efficacy (Bandura 1995) will affect the way the teacher plans lessons, the tasks they are prepared to use and the way that they will be able to enter into a shared focus on learning mathematics. Learning relationship will be compromised and will not work to the benefit of the students.

If teachers themselves have anxiety, they will have negative attitudes towards mathematics, mathematics anxiety is negatively correlated with self-efficacy (Hoffman, 2010) leading to teachers who do not believe they can teach well. Having had negative experiences when learning mathematics themselves, may have led to a lack of content knowledge and a lack of motivation to remedy the situation. Many of those who teach mathematics may find themselves in this situation, probably especially at primary level. In a class led by a mathematically resilient teacher young children may be invited to explore ideas, to play with numbers, to challenge one another to find a hard one or an easy one; they may be asked what is the same and what is different. Resources will be used creatively to stimulate discussion and suggest variations on the ideas being learned together. They will work socially using mathematical language to explain their ideas and will listen to and learn from and with one another. When the same class is led by a mathematically anxious teacher, they will do exactly what the resources tell them to do, the teacher may spend a long while telling the class exactly what to do, questions are unlikely to be invited, listened to, or answered carefully. The teaching relationship will be severely compromised by the teachers' own anxiety (Jain & Dowson, 2009), affecting the students’ attitudes towards mathematics, their likelihood of success and creating a negative cyclical structure.

Mathematics anxiety can be treated and given what is already known about the prevalence of mathematics anxiety among those who teach mathematics, offering treatment opportunities as part of every teacher training course seems a sensible first step to improve the learning of mathematics in any country.

What do I know and what needs to be found out?

I have outlined some important ideas that I am already aware of in my quest to offer mathematical resilience to all learners in educational settings. But I still have many questions. I know that there has to be a sense of equity within the classroom. Each actor has their own role and responsibility. It is the teacher’s role to teach, to set out the ground rules in the classroom and to ensure safety. It is their job to plan and promote learning opportunities that allow mathematics to be explored and learned. It is the learner’s role to learn, to take those opportunities and make the most of them, with the teacher’s and other learners’ support and to support others around them. There must be mutual respect, both teacher and all learners must offer each other unconditional respect for each other's values and points of view and work together to increase mathematical learning for all. My question is how do teachers establish this sense of reciprocal responsibility and equity? What factors allow this to happen?

I know that a classroom in which mathematical resilience is developed must be a dialogical classroom. Everyone must have a voice, and everyone must be listened to. I know that attention must be given to developing students' abilities to take their rightful place within the social world of the classroom by helping them use mathematical discourse for themselves and developing their active listening skills. My question here is how can the social brain be activated in the classroom, how can active listening be established and how can the reluctant be given a voice?

I know that mathematics needs to be taught with care, for understanding not just for exam success. I know that often both the teacher's and the learner's relationship with mathematics must change, anxiety on both sides can interfere with offering the intertwined care for mathematics and for the learner that is needed. Only when anxiety is addressed will all players in the classroom be free to explore mathematics, to reason and think in mathematical ways and, to understand, not memorise, mathematical concepts through a mutual focus on what is to be learned.

I know the offering and receiving of support has an important place in the mathematically resilient learning environment. I know that helping others explore a concept deepens the supporter's understanding and it is depth of understanding that is needed not 'coverage'. It is also a way of using the social brain, the parts of the brain that promote the human natural tendency to work together and which teenagers and younger learners are exploring and learning to use. Are there ways of using the social brain to learn mathematics that have not yet been fully explored?

I also know that it not straightforward to create mathematically rich learning opportunities on daily basis where learners can explore the full gamut of mathematical ideas. Teachers cannot be expected to quickly and easily produce challenging, social mathematical tasks and activities in every lesson. What do teachers need and how can this be provided?

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The Relevance of a Holding Environment in building Mathematical Resilience

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This work is linked to a project developed in three state schools in the city of Rio de Janeiro (Brazil). The project, entitled 'Addressing Mathematics Anxiety in Secondary Schools with a STEAM Approach', aimed to build mathematical resilience through STEAM workshops. This paper focuses on data from one of the research sites, exploring students' perceptions of their mathematics anxiety, and the influence of a supportive environment on developing mathematical resilience. The students were experiencing mathematical difficulties, failing the subject, and reporting mathematics anxiety as a significant concert. The researchers felt it was essential to understand the internal and external factors influencing students' disengagement. In addition to discussing the concepts of Mathematics Anxiety (MA) and Mathematical Resilience (MR), this paper discusses the role of a welcoming or supportive environment as a crucial factor in fostering connections and strengthening MR.

Keywords: Mathematical Resilience; STEAM; Self-perception; Holding environment.

Introduction

For many people, mathematics as a subject in the school curriculum is synonymous with failure and unpleasant memories. In order to deal with students' mathematical difficulties and to think about teaching programmes and methods, it is necessary first and foremost to recognise the existence of Mathematics Anxiety (MA) and to look for ways to overcome it through developing Mathematical Resilience (MR). In this scenario, developing mathematical resilience is through the construction of healthy and effective experiences for its recipients. For effective learning, a safe and supportive environment is a priority, as it is through building relationships and trust with the school that students learn. MA has been discussed by researchers since the 1980s as a recurrent phenomenon that paralyses individuals and prevents them from dealing with mathematics, generating physical and psychological symptoms capable of blocking the processes of learning and dealing with numerical codes and mathematical dynamics (Carmo & Ferraz, 2012).

Resilience is a concept derived from physics and brought to the field of human health by Brandão et al. (2002); it involves responses of resistance or adaptation as a way of coping with external pressures that might otherwise weaken the individual. MR can be defined as the learner's ability to persist in learning mathematics despite previous harmful, negative or frustrating experiences in trying to learn this subject (Kooken, Welsh, McCoach, Johnston-Wilder& Lee, 2013). Among the factors for success in mathematics, the authors identify

Value – it is important that students understand the value of the mathematics they are studying has to them and why they are learning this subject.

Struggle – mathematics always requires effort to learn and persistence and perseverance in overcoming challenges.

Growth – the growth mindset (Dweck, 2006) is necessary because of the prevalence of a fixed mindset in mathematics teaching.

Para and Johnston Wilder (20230 also identified the need for a sense of community – being supported by a learning community and Johnston-Wilder et.al. (2020) recognized the need for self-safeguarding – that learners must take action to keep themselves safe from MA.

The research site - Colégio Pedro II

The aim of the research was to use the Mathematics Anxiety Scale (MathAS) developed by Carmo (2008) to map students with high or extreme mathematics anxiety in a 2nd year secondary school class, aged from 15 to 18 years. After this initial mapping, the students would be invited to take part in workshops using STEAM strategies, so that through encountering and solving problems using a 'hands-on' methodology, it would be possible to build learning strategies and mathematical resilience. The intervention design is shown in Figure 1.

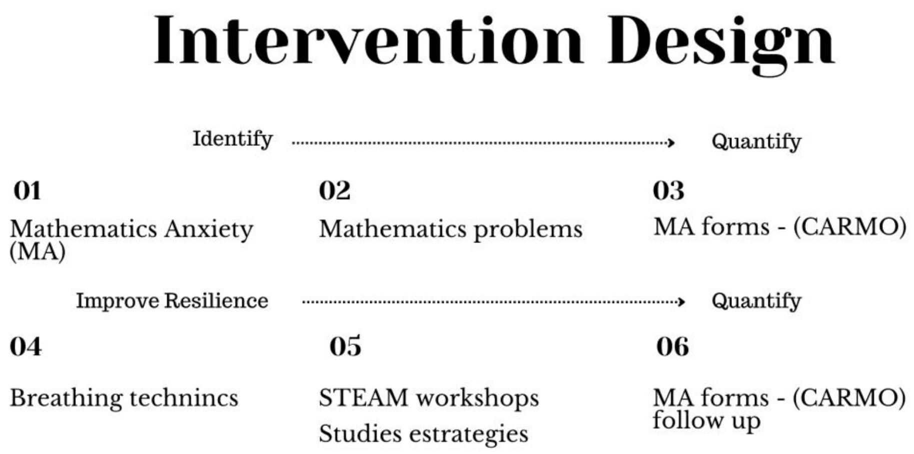

Figure 1: The intervention design

In order to develop and implement this model, we spent two years trying to attract 2nd year secondary school students and consolidate a group with whom to run the workshops. However, unlike at the other two research sites, here all three attempts were unsuccessful. This made it impossible to run the STEAM workshops in the same way as in the other two research sites. In an attempt to understand this context, we have listed the institutional difficulties and mishaps that may have contributed, as well as facts and statements made by the students during this process. The instruments used and the reports collected indicated that mathematics anxiety was a significant phenomenon in this school context; the students were not open to taking part in the planned STEAM workshops which can be seen as a form of psychological self-safeguarding in the context of anxiety about learning mathematics (to protect themselves from further harm).

The research reported here aimed to develop an intervention group at one of three schools involved in the project, named School 3 to address Math Anxiety (MA) through the implementation of STEAM-based workshops. Two major attempts were made: one in 2022 and another in 2023.

In 2022, the researchers began with a 2nd-year morning class, but participation was very limited. Only 6 out of 30 students submitted consent forms and completed the Math Anxiety Scale (MathAS). Among them, only one showed low MA, while the rest exhibited high or extreme MA. Despite follow-up efforts (emails and outreach), none of the selected students attended the scheduled workshops, and they eventually declined to participate altogether, without providing formal justification. Due to scheduling constraints (exam periods), there was not enough time to restart with a new class that year.

Throughout 2022, the focus shifted toward scientific initiation activities, where a group of voluntarily interested students — most of whom also dealing with MA — joined discussions and engaged in reflective sessions. Although these were not part of the formal intervention, they organically created a supportive environment for addressing MA.

In 2023, learning from previous challenges, the team broadened its approach: expanding from 1 to 3 target classes, switching to the afternoon shift (to free up the morning for workshops), and improving communication through campus blogs, Instagram, emails to students and guardians, classroom visits, and posters. Despite these changes, only 4 students attended the initial session, and only one returned the following week. Additional attempts to invite more students and involve math teachers were unsuccessful. They did not seem to be interested.

Because of the poor attendance, the intervention could not be fully implemented or evaluated in this setting. However, scholarship students actively engaged in the project benefited significantly — developing coping strategies and showing improved resilience toward MA, as measured by the MathAS. These students were deeply involved in methodological planning and thus were excluded from formal analysis to avoid bias.

The study concludes that although there was clear evidence of MA among students, there was minimal openness to the proposed intervention. This raises concerns about the persistent stigma and lack of prioritization surrounding mental health issues in educational environments. The lack of engagement limited the impact of the project within this particular school, even though it had meaningful effects on the student researchers themselves.

Research as a welcoming space

The obstacles in this research site seemed insurmountable. How can we build mathematical resilience in contexts that are not open to engagement? This became a structuring question for the research group within the school. During the year 2022, when the STEAM workshops did not take place, the scientific research continued, discussing the context of MA, developing research tools, as well as discussing issues related to everyday school life. The research group, which initially consisted of three female secondary school students working on their science initiation projects, grew; other students volunteered to join the group. From then on, the meetings were divided between research studies and discussions about mathematics anxiety and everyday school life.

Today, analysing this process with the necessary distance, it can be said that the studies of this research group were for its members a space for coping with their own mathematical anxiety, since all the participants, according to the mathematics anxiety instrument proposed by Carmo (2008), were students who had to deal with mathematics anxiety and wanted to develop strategies to overcome it.

In the formative scientific initiation studies, in addition to studying the theoretical aspects of mathematics anxiety, the volunteer students joined the group to study, share their experiences of MA and reflect on coping processes and building resilience. Weekly tutorials and advice on building study habits, relaxation techniques and anxiety management were available and took place on a fluid or scheduled basis according to the students' needs, either to monitor their academic performance or to share an obstacle or uncertainty they were experiencing, it provided a safe space for reception and conversation. In this format, fifteen female students participated in this format, most of them in their second year of secondary school, and most of them black.

The processes we went through allowed us to question various issues such as mental health, teaching and research methods, forms of assessment and tools, and data analysis. Initiating research and creating safe spaces for authorship and conversation among other students was a form of learning and acceptance for all. It was often necessary to create a space for them to share their experiences. As well as tackling the big research problem: how do we build mathematical resilience in a research group? Over time, these students came to trust the research space and formed bonds with their colleagues.

Holding Environment and Mathematical Resilience

For Winnicott (1996), the idea of the environment is fundamental to the development of the individual. To be safe, to have adequate support from a caregiver and to be in a constant process of assimilation and adaptation is what enables the development, autonomy and learning of a so-called healthy individual. In this way, the school and its actors must promote the continuity of these processes in their practices and cultures. Teachers and educational professionals are a fundamental part of the consolidation of learning, the construction of ideas of ethics and citizenship, and are responsible for providing the necessary support so that the failures and obstacles experienced can be re-signified in the form of knowledge and the acquisition of new skills, leading to the maturation of the individual. According to Winnicott (1996, p. 22):

> The life of a healthy person is full of anxieties, conflicting feelings, doubts, frustrations and positive characteristics. The main thing is that the man or woman feels that he or she is living his or her own life, is taking responsibility for action or inaction, and is able to accept praise for success or blame for failure. In other words, the individual has moved from dependence to independence or autonomy.

In order to learn, it is necessary to establish a relationship with the environment. Being in a safe and trustworthy environment promotes a state of alertness and allows for the construction of learning spaces. Vieira (2019, p. 140), when discussing the concept of a holding environment from Winnicott's perspective, states that:

> It should be understood, however, that environment is not the same as space. Environment is something more than just physical aspects such as the colour of the walls, the temperature, the number of windows and the size of the chairs - although these are important and contribute to its construction, they do not define it. For Winnicott, the concept is about relationships, establishing a bond and building a *transitional space* in which creativity can flourish.

The idea of creativity, learning construction and resilience are aligned because a healthy individual, despite obstacles, with the support of a supportive *environment*, would ideally be able to build personal tools for mathematical resilience. In this way, we believe it is necessary to discuss the impact of the school environment, the cultures and practices developed by the institution and the classroom environment on the promotion of mathematical learning. According to Vieira (2024, p. 22), the positive teacher-student relationship, the attachment to the school environment and the security it provides are structural factors for a supportive environment:

> To ensure a positive classroom ambiance, it must first be built for teachers at an institutional level, in their schools. Teachers who are respected for their differences and who use speaking and listening spaces are better able to work collaboratively, develop projects and form working groups. The feeling of belonging to a group improves interpersonal relationships and trust among colleagues, and the good results translate into better teaching and learning environments.

Conclusion

It is important to point out that mathematics anxiety is a reality for many of the students who have gone through our research, but other issues have also affected them to the point that they have not participated. It was therefore important to look at these elements. During the time of the research, other students approached the group with an interest in what academic research is and how it is structured, while others sought emotional support even if they did not want to get involved in other levels of engagement. At times, the training rooms with the researchers became places of listening, where students brought their school demands and lived experiences, especially those that caused suffering, anxiety, prejudice or were perceived as negative: the pain and consequences of the pandemic, the transition to secondary school, the lack of teaching by some teachers and their difficulties in overcoming a school environment that they did not find very welcoming.

During these months, the reports from our secondary school students made it clear that they also needed to develop mathematical skills and resilience, improve their study habits and build paths of authorship and autonomy in the face of the challenge of being a student at Colégio Pedro II. Directly or indirectly, these discussions expanded. Although we all wanted to do the workshops as an initial goal of the project, we also wanted to share everything we had studied and thought about. This project was successful because it was able to promote other spaces of reflection and learning for a group of female students who did not know what science or research could be and who were able to face obstacles to mathematical resilience in a collaborative and respectful way.

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Empowering our mathematics resit students– a case study

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Most students in their GCSE (General Certificate of Secondary Education) resit classes experience examination anxiety, many of them suffer from an extreme level of stress when entering the examination environment, despite having it adapted to their access arrangements. Even students, who perform well in class, frequently experience "brain freeze" preventing them from effectively reflecting their real understanding. In response, our mathematics department actively explores strategies to enhance students' self-efficacy and reduce examination-related anxiety. This case study examines some challenges faced and the range of activities and resources we introduced to increase mathematical resilience and empower students to become more confident and capable problem solvers - both in their examinations and in broader aspects of their lives. It also includes an analysis of the impact of arranging a student-centred, fun revision session in the examination hall on students' feelings and their willingness to tackle a mathematics task.

Keywords: mathematics anxiety, mathematical resilience, examination hall, empowering

The Background of our Learners

The GCSE mathematics examination is a summative assessment which can have serious consequences: progression to the next level of study - or not; opening opportunities - or not; being judged by the society as successful – or not. Mathematics resit students at our college are a diverse group of learners, typically aged 16 to 19, although older adults return to education through vocational or access courses. A significant number come from varied educational and socio-economic backgrounds, and most are working to achieve a grade 4 in GCSE mathematics after one or more previous unsuccessful attempts.

When joining resit classes, students are facing multiple challenges, the foremost being their negative feelings towards the subject. Having experienced 'failure', most students have developed avoidance strategies, fear, stress, and mental blocks (Hunt & Kirkland, 2024). Many of them do not believe they will ever achieve a 'pass'. These students do not want to study mathematics, but the Government's Condition of Funding Policy (Department for Education, 2024) requires attendance at mathematics lessons until 18 years of age, unless at least a grade 4 has previously been achieved, they are exempt for medical reasons, or they hold an equivalent qualification from overseas.

> "Compulsory resits in English and mathematics are contributing to increased anxiety and stress among college students."— Stuart Rimmer, TES (tes.com)

Students sign up to study a subject they feel passionate about and see as their future career but are prevented from progressing until they achieve a mathematics grade 4. Accordingly, they often see mathematics as a threat rather than an opportunity, their mathematics teachers as aliens rather than guides or helpers. Above the *must factor*, many learners face other difficulties: coming from disadvantaged backgrounds, housing issues, being a carer for a parent, or living independently, forcing them to work long hours. A high proportion of our students have special educational needs, making the learning process a real effort.

Starting the New Academic Year

Many resit learners arrive feeling anxious, demotivated, and even ‘traumatised’ by past experiences (Boaler, 2016). A strong induction can help shift this mindset by showing that mathematics is not just a subject to “get through,” but a valuable life skill with real-world relevance. Effective induction includes team-based activities, links to vocational pathways, and a 'Fear in the Hat' exercise, where students anonymously share their mathematics-related anxieties. These common fears—such as fear of making mistakes or forgetting formulas—highlight the emotional barriers many students face. 68% of college learners experience high levels of mathematics anxiety (Betz, cited in Hunt & Kirkland, 2024), making the creation of a safe, supportive environment that prioritises understanding over speed (Johnston-Wilder et al., 2014) vital for student confidence and success.

Four principles to support progress and reduce anxiety

All our learners (except those who are new to the country) come to us with a certificate saying *‘you have failed your mathematics exam’*. Changing their mindsets and helping them believe that they are on a journey to success is vital. They must start seeing their certificate as saying, ‘*you have not yet passed your mathematics exam, but you are capable, you are at the right place where you will get the right support’.* How we do this, is summarised in 4 points below.

The first principle is - make students feel safe.

Maslow’s hierarchy of needs supports the significance of safety in order to perform (Maslow, 1943). Therefore, we work to make the classroom a safe environment where students feel making mistakes is a natural part of the learning process, rather than a reflection of their lack of understanding or ability. A range of studies, including the Commission on Young Lives (2024) highlight the significant impact of the COVID-19 pandemic on young people's mental health. According to UK Children’s Commissioner, (2020) post-lockdown many adolescents described themselves as "socially anxious" and feeling "left behind". The effect of the pandemic is clearly visible in our mathematics classrooms. Some students completely refuse, or find it stressful, to work with peers and are reluctant to participate in any sort of competition. An online game was very popular before the pandemic but is no longer accessible for many learners it ranks participants on the speed and the accuracy of their responses, making them feel their lack of subject knowledge is visible to everyone. One of my highly anxious students told me that ‘it is the worst possible combination when a mathematics question is combined with a competition’. Blooket is the favourite now. It allows students to use their phones, they see the questions as well as the feedback on their responses while playing a strategy game. One version of this app allows them to take coins from their peers or swap with them, ranking participants on the number of collected coins (not the number of correct answers). Interestingly, the quietest, knowingly anxious learners appear keen to play this game and often get to the top.

Research shows that the impact of collaborative learning is “consistently positive” (EEF, 2024). Being a Lead Teacher on the Mastery Mathematics research project (Wake et al., 2023) really opened my eyes to the significance of well-planned lessons, which encourage students to collaborate, explore ideas and learn from each other through interaction, (Boaler, 2016).

> "For most of us mathematics, like music, needs to be expressed in physical actions and human interactions before its symbols can evoke the silent patterns of mathematical **ideas** (like musical notes), simultaneous relationships (like harmonies) and expositions or proofs (like melodies)." (Skemp, 1983, p. 206)

Often, students focus on well-presented work, rather than understanding and making connections. They tear a page out when a mistake is made, destroying the evidence. Using mini white boards in lessons has a significant impact on reducing students' worry about making mistakes, as they have the freedom to clear the board whenever they want. In lessons, they are encouraged to take pictures of their own or their peers' work when they are proud of what they have created.

The second principle is - make students feel understood.

This process starts during induction, when we play the '*fear in the hat'* and it continues with asking learners to complete a questionnaire about their mathematics learning experiences, preferred learning environment and the mathematics topics they like or find scary. There is a question about examination support and there is space for them to tell anything they want to share. Petronzi's (2018) argument that mathematics anxiety originates from the early years of education has been underpinned by many responses. One of my students noted down that a supply teacher in year 2 primary school called her *'dumb'* and she still believes she can never be good at mathematics. Most students are keen to tell us how they feel and how to best support them. These questionnaires provide extensive evidence of students' awareness of the importance being fluent in basic mathematics. However, for most their experiences have made them feel vulnerable and 'helpless' (Hunt & Kirkland, 2024. Pg1). This exercise gives us an opportunity to start building connections, asking learners to contribute to class discussion on specific topics they like and target topics that they identify as 'scary'.

The Growth Zone Model (GZM) (Johnston-Wilder et. al., 2013) is displayed in every classroom, giving students the opportunity to express their feelings before or after the lesson. The GZM is included in students' booklets, with strategies to help develop resilience if they think the challenge is too much for them. Lessons are developed to support learners staying in their *flow channel* (Csikszentmihályi, 1990).

The third principle is - make students feel supported.

Many of our students describe mathematics as a huge amount of information which is not relevant to them. Our goal is to help them to find the relevance of mathematics and see their retake year as a gap-filling exercise. We regularly bring real-life scenarios to the mathematics lessons. Our curriculum plan includes some mastery mathematics research lessons (University of Nottingham n.d.) which require students to collaborate, think hard and *develop an understanding of mathematical structure* while working on everyday-life related problems. Based on the 'Maths *for Professionals'* workbook series developed by the Focussed 15 project, our department collaborates with vocational lecturers to collate the overlapping skills between their main course and GCSE mathematics. We created a range of mathematics booklets to be used in specific vocational lessons. Photos taken during vocational lessons (such as Multi Skills or Carpentry) and students' artwork is used to play a *'Where is mathematics in that?'* game, which emphasises the importance of having good mathematics skills to become well-equipped for their profession.

We start the year with a thorough diagnostic assessment, leading to specific targets being set depending on the needs of the individuals. A mathematics revision booklet was developed with a glossary (to support students with language barriers), a collection of command words and a 'learning journal' where students can record new pieces of information or something they often forget in their own way. Regular assessments and mock examinations take place during the year, followed by setting SMART targets with clear guidance on how to achieve their goals.

The fourth principle is - make students feel valued.

Many of our students suffer from low self-esteem and low confidence, which reduces their willingness to tackle a mathematical problem. Asking them to support their peers often has a positive impact on their own progress. In the preparation for the examination, we use activities to increase resilience, one is 'chain-help' when the first student has a question they need help with explained, if other students become stuck on the same question, the first explains to the next and the chain continues. In some lessons, students create posters about high-mark questions, writing step-by-step guidance and advice on how to avoid making mistakes and losing marks.

We regularly take part in activities where students have an opportunity to participate in games or competitions such as the International Pi-day, FE Mathematics Challenge (MEI), Mathematics in Action or Big Idea Challenge. Pictures and articles of the events are published on the college's website, which makes the students feel a valued part of a learning and using mathematics community.

In the Examination Hall

Test anxiety affects individuals, regardless of their academic level (Zeidner, 1998) as the examination hall is a strange and scary environment. Despite their high attendance in mathematics lessons and consistent completion of weekly homework, many students find the examination hall a unique struggle. We take them to the hall a few times before their final examination in order to reduce their anxiety. In May, about one month before the examinations, a large cohort of resit students took part in a revision opportunity in the examination hall. Multiple classes worked collaboratively in the shared space, familiarising themselves with the environment while promoting group discussion, peer support, and increased engagement.

The intervention was designed through a collaboration between the authors and evaluated using Doing Mathematics *Revision Together Survey 1 and 2*, which explored key dimensions, including students' comfort with the examination setting, confidence in starting mathematics questions independently, willingness to seek help from teachers, and openness to collaborative discussion. Students were also asked to compare their engagement in this revision session with typical lessons. The data gathered aimed to inform future practice and identify strategies that could help reduce anxiety and foster more confident, independent learning.

A comparison of pre- and post-intervention survey responses indicates a modest but meaningful shift in students' perceptions following the large-group revision session. Notably, the number of students reporting feeling "very uncomfortable" in the examination setting dropped from 19 to 7, suggesting that the intervention helped reduce anxiety associated with examinations. Confidence in starting mathematics questions independently also improved slightly, with fewer students reporting low confidence. Comfort with contributing to group discussion also improved, indicating a growing acceptance of collaborative learning. Willingness to attend Mathematics Hub workshops remained stable, with a slight decrease in discomfort. Overall, the intervention appeared to positively influence students' attitudes toward the examination environment and group-based revision.

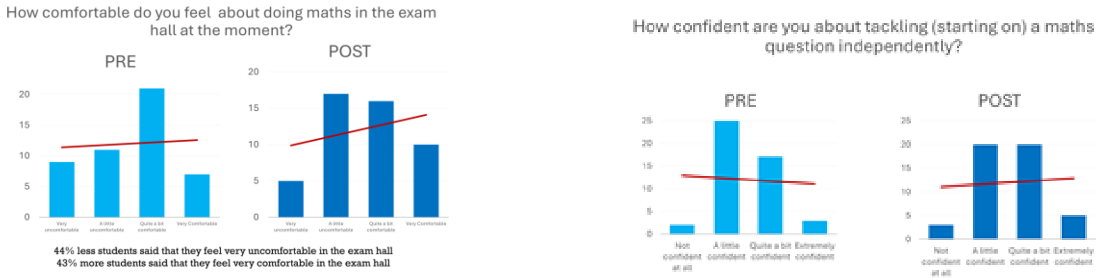

Figure 1: A comparison of pre- and post-intervention survey responses

Implications and Recommendations

These findings suggest that familiarising students with the examination environment in a low-stakes, collaborative way may help reduce anxiety and build confidence ahead of high-stakes assessments. The intervention appeared particularly effective in easing discomfort around the physical setting and promoting group-based engagement. Going forward, we recommend that future revision strategies maintain a blend of familiar classroom-based and shared examination-hall formats, providing structured opportunities for peer collaboration.

Conclusion

When trying to understand, and tackle anxiety amongst students in our GCSE mathematics classes, we are not only aiming to achieve better attainment but helping the students develop resilience and increase self-esteem and self-belief in other aspects of their lives. Our mathematics department consistently experiments with new approaches to make mathematics meaningful, relevant and approachable for our learners. Taking our students to the examination hall for fun activities can significantly reduce their fear from the environment and hopefully lead to better test results and develop more confident problem-solvers for our society.

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Building Mathematical Resilience using emotional self-control strategies and STEAM approach[1]

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In this work we investigate the use of tools for emotional self-control and activities defined in the STEAM approach as a strategy for dealing with Mathematics Anxiety (MA) and building mathematical resilience in secondary school students. We selected second-year technical high school students from a public high school in Rio de Janeiro (FAETEC/RJ) who have high or extreme anxiety according to a scale already validated in scientific papers. We used three tools to tackle MA: workshops on emotional self-control; study habits, and STEAM. The STEAM activity we use at FAETEC-RJ is influenced by superhero therapy or geek therapy, which seeks to develop resilience incorporating creative activities. From the field notes collected, we verified that the students found a meaningful space to talk, a space where they could share their bad experiences (previous and current) in mathematics, and this supports the idea that collaboration adds value to building mathematical resilience. We also observed the benefits of emotional self-control and relaxation techniques to control anxiety.

Keywords: Mathematical Resilience, Mathematics Anxiety, Emotional self-control, Study habits, STEAM, Superhero therapy

Introduction

Today, there is a growing demand for professionals with science, technology, engineering, arts and mathematics (STEAM) skills. Many countries are therefore interested in promoting and improving education through STEAM activities. However, one of the main obstacles to this development is the low level of students’ skills in numeracy and mathematics. In Brazil, 27% of students attained at least Level 2 proficiency in mathematics, significantly less than the OECD countries’ average of 69% (OECD, 2023). In addition, girls are generally less confident than boys in their ability to solve mathematics and science problems and are more likely to express anxiety about mathematics, even among high-performing girls. On average across OECD countries, the difference in mathematics performance scores between high-achieving girls and boys is 19 points (OECD, 2015). One of the reasons that partly explains this scenario is related to a recent phenomenon, observed and confirmed by OECD data on the impact of emotions on students’ performance and well-being (OECD, 2013), is Mathematics Anxiety (MA).

MA is a phenomenon specific to learning mathematics and can be defined as ‘a feeling of tension and anxiety that interferes with the manipulation of numbers and the solving of mathematical problems in everyday life and in academic situations’ (Richardson & Suinn, 1972, p. 551). In addition, Carmo et al. (2019) point to the multidimensional nature of mathematics anxiety, which is characterised by a range of uncomfortable physiological responses (dizziness, hyper- and hypotension, cold extremities, palpitations, stomach aches,

[1] This work is part of the project entitled ‘Addressing Mathematics Anxiety in Secondary Schools with a STEAM Approach’, FAPERJ (SEI-260003/013048/2021).

etc.), uncoordinated cognitive responses (difficulties in remembering content, difficulties in making connections, extracting information from questions) and behavioural responses to mathematics teaching and learning situations (fight, flight and freeze). Students with high levels of mathematics anxiety have lower levels of engagement and enjoyment in learning mathematics (Henschel & Roick, 2017; Wigfield & Meece, 1988), lower perceptions of their own competence in mathematics (Petersen et al., 2017), and underestimate mathematics and its usefulness (Wigfield & Meece, 1988).

Several strategies have been used to develop what has been called Mathematical Resilience (MR). Resilience – from the latin word “Resilire” means “to jump back” or “to recoil”, a concept that has its origin in Physics related to deformation and the ability to resist deformation and that was brought to the human health context as the capacity to resist external pressures, remaining healthy or dealing with oppressive situations in an adaptive and productive way (Brandão et al., 2011). Mathematical resilience can be defined as the ability to persist in learning mathematics, despite previous or current negative and frustrating experiences in trying to learn this subject (Kooken et al., 2013). These strategies involve changes to the classroom environment, as well as the use of new teaching methodologies and approaches such as STEAM.

Teaching mathematics using the STEM and STEAM approach (with an A for art and design) is based on learning through projects or challenges, in an attempt to move away from purely expository lessons that are uninteresting and largely decontextualised. It was introduced in response to an increasingly volatile, uncertain and ambiguous world of values and relationships. The volatility of today's world demands creativity and innovative solutions to meet the challenges of the new times. Therefore, as Freire stresses, education cannot be limited to the development of logical-rational skills but must also include other fundamental dimensions of the human being, be they emotional, social, cultural, historical, physical or existential (Freire, 1981). STEAM activities are essentially ‘hands-on’, where the student is the protagonist, participating in the construction of his or her own knowledge. Bringing art and science closer together in STEAM is an interdisciplinary proposal that is relevant in education for the contemporary world. Lima (2020) points out that “art teaches creativity, uncertainty, resilience, the ability to relate, to tolerate what is different, to collaborate, to solve problems, to think critically, to develop imagination, to expand and diversify means of expression, and to adapt to new and challenging situations” (Lima, 2020, p. 122). It has also been observed that participation in artistic activities is linked to the reduction of prejudices, helps to increase self-esteem and motivation to learn (Trusty & Oliva, 1994).

The STEAM activity that we use at FAETEC high school has influences from superhero therapy or “nerd” therapy (from the English “superhero therapy” or “geek therapy”) that seeks to develop resilience. It is part of a bigger project involving three schools in the state of Rio de Janeiro as one of the positive actions and efforts Brazil is making to include girls in the hard sciences (FAPERJ – 2021 “Girls and Women in the exact and earth sciences, engineering and computing programme”). The idea of the project was the use of emotional self-control and activities defined in the STEAM approach as a strategy for coping with MA in the high schools. We also used the Brazilian Programme for Reduction of Mathematics Anxiety developed by Carmo (2008).

Intervention Results

The intervention was designed in 9 sessions (once a week for 2 hours each). We first applied the MathAS scale which is a Lickert scale created by Carmo (2008) and validated in Mendes (2012) in which the student had to answer 25 items whether they felt no, low, moderate, high or extreme anxiety to questions such as: “When I see the word 'maths' written, I feel...”; “A few days before maths class I feel...”; “When the maths teacher asks me questions about maths, I feel...”, etc. Nine students from a secondary school class took part in the study, seven females and two males, aged from 16 to 18 years. These students were given MathAS scale and we found that of the 9 students who took part in the scale, 5 had high mathematics anxiety, 3 had moderate anxiety and 1 had low anxiety. Among the students with high MA, all 5 agreed to take part in the project. After applying MathAS, the participants were invited to take part in a brainstorming technique, which consists of saying everything that immediately comes to mind when they read the word ‘maths’. Words such as ‘fear’, ‘anxiety’, ‘panic’, ‘sadness’ and ‘anger’ came to their minds.

We also used painting and drawing in this activity as shown in Figure 1. The second session was devoted to teaching them emotional self-control with relaxation and breathing techniques (Jacobson’s progressive relaxation and autogenous relaxation). We used these techniques in every meeting for 5-10 minutes before the activities.

Figure 1: Students’ representation of feelings towards mathematics

A session of study habits (how to study and tips on how to promote a better environment to study) was held and we collected individualized feedback at the end of each session. We developed characters from recycled materials with the attributes of hero, villain and anti-hero in three sessions. Two of these characters are depicted in Figure 2.

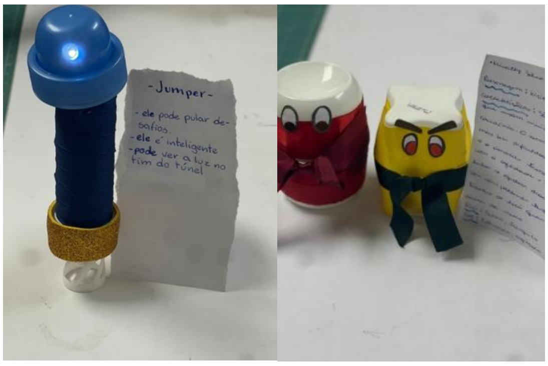
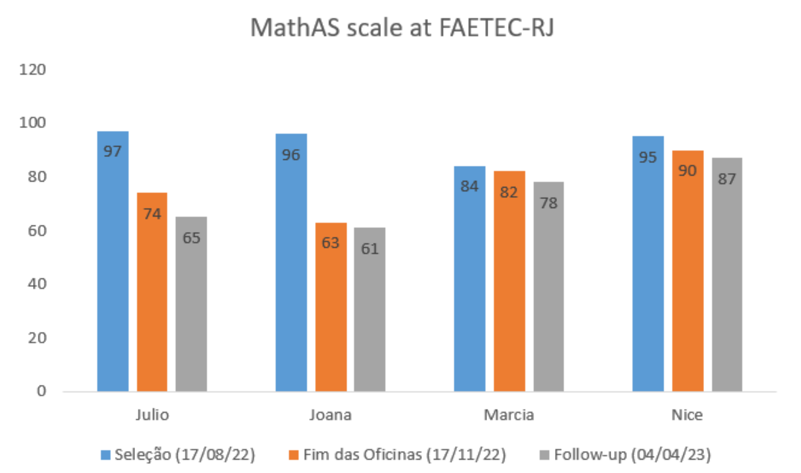


Figure 2: Students’ characters and their powers/attributes.

A session was devoted to solving everyday situations with the help of the characters. And another session was used to present a situation with mathematical content. In this last session, we applied again the MathAS scale and 3 months later we had a final follow-up session. The results of the three applications of the MathAS scale can be seen in Figure 3.



Likert Scale	Score	Anxiety Levels
1 = No Anxiety	25	No Anxiety
2 = Low Anxiety	26-50	Low Anxiety
3 = Moderate Anxiety	51-75	Moderate Anxiety
4 = High Anxiety	76-100	High Anxiety
5 = Extreme Anxiety	101-125	Extreme Anxiety

Figure 3: Results from MathAS scale in the whole intervention.

The sessions at FAETEC included geek therapy as STEAM approach. Ongoing research into geek therapy has demonstrated its ability to build rapport, create understanding and insight, and provide therapeutic interventions very similar to traditional therapy models (Yen et al., 2016). The idea is that in the first phase, the hero who is an ordinary person, answers a call to adventure and moves into a magical world beyond the normal world. In the second phase, the hero, with the help of new powers and other helpers, faces challenges, resists and overcomes them, and is rewarded with new powers or the discovery of inner strength; and in the third phase, the hero returns to the normal world and can use his new abilities to contribute to the environment and the community.

Figure 4 – Field notes from students collected during the last session.

Julio – "I try to think about the moment, that everything passes. You have to think that that moment isn't forever... One thing that helped me and that I'll carry forward is … I can choose a career that involves maths, which isn't impossible. At the moment I'm not managing to put it into practice, but I try to put the tips on study habits into practice."
Nice: "I think we've found a space to talk about it, maybe we still have anxiety, but we've found a place to vent about it, it's less stuck, now we know it exists (maths anxiety) and that we're not isolated."

We carried out another measurement three months after the last session (follow-up). The aim of this last stage was to check whether the interventions and the knowledge of the tools learned during the sessions had actually helped the students to cope with their mathematics anxiety. During the follow-up, we asked the students if there had been any difference in coping with MA, what it was, and how they felt before and at that time. Field notes were collected, and an example is shown in Figure 4.

Conclusion

We observed that all the students who took part in the intervention at FAETEC showed a reduction in their MA (Figure 3). In addition, we noticed from the field notes collected (Figure 4) that the students found a meaningful space to talk, a space where they could share their bad experiences (previous and current) in mathematics, and this corroborates the idea that collaborating in a community adds value to building resilience (Brito & Koller, 1999). We also perceived the benefits of emotional self-control and relaxation techniques for controlling anxiety. It was observed that students became more aware of what was meant by 'study' as they were introduced to the Study Habits session. Since behaviour is a product of interactions between the individual and the environment, we presented typical actions in studying behaviour (e.g. focusing, having time, having a methodology, reading, organising, among others). In addition, we highlighted the importance of the context in which the actions took place (organisation of space, adequate lighting, isolation from distractors, for example).
The STEAM activities helped to promote interdisciplinary learning and develop important skills such as creativity and innovation; collaboration and teamwork; flexibility and adaptability in the choice of materials for building the characters; in addition, the hands-on activities led to greater interest and focus on the part of the students.

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Reflective writing for mathematical resilience: Transforming mathematics teaching through insights into student difficulties

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Mathematics teachers significantly influence their students' mathematical abilities, attitudes, and success. Pre-service mathematics teachers need to understand the classroom challenges, which depend on their preparedness and awareness of students' learning approaches. Reflective writing provides teachers with an opportunity to enhance their self-efficacy in mathematics, which ultimately benefits student learning and fosters students' mathematical resilience. Rolfe, Freshwater, and Jasper's (2001) Framework for Reflexive Practice asking 'what?' 'so what?' and 'now what?' helps teachers to address and improve upon teaching challenges. Pre-service mathematics teachers were invited to complete an online survey about their use of this model, and to reflect on challenging lessons as well as the effectiveness of their teaching strategies. This paper presents some preliminary findings and considerations for future direction.

Keywords: Pre-service teachers; Secondary school mathematics; Reflective writing; Mathematical self-efficacy.

Introduction

The beliefs and practices of mathematics teachers have a significant impact on the teaching of mathematics and play a central role in shaping their students' mathematical abilities, attitudes to mathematics, and overall success in mathematics. For pre-service teachers, understanding the challenges of the secondary school mathematics classroom is underpinned by their level of preparedness, and awareness of their students' approaches and attitudes to learning mathematics. In this regard, the practice of reflective writing, and reflection more generally, lends itself to the development of teachers' and ultimately their students' mathematical self-efficacy, thereby contributing to the promotion of mathematical resilience in the secondary school context.

Rolfe, Freshwater and Jasper's (2001) Framework for Reflexive Practice poses three questions to frame the practice of reflective writing: what? so what? now what? This framework is particularly useful when a student teacher recognises a problem to reflect on (what?), documents their observations about that problem (so what?), and confirms what they would do differently next time in a similar situation (now what?). It is important that this process is followed by an evaluation of the effectiveness of the 'so what?' Pre-service mathematics teachers were invited to complete an online questionnaire after completing a school placement. Guided by Rolfe et al.'s Framework for Reflexive Practice, respondents were asked to recall a mathematics lesson they perceived as challenging for their students, share their reflection on it and how effective the proposed change in practice was subsequently. The findings provide an insight into the benefits and challenges of reflective practice to pre-service teachers' understanding of their approach to facilitating secondary school students' ability to learn mathematics.

Reflection for mathematics teaching

Reflection fosters a continuous process of learning about oneself and how one engages with all aspects of one's life (Bolton, 2010). The role of reflection in teaching and teacher professional development is crucial as it enables educators to engage in a deliberate and intentional examination of their beliefs, knowledge, and practices (Dewey, 1933). Through reflection, teachers can contribute to a deeper understanding of their pedagogical approaches while encouraging continuous learning and adaptation (Conway, 2001; Ketonen & Nieminen, 2023).

Crucially, reflection is an important process in – and objective of – teacher education, as a core competence for the teaching profession (Ketonin & Nieminen, 2023). It helps to disrupt and reconstruct pre-existing beliefs and assumptions about education, and to examine the teaching experience, both of which are essential for teacher development. Reflection facilitates the understanding of new educational theories and concepts as well as their application in teaching practice (Ketonin & Nieminen, 2023). In this respect, it enables educators to make informed and deliberate changes to enhance their effectiveness and professional growth. Regular engagement in reflective practice enables teachers to develop a more thoughtful and responsive approach to their work, ultimately leading to better educational outcomes for their students (Conway, 2001; Ketonen & Nieminen, 2023).

The teaching and learning of mathematics is a key focus for researchers, educators, policy makers, and the general public (DES, 2014; OECD, 2020). Effective teaching of mathematics is crucial for student success; for pre-service teachers of mathematics their first encounter with students is usually the school placement experience, which comprises a core component of their teacher education. Teachers' attitudes, expectations, teaching styles, and subject knowledge play a significant role in students' learning and enjoyment of mathematics (Prendergast & O'Donoghue, 2014). This is particularly significant for mathematics, as the subject can evoke strong, adverse emotional responses. These responses can lead to mathematics anxiety (Richardson & Suinn, 1972), which, if not addressed, carry over from school into further and higher education as well as into work contexts and everyday life situations (Ryan, Fitzmaurice, and Johnson, 2023).

Effective teaching of mathematics in a supportive and psychologically safe learning environment can foster mathematical resilience (Johnston-Wilder & Lee, 2010) and make all the difference for the struggling student. Teachers' awareness and understanding of the sources and impact of mathematics anxiety on individuals coupled with appropriate tools to facilitate mathematical resilience in students can help teachers adapt and improve their practice to counteract the adverse impact of mathematics anxiety (Johnston-Wilder & Lee, 2010). In this regard, reflection on past experiences as a mathematics learner, and reflective practices as a pre-service or in-service teacher can benefit the teacher, and ultimately the teaching and learning of mathematics (Stoehr, 2015).

Approaches to reflection

By approaching reflection systematically, as an ongoing and multifaceted process, teachers can continuously improve their practice. Different theoretical and practical approaches help to facilitate reflection at different stages of the teacher-education journey; for example, theory-bound reflection may be more appropriate for early stages, while models that focus more on linking theory and practice may be more appropriate to later stages (Chan & Lee, 2021; Korthagen, 2017). Traditional reflection theory, such as Schon's (1987) 'reflection-in-action, reflection-on-action' model, relates more to action, mirroring an emphasis on practice during and after teaching. Further, Mezirow's (1991) conceptualisation of the theory sees reflection as reconstructing prior knowledge, emphasising awareness of experiences and changing perspectives.

The right choice of framework provides a structured approach to reflection, enabling teachers to systematically analyse their experiences, make informed decisions about their practice, and ultimately improve their effectiveness in the classroom. Rolfe, Freshwater and Jasper's (2001) Framework for Reflexive Practice represents a simplified approach for the pre-service teacher to conduct reflection to facilitate learning from the experience, or reflexive practice (Jasper, 2003). It presents three simple questions, each accompanied by cue questions to enhance reflection, namely:

What?	descriptive level of reflection; identify experience and describe in detail
So what?	theory and knowledge build on level of reflection; analyse and interpret situation
Now what?	action-oriented level of reflection; explore alternatives and plan action

(Rolfe et al., 2001)

The intention is that action takes place as an outcome of the reflective process; in this respect 'the experience is changed, producing a new situation' (Jasper, 2003: p.102).

Research Aim

The aim of this research is to investigate pre-service teachers' experiences of reflective practice during their semester-long school placement with a view to understanding the perceived benefits of reflective practice in informing teaching methods for number-specific subjects, i.e. mathematics. The intention is to use the data collected to contribute to an understanding of individuals' experiences, and to inform the delivery of subject-specific methodology modules in teacher education programmes, primarily for mathematics. Guided by Rolfe et al's (2001) Framework for Reflexive Practice the respondents will document their experiences of teaching a mathematics lesson that they perceived as challenging, sharing their reflections on it and how effective the proposed outcome was.

Research Design

Ethical approval for this research was granted by the relevant research ethics committee. Final-year pre-service secondary school mathematics teachers in an Irish teacher education college (n = 30) were invited to complete an online questionnaire after completion of a one-semester school placement. The questionnaire was anonymous, and apart from asking for gender identification, no personal data from students were requested. The questionnaire design was structured using an adapted version of Rolfe, Freshwater, and Jasper's (2001) Framework for Reflexive Practice (Table 1) for use with pre-service teachers compiling a reflective diary of school placement experiences (Adenusi, 2021). The intention is to analyse the qualitative data obtained using thematic analysis – managed by using NVIVO – to allow for comparison between the participants' accounts, as well as allowing insights into the participants' experiences.

Table 1: Adapted version of Rolfe, Freshwater and Jasper's (2001) Framework for Reflexive Practice (Adenusi, 2021)

What?	What happened? Describe the experience/problem, state the facts, no judgement Describe your understanding of the content of the class

So what?	What did you learn from the class/lesson/experience? Why was that important for you? Why was this important overall?
Now what?	How will you apply what you have learned? What will you do as a result? or next? Make a plan for the next time you are in this situation.

Findings and Analysis

A total of three students responded. This was disappointing, but – on reflection – the call for responses was put out at a time when students have returned from placement and have a number of programme-specific assignments to submit. However, the author decided to work with the responses received in order to gain an insight into the experiences of those who responded. Of the three respondents, two submitted incomplete questionnaires, with respondents not answering all parts of the framework. Consequently, the findings presented in the following paragraphs represent those of one student who identified as female – Joanna (pseudonym); below are the responses to each question (quotation) followed by analysis.

Question 1: What? (What happened?)

> The most difficult challenge I believe I faced is thinking that I am not cut out to be a teacher.
>
> I felt this way because I thought I do not know all the maths content, how am I therefore going to know if my students understand me.

Joanna identifies a challenging situation and describes her feelings around this. Rather than being a specific incident, she describes a challenging feeling that permeates her experience of teaching mathematics. She questions her knowledge of mathematics and wonders about the impact of that on her students. There is a sense of worry and concern in her response.

Question 2: So what?

> There were so many questions and what ifs.
>
> For me to relax and realise that this is what I am meant to do, I decided to read a lot of material on [the syllabi] to refresh my memory, and I completed numerous mathematics questions which further reiterated to me that I can do this.

Building on her response to question 1, Joanna describes her approach to dealing with the challenge identified, showing her learning from the experience, and what was important to her. Her approach is proactive, and she is aiming to equip herself in different ways – including emotionally, cognitively, and practically – with what she needs to be able to learn from and move on from the challenges identified in her response to question 1.

Question 3: Now what?

> I have learned that the possibility of me knowing all the material related to mathematics is virtually impossible.
>
> I must constantly remind myself that I am only human. I do not know the answers to everything and there is nothing wrong with that.
>
> I will however always promise my students that when I do not know the answer I will admit it and apologise, but I will ensure that I make it my business to have the answer to that question before the next lesson.

Joanna begins her response by acknowledging what she has learned from the experience and being aware of realistic limitations in her learning. Joanna presents an alternative for her approach to practice – asserting that she may not know all the answers and her response to students in such a scenario. Subsequently, she indicates a plan of action to address such a scenario – to admit not knowing and to apologise – and ensuring she solves the mathematics problem for the next lesson, indicating a proactive strategy for her scheme of work.

Discussion and Conclusion

The benefits of reflective practice – including reflective writing – for pre- and in-service teachers are manifold, contributing significantly to teacher self-efficacy, enhanced preparation for and execution of classes, and facilitating professional development and growth. To be of benefit and to contribute to changes in teaching and education, reflective practice needs to be habitual and critical (Larrivee, 2008); it needs to go beyond superficial analysis to include deep self-analysis of teachers' values, beliefs, and assumptions, addressing emotional and motivational aspects of their professional and personal identities (Aghakhani, Lewitzky & Majeed, 2023).

As a core element of teacher education programmes in Ireland, the school placement experience allows pre-service teachers to gain an understanding of the effectiveness of what they have learned in an authentic learning environment. Further, teacher professional development is essential for contemporaneous, effective teaching at all stages of the teaching career, from pre-service to in-service. Consequently, reflective practice and self-evaluation of performance are crucial for improving the quality of education; for creating meaningful and supportive learning environments (Aghakhani et al., 2023); and for helping to inform and enhance Initial Teacher Education.

Reflective teachers are better equipped to analyse and improve their relationships with students. Through reflection on her mathematics class experiences, Joanna acknowledges her challenges in teaching mathematics, which are marked by self-doubt and concern. She adopts a proactive approach, equipping herself emotionally, cognitively, and practically. By admitting gaps in her knowledge and committing to solving the issues by the next lesson, she focuses on personal growth and enhancing her teaching effectiveness.

Every teacher needs to understand and experience the benefits of reflective practice for their self-efficacy and professionalism. This is particularly relevant for mathematics teachers, who have to tackle challenging emotion-laden situations in respect of their students doing mathematics. However, to learn how to manage such situations effectively takes time and practice, and it is a process that requires more than content knowledge and teaching. Through reflecting, the teacher of mathematics can strive to capture and learn from experiences, thereby gaining insight and wisdom needed to navigate similar situations more effectively in the future.

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The 4R Regulation Rectangle: A novel model for using 'time-out cards' effectively in schools and developing students' psychological flexibility.

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Many schools in the United Kingdom incorporate 'time-out cards' as part of their behaviour management. This intervention enables designated students to temporarily leave the classroom when experiencing intense emotions, such as anxiety or anger. These cards provide a structured opportunity for collaboration among students, parents, and educators to foster self-regulation and enhance the student's well-being. However, without careful implementation, there is a risk of misuse. This paper will introduce the '4R Regulation Rectangle,' a novel, pragmatic model for self-regulation that highlights the essential components of effective time-out card usage. Drawing on principles from Acceptance and Commitment Training (ACT), the model is a tool that can not only facilitate the proper implementation of behavioural interventions but also promote the development of students' psychological flexibility more broadly. While further empirical research is required to assess the model's effectiveness in this broader context, preliminary findings from similar applications of ACT suggest promising potential.

Keywords: Time-out Cards; Self-Regulation; Acceptance and Commitment Training; Growth Zone Model.

Self-Regulation

Self-regulation is the ability to manage emotions, thoughts, and behaviours - is widely recognised as a critical skill underpinning students' academic success, emotional well-being, and positive behaviour in school (Rodríguez et al., 2022). Research indicates that children who can manage their attention, impulses, and emotions tend to achieve higher academically and exhibit better classroom conduct (Blair & Raver, 2012). The capacity to control one's emotional reactions helps students cope with stress and interact more positively with peers and teachers, contributing to healthier social-emotional adjustment (Eisenberg, Spinrad, & Eggum, 2010). Strong self-regulation skills support learners in meeting academic and behavioural expectations, whereas deficits are associated with difficulties in learning and increased behavioural problems (Cipriano et al., 2023). Educators can build self-regulatory competencies through social and emotional learning programmes, which improve students' behaviour and boost academic outcomes (Durlak et al., 2011).

Time-out cards

One tool that promotes self-regulation is the *time-out card*: a pre-arranged signal or pass allowing students to take a brief, self-initiated break when they feel emotionally overwhelmed. It offers a constructive, student-led alternative to the traditional punitive *time-out*, shifting control from teacher sanction to a personal coping strategy. Indeed, time-outs delivered in anger without support or explanation can damage trust and erode the positive classroom climate necessary for learning (Terada, 2020).

By enabling voluntary de-escalation, time-out cards foster autonomy and emotional responsibility—core elements of self-regulation (Eisenberg et al., 2010). Their effectiveness, however, depends on skilful, discriminant use within a clear policy framework. Schools often limit access to students with specific needs, such as emotional dysregulation linked to anxiety or anger, often intensified with conditions like autism or ADHD, and may set guidelines for the duration, location, and recording of each use. Clear communication with students, teachers, and parents further supports successful implementation.

Regular monitoring ensures that time out cards remain a supportive tool rather than a crutch, some schools require fortnightly renewal. Alternatively, some school embed time-outs in classroom routines accessible to all, reducing stigma—for example, through a 'calm corner' or 'peace area' (Cihak & Gama, 2008). Empowering students in this way can reinforce self-regulatory skills crucial to both academic and personal success (Blair & Raver, 2012). The 4R Regulation Rectangle introduced herein provides a pragmatic framework to support interventions such as time-out cards. Before outlining the framework, I present two hypothetical case studies illustrating the emotional regulation challenges students face.

Case study 1: Abu - Abu's experience highlights the limitations of using time-out cards without a broader framework for emotional regulation. During a typical mathematics lesson, Abu's frustration gradually increases, leading to arguments with classmates and the teacher. The teacher attempts to manage the situation by applying the school's behaviour policy, but Abu gets more irritated. In order to continue the lesson without disruption, the teacher eventually asks Abu to leave the room. He refuses and a member of the school's senior leadership team is called in to coax Abu into the 'behaviour hub' where he spends the remainder of the day in isolation. Abu returns to the mathematics classroom the following morning. His frustration remains unresolved, and the cycle continues. Although Abu has been issued a time-out card, it is underused because he has not developed the skills to recognise his emotional state or reduce it to a more helpful level. By the time the situation reaches its peak, it is too late for the time-out card to be used proactively. Moreover, there is no structured process for helping Abu reintegrate into the classroom or help him regulate his emotions.

The Growth Zone Model (GZM) (Johnston-Wilder et al., 2020), suggests Abu has a small comfort zone and growth zone and a relatively large panic zone (Figure 1a). In the panic zone, Abu experiences overwhelming emotions that impair his ability to engage to think clearly. As Abu moves readily into the panic zone, he spends most of his time in 'fight mode', aggressively defending himself from perceived threats. By helping students recognise early signs of emotional distress when they are in the growth zone, tools such as time-out cards can be used proactively, allowing for better emotional regulation and smoother reintegration into the classroom.

Case study 2: Brooke - When Brooke's mathematics teacher says that they will be practising algebra in the lesson, she immediately panics. She uses her time-out card to leave the classroom and spends the remainder of the lesson in a social area outside. Brooke has no intention of returning to class. She uses the card as a means of avoidance, rather than as a tool for emotional regulation.

Again, the GZM suggests Brooke's reaction is brought on by a very narrow growth zone (Figure 1b). Initially, Brooke is in her comfort zone, where tasks are manageable and she gets most questions correct, however, faced with engaging with algebra, she responds with escalating anxiety, and shifts into the panic zone. The time-out card is used to escape the discomfort – for 'flight' and Brooke misses the opportunity to work within her growth zone to learn and develop resilience.

Figure 1: Growth Zone Models for (a) Abu and (b) Brooke

The 4R Regulation Rectangle

Both cases illustrate the importance of using time-out cards effectively as part of developing a student's self-regulation. I propose the *4R Regulation Rectangle* as a framework for guiding this effort. The model integrates existing psychoeducational principles and tools to offer students more successful ways to manage uncomfortable emotions, thoughts, and sensations. These are divided into four broad processes and repertoires of skills: *recognise, remove, reduce*, and *return*, and can be visualised as a rectangle (Figure 2).

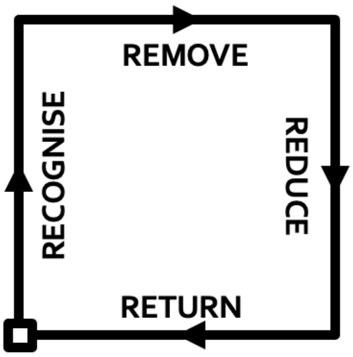

Figure 2**:** The 4R Regulation Rectangle.

Recognise **-** The first step in regulating behaviour is to *recognise* and be aware of experiences such as physical sensations (e.g., heart racing), thoughts (e.g., "I can't handle this"), or feelings (e.g., anxiety). For example, Abu's failure to recognise his growing frustration prevents him from using the time-out card before the situation escalated. Early recognition of emotions allows students to adapt their behaviour to situations in diverse ways. These attentional skills can be developed techniques such as the *5-Point Scale* (Buron and Curtis, 2003), the *Emotional Thermometer*, the *Growth Zone Model* (Johnston-Wilder et al., 2020), and brief mindfulness exercises (Norris et al., 2018). Teachers can further embed these self-awareness skills with psychoeducation, explicitly discussing emotions with students and helping them notice their on-going experiences.

Removal - refers to distancing oneself from a triggering situation to allow for emotional regulation. While this can involve significant actions, such as leaving the classroom, it can also be more subtle, like moving to a quieter area, working through the graduated slow down-pause-stop approach, or doing an exercise to observe rather than engage with unhelpful thoughts (Hayes et al., 2006). This step is intended to interrupt emotional escalation, preventing further confrontation and disciplinary action. However, when used to avoid the situation, removal can become an equally unhelpful automated response that undermines resilience. Use appropriately, students use the 'distance' gained not to avoid but to engage with self-regulation.

Reduce - Once removed from a triggering situation, students need to *reduce* their emotional arousal. For some, breathing exercises or a short walk may suffice, while others might require more structured interventions, such as talking to a trusted person, expressive writing, reappraising the situation, or using the *BOLD* technique demonstrated in the next case study (Ciarrochi, Hayes & Bailey, 2012). Despite its name, the deeper goal of this stage is not to 'reduce' or get rid of the unwanted emotions but to *accept* them (Hayes et al., 2006). These techniques can become futile 'control strategies' that pathologise and evaluate emotions rather than allowing the student to simply experience them. Reduction is about developing the willingness to have uncomfortable or unwanted thoughts and feelings whilst continuing to act meaningfully. Practising these techniques in low-stress environments can help build coping skills over time, and offering a variety of strategies can allow students to experiment and find what works best for them.

Return - The final phase of the 4R Regulation Rectangle is for students to *return* to learning. This means re-engaging cognitively and emotionally with the situation or task. Given the previous triggering experience of the environment, students may be cautious of returning. However, if the work of the previous steps is completed appropriately, the context and function of the situation will be different on return. The return phase can be facilitated through restorative conversations, where students reflect on their emotional experiences, repair relationships, and plan for how they might respond in future interactions. This process requires collaboration with teachers and peers and aims to restore a sense of agency and readiness to tackle challenges. Doing so reinforces the idea that using the time-out card appropriately is a strength, not a weakness. This phase can also help teachers identify potential precursors to emotional escalation, allowing for systemic adjustments in their practice.

Psychological Flexibility

If the 4R Regulation Rectangle is a framework for organising and applying self-regulatory techniques and tools, *psychological flexibility* is the underpinning concept for ensuring that this is done effectively. Psychological flexibility is the ability to act in a meaningful way, even in presence of emotional discomfort. Specifically, this entails developing a repertoire of behaviours that allow individuals to be (i) *open* to experiencing unpleasant thoughts, feelings, and sensations, (ii) *aware* of these experiences in the present moment, and (iii) *engage* with activities that are important to them (Figure 3). These three pillars have been shown to underpin a broad range of outcomes, including reduced anxiety, depression, and stress, alongside improved emotional regulation, resilience, and well-being (Hayes et al., 2006). Numerous therapeutic and educational interventions have been shown to, unintentionally, support the promotion of psychological flexibility, however *Acceptance and Commitment Training* (ACT) is the only programme developed to specifically to target it and has demonstrated a great level of effectiveness in doing so (Hayes et al., 2006). *Acceptance, defusion*, and *self-awareness,* are fundamental components of ACT and form the basis of its array of techniques.

By integrating the principles of ACT into the 4R Regulation Rectangle, time-out cards can be reframed as a value-based tool. *Recognise* fosters awareness of internal experiences, enabling responses aligned with personal values rather than automatic reactions. *Remove* allows individuals to step back from challenging situations, creating space for value-consistent action. *Reduce* supports the regulation of emotional intensity, maintaining psychological flexibility and the capacity to act in line with values. *Return* represents a recommitment to engage with tasks or relationships in a way that reflects core values, even after dysregulation. Together, the 4Rs embed self-regulation within a broader, values-oriented framework that prioritises meaningful, deliberate action in the presence of unwelcome experiences.

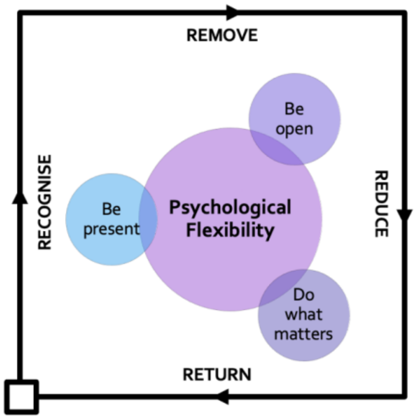

Figure 3: The 4R Regulation Rectangle with underpinning psychological flexibility model.

Case study 3: Conor has emerging self-regulation skills and uses his time-out card to foster psychological flexibility. During a mathematics lesson, he gives a wrong answer, and his teacher tries to explain what to do. Conor feels anxious and a bit humiliated as his peers watch the unsuccessful exchange. *Recognising* his growing frustration, Conor chooses to use his time-out card once the class begin practising, *removing* himself from the room and into the corridor. There he paces around before practising the BOLD technique that knows helps him *reduce* his sense of panic. He first *breathes* deeply, then *observes* his racing heart and tense body and how the breathing relaxes him. He *listens* to what matters to him – trying his best to learn mathematics and working with others and *decides* to *return* to the classroom and ask his friend for help. Conor also talks to his teacher after the lesson to explain he does want to contribute to the lesson but feels that he often needs more time to think about questions before answering. This open conversation fosters mutual understanding, allowing the teacher the opportunity to adjust their approach for future interactions.

Future Directions

The 4R Regulation Rectangle is still in its early stages of development, with further research needed to assess its effectiveness. Initial informal feedback from educators and students has been promising, but more data is required to refine the model and measure its impact on students' regulatory skills, psychological flexibility, academic performance, and overall well-being. Another area of exploration is the use of visual and non-verbal cues to support the 4R Regulation Rectangle in the classroom. Teachers could incorporate posters or prompts with the model's four stages, such as on the back of the time-out cards themselves. Additionally, school-wide training and implementation of the model could create a shared language around emotional regulation, fostering a collective approach to social and emotional learning efforts across the entire school and with parents. As a long-term scheme, pastoral support staff can build a catalogue of tools and ACT techniques within each phase of the 4R framework to allow them the flexibility to identify students' skills and offer personalised support. Through continued refinement and collaboration, the 4R Regulation Rectangle has the potential to be a valuable tool for fostering resilience and academic success.

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Developing mathematical resilience – a case study on the challenges involved in leading meaningful change in a highly academic secondary school

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All teachers are tasked with equipping students with the skills needed to become lifelong, resilient, independent learners and middle leaders influence change. In a busy work environment, the competing pressures of enabling learners to progress, day-to-day leadership, and ensuring accountability, make embedding change challenging. Beginning with the hypothesis that mathematics anxiety affects highly attaining students, here I describe the progress of a doctoral research project within a selective boys' school in Kent. The project aims to enable all students to develop a resilient approach to learning mathematics. I discuss the process from the initial pilot through to a large-scale intervention and follow-up survey and the indicative results from this. I also address the issues that arise when competing pressures begin to interfere with the research process leading to a consideration of the next steps in the research project and lessons learned about practitioner researchers as well as the learners.

Keywords: Agency; practitioner research; mathematical resilience.

Introduction

This paper describes the process followed in a doctoral research study in a highly academic selective school in North Kent, UK. While the continuing existence of selective schools in the UK is contentious (Clark, 2010), such issues are not addressed here but rather the reality of the setting and system in place are accepted. As an academically successful secondary school, external GCSE exam results at age 16 had been consistently strong over a significant period with over 80% of students attaining the top grades in Mathematics. However, changes to the GCSE course were implemented from 2017 with the aim of increasing the level of demand in the course and the grading system was extended (Jadhav, 2018). The new grading system aimed to identify the highest attainers using grade 9, which is awarded to a small proportion of students each year (in mathematics, this tends to be around 4%). Whilst results in 2017 and 2018 remained strong, albeit at a slightly lower rate, the school's results in 2019 were significantly worse.

Students in the sixth form, aged 16-18, follow the International Baccalaureate Diploma programme and results remained strong with an average points score of 35 or higher. All students are required to continue to study mathematics until the age of 18, either at Standard Level or the significantly more challenging Higher Level. However, average results do not give a complete picture; the academic nature of the school, makes it reasonable to expect a significant proportion of sixth form students to choose the more challenging higher level. In reality, in a typical year only 10-20% of students did so despite outstanding mathematics results at age 16. The impact of this is that very few students chose to apply for mathematics courses in higher education.

Given these concerns, it became a priority to discover why the cause and to remedy the situation. As the head of the mathematics department, I became responsible for implementing changes to practice that would offer a solution.

All students at the school must pass the Kent Procedure for Entry to Secondary Education test. In principle this means that students at the school are academically strong in the areas of Mathematics, English, and Verbal and Non-verbal Reasoning. However, other studies (Thompson et al., 2016), clarify that significant numbers of such students will show signs of mathematics anxiety (MA) in spite of a higher-than-average prior attainment (Gürefe & Bakalım, 2018; Lee, 2009; Maloney & Beilock, 2012). Furthermore, any intervention aimed at reducing the impact of MA must consider that these students bring with them high expectations (from parents, teachers, and school leaders) of academic success.

Initial steps - inspiration

Human interactions are inherently complex with many confounding variables, so an approach based on design thinking (Brown, 2008) was adopted which uses the concepts of inspiration, ideation, and implementation in the context of a confounding problem. I go further and compare the idea of a confounding problem as being more closely related to a “wicked problem” (Crowley & Head, 2017) for the following reasons:

- The problem is complex and difficult to solve.
- The problem has many uncontrollable variables and is likely to produce a “boutique remedy” (Paunesku et al., 2015) for this issue that may or may not be scalable.
- Solutions are likely to be contentious; other members of the mathematics department may have alternative suggestions for a possible solution.
- There is no ultimate solution to the problem. Improvements are likely to be incremental in nature

Ideation and implementation

While gaining inspiration for the study was relatively uncontroversial, as a new head of department, the political impact of change being introduced was an important factor in the design process. A key factor in the early stages was to establish a joint vision for the department, created via discussion within the department (Thomas, 2017) with the principles of joint venture and joint ownership at the core. The process of data gathering and analysis to establish baseline data began with a small-scale pilot using small groups of students in years 11 and 13 (ages 16 and 18). Initial data was gathered using the modified Abbreviated Mathematics Anxiety Scale, or mAMAS (Schillinger et al., 2018). In addition, interviews were conducted with small focus groups in years 10 and 12 (ages 15 and 17) to determine students’ thoughts on what it meant to be a resilient learner in mathematics (Thomas, 2020). Interviews were coded to identify key aspects related to the construct of mathematical resilience (Johnston-Wilder & Lee, 2010) and a high degree of agreement was seen between the thoughts of both year groups, summarised with the following quote from a year 10 student, when considering the challenge of attaining grade 9:

> I believe that it’s not like it’s unachievable. It’s challenging, as you said, but it’s designed to push us so that we work hard. When the hard work’s paid off, it feels good to have achieved a grade.

Data from the mAMAS, perhaps unsurprisingly, indicated that the greatest degree of anxiety stemmed from points in lessons where students were expected to make public contributions to solving problems, and in high-stakes assessments where they felt a judgement was being made about their performance.

Following this, an intervention was planned based on the three-part toolkit suggested by Johnston-Wilder et al. (2020). Students were introduced to the concepts of the hand model of the brain (HMB, Siegel, 2020), the relaxation response (RR, Benson & Klipper, 1975), and the growth zone model (GZM, Johnston-Wilder & Lee, 2018). In addition, a pedagogical approach based upon selected aspects of Rosenshine's Principles of Instruction (Sherrington, 2019) was trialled. The concepts used were:

- Think/pair/share, aimed at allowing rehearsal time for students before being asked to contribute publicly.
- Modelling answers rather than presenting neat solutions to problems so that students could see work being completed "live", with all of the resulting risks of the teacher making an error and having to spot and correct it.
- Scaffolding to allow all students to access challenging tasks while still receiving the support needed to experience success.

A more detailed pilot study took place in the spring term of 2020 (Thomas, 2020) resulting in the subject of a case study making rapid and sustained progress after applying the steps in the planned intervention, eventually achieving grade 6 in the GCSE examination and similar success in the IB Diploma.

The Covid-19 epidemic stalled progress on the study but the enforced time away from school was used to generate baseline data for the resumption of the study. Although the mAMAS had been used in the pilot study, I made the decision to change to the Betz mathematics anxiety scale (Mahmood & Khatoon, 2011) so that a more nuanced assessment could be made concerning levels of mathematics anxiety. A large-scale survey was distributed to all students resulting in 753 responses, allowing for a high degree of confidence in the resulting analysis. The analysis gave a similar message to the results of the pilot; levels of anxiety in lower year groups were low but increased significantly as students approached external examinations. Students in the sixth form reported the greatest levels of anxiety. When the evidence from the data was presented to the department, it is fair to state that staff were surprised due to the lack of visible evidence of anxiety reported. However, MA remained an issue to be addressed.

Follow up interviews took place with four sixth form students and five teachers within the department. Student interviews gave context to the lack of visible MA as responses indicated that all had a clear idea of how to be resilient in their learning and had strategies developed over time that enabled them to deal with the negative impact of MA. Interviews with staff were similarly enlightening, Many comments linked their personal experiences with MA, but it was not easy for them to identify this. However, they seemed to understand the role struggle and growth mindsets played in their ability to be successful in mathematics.

As school life returned to normal, the intervention was introduced to teachers via department meetings, and all teachers were asked to teach a session explaining the cognitive impact of MA and the strategies to be employed when working memory became overloaded and affected learning. This part of the study was spread over an academic year with further data collection at the end of the year. In this, students were asked to identify which of the strategies introduced in the intervention they could recall and which they found themselves using most often. This data is presented in Table 1 and Table 2 below. In addition, teachers were surveyed on their response to the intervention; a summary is given in Figure 1.

	HMB	GZM	RR
Remember seeing	42.7	65	30.1
Useful/Somewhat useful	13.6	50.5	25.3

Table 1: Summary of student responses to which of the strategies in the intervention they could remember and found useful (n=103)

	Identify red zone questions	Summarise knowledge of topic	Just start writing	Use a relaxation technique	Annotate diagrams	Skip the question	Identify leaving the red zone
Always	23	18	50	2	34	10	6
Sometimes	29	30	37	13	30	45	17
Rarely	19	39	7	32	21	28	17
Never	32	16	9	56	18	20	63

Table 2: Summary of student responses to the question of which techniques for moving out of the red zone were used (n=103). Red indicates modal response.

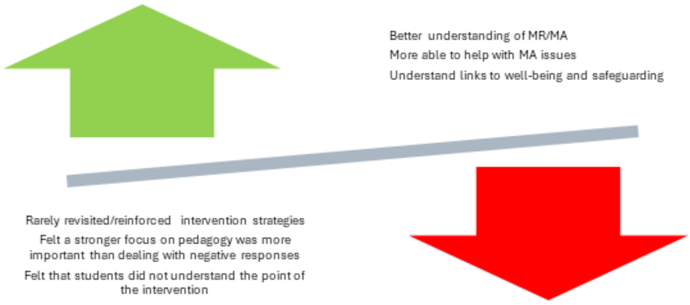

Figure 1: Positive and negative impacts based on staff feedback at the end of the study period

While the data presented in Table 1 and Table 2 was initially disappointing in terms of how little effective use was made of two of the strategies in the Mathematics Resilience Toolkit (Johnston-Wilder et al., 2020), it was nevertheless pleasing to note that students found the GZM useful with over 50% making use of it in their learning. When triangulated with staff feedback, the reason for the disappointing data became clear; without regular reviews and reminders, it is unrealistic to expect students to fully embed the tools into their learning. However, two recent interviews with teachers indicate that the concepts surrounding MA and building resilience have become more embedded in the department's pedagogy than may be evident from Figure 1.

Final reflections

This study was aimed at determining the extent to which it may be possible to develop an already successful community of practice to ensure that all students are able to make progress in their mathematical journey. The evidence of the existence of MA within an academically strong selective school is in line with previous research and analysis of interviews indicate a strong tendency towards students understanding the importance of resilience. While the data may give an equivocal answer, there are positive indications that students have benefitted from the introduction of the Toolkit alongside changes to pedagogy within the department.

However, questions remain concerning the drive to continue to build on the successes described in this paper while also addressing the need for further development in aspects of resilience in our students. Campbell (n.d.) makes the case for teachers to participate in practitioner research in schools; research of this nature, with the ambition to reach beyond a single setting, carried out by practicing teachers, offers a sound approach to increasing the agency and professional expertise of the teaching profession.

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The Effectiveness of Mathematics Anxiety Intervention Programme Among Secondary School Students

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Mathematics anxiety is one of the most important factors that may block students' learning of mathematics. The concept is defined as negative emotional and cognitive reactions to mathematics or numbers accompanied by feelings of tension and anxiety. These negative emotions and cognitions can inhibit the ability to work with numbers and solve mathematical problems. Studies aimed at preventing and reducing mathematics anxiety may help students to improve their mathematics performance. This study investigated the effect of a Mathematics Anxiety Intervention Programme on the level of mathematics anxiety and mathematical resilience of secondary school students. The hypotheses of this experimental study, which included an experimental-control group design with pretest-posttest measures, were tested using SPSS 23 statistical programme. The results showed that the Intervention Programme had a significant effect on the mathematics anxiety level of the experimental group. No change was found in the mathematics anxiety level of the control group.

Keywords: Mathematics anxiety; mathematical resilience; intervention programme

Introduction

Mathematical literacy can make a significant contribution to students' overall academic achievement. This is because these skills help students acquire knowledge in a systematic way, make logical predictions and make realistic comparisons (Alkan, 2011). Therefore, mathematical skills are useful and beneficial at all levels of education. However, students encounter obstacles in learning mathematics due to many variables. These variables can be listed as students' beliefs about mathematics, teachers' attitudes, learning styles, learning disabilities and students' emotional reactions. At the same time, mathematics anxiety is considered as one of the most important factors that undermine students' ability to learn mathematics (Rossnan, 2006; Carey et al, 2019; Devine et al, 2017).

Mathematics anxiety (MA) is defined as negative emotional and cognitive responses to mathematics or numbers accompanied by feelings of tension and anxiety (Richardson & Suinn, 1972, Hembree, 1990). These negative emotions and cognitions can inhibit the ability to work with numbers and solve mathematical problems. Therefore, providing psychological services to individuals to reduce or eliminate mathematics anxiety may remove one of the obstacles to developing positive attitudes towards mathematics and learning mathematics.

Review of Literature

Mathematics Anxiety

Mathematics anxiety (MA) feelings interfere with the ability to manipulate numbers and solve mathematical problems. In a comprehensive review of the potential causes of mathematics anxiety by Carey et.al. (2019) these causes were considered under three categories: environmental (e.g teacher attitudes), personal (e.g. low self-esteem) and intellectual factors (e.g. dyscalculia). Therefore, as an environmental and personal factor childhood trauma may be one of the significant predictors of mathematics anxiety.

These negative experiences consist of negative or traumatic memories that include negative assumptions and feelings about self-efficacy perceptions in mathematics (Yorgun & Mert, 2024). The Turkish literature on mathematics anxiety suggests the structure of mathematical concepts, teaching and learning styles, age, gender, socio-economic level, attitudes towards mathematics and self-esteem as the causes of mathematics anxiety (Nazlıçiçek, 2007; Baloğlu, 2001; Baloğlu, 2004; Alkan, 2011; Durmaz, 2012; Yorgun & Mert, 2024)). However, due to the limited efforts of researchers, no study was found to develop a psychoeducational programme aimed mathematics anxiety and investigated its effectiveness. Therefore, this study developed an intervention programme based on the research findings on the causes and predictors of mathematics anxiety and investigated the effectiveness of this programme.

Mathematical Resilience

Mathematical resilience may be considered as the adaption of psychological resilience to mathematics learning. Students may feel confused sometimes when they learn mathematics and during these times, they need an inner power to keep trying to learn. This inner power is defined as mathematical resilience. Johnston-Wilder and Lee (2010) assigned four dimensions to mathematical resilience considering someone may develop mathematical resilience having some knowledge and skills related with these dimensions. These are value, struggle, growth mindset and supports

Mathematics Anxiety Intervention Programme

The Mathematics Anxiety Intervention Programme is a psycho-educational programme that is a combination of group counselling sessions and an academic lecture. In other words, during the psychoeducational sessions, group members may develop awareness of their feelings and at the same time learn some specific skills like anxiety management, anger control, relationship building and self-esteem. While writing the group programme and the content of sessions, the findings of the literature on how the development of psychoeducation groups were used (Brown, 2008). Based on the findings of the mathematics anxiety literature, it was decided to use those sessions in the group programme: Session 1- Introduction and information about group work; Session 2- Learning about the neurobiology of traumatic anxiety; Session 3- Identifying mathematics anxiety; Session 4- Identifying mathematics myths; Session 5- Recalling and reprocessing negative mathematics memories; Session 6- GZM Model (Growth Zone Model); Session 7- Learning anxiety regulation skills; Session 8- Building Mathematical resilience; Session 9- Imagining the resilient self; Session 10- Evaluation and closure.

Method

Sample

The sample of the study consisted of 5th, 6th and 7th grade students. The study group consisted of 5th, 6th and 7th grade students who continued their education at Mustafa Çukur Secondary School in Bayraklı District of İzmir in 2023-2024. After obtaining the necessary official permissions from the Bayraklı District Directorate of National Education, a study plan was prepared with the school's psychological counsellor and studies were carried out to identify students with high mathematics anxiety and to develop and implement the group programme. Students who scored high on the Mathematics Anxiety Scale were invited to participate in the study by informing them of the purpose and method of the study through individual interviews. It was decided that the number of members of the psychoeducational groups should be 12 (twelve) in order to enrich the group interaction and to allow each member to find time to express themselves (Brown, 2018). For this reason, students who agreed to participate in the study were randomly assigned to one of the experimental and control groups, taking care to ensure similarity in terms of Mathematics Anxiety Scale scores and gender variables. Table 1 shows information on the year level of the participants.

Group	Year			Gender	
	5th	6th	7th	Girl	Boy
Experiment	4	5	1	7	3
Control	7	3	1	7	4

Table 1: *Distribution of participants by year level and gender*

Table 1 shows that 4 of the participants in the experimental group were in Year5, 5 in Year 6 and 1 in Year 7, while 7 of the participants in the control group were in Year 5, 3 in Year 6 and 1 in Year7. By gender, 7 girls participated in both groups, while 3 boys took place in experiment group and 4 boys in control group.

Data Collection Instruments

In this study, two scales (Mathematics Anxiety Scale and Mathematical Resilience Scale) and Personal Information Form including variables such as gender and grade were used as data collection tools.

The Mathematics Anxiety Scale

This scale developed by Bindak (2005) consists of 10 items on a 5-point Likert scale ranging from always to never. While nine of the items reflect negative expressions, the remaining item reflects a positive attitude towards mathematics. The maximum and minimum scores that can be obtained from the scale are 50 and 10 respectively. Higher scores indicate greater mathematics anxiety. Reliability and validity analyses of the scale were carried out with data collected from secondary school students. The scale consists of one factor and the explained variance ratio was calculated as 51.7%. Cronbach's alpha internal consistency reliability coefficient was found to be 0.84.

Mathematical Resilience Scale

This scale was developed by Kooken, Megan, Welsh, Betsy McCoach, Johnston-Wilder, and Lee (2016) and adapted to the Turkish context by Çetin, Duymaz, and Yıldız (2018). The scale consists of 24 items on a 7-point Likert scale ranging from strongly disagree (1) to strongly agree (7). It was first translated into Turkish by 3 people with excellent knowledge of English. The translated forms were then compared and made into a single form and translated into English again by 3 different experts in the field of English. The final version of the scale was administered to 5th-8th grade students attending secondary schools. As a result of the study, it was found that the Mathematical Resilience Scale, previously developed and adapted for university students, could be used as a valid and reliable tool for secondary school students. Cronbach Alpha reliability coefficients were calculated as 0.88 for the total Mathematical Resilience Scale, 0.91 for the value dimension, 0.77 for the struggle dimension and 0.74 for the growth dimension.

Statistical Analysis

In order to investigate the hypothesis of this study, the data was analysed using the SPSS programme. When the size of the group was taken into account, it was decided to employ non-parametric techniques. Because small samples is considered as a thread to the criterion for normal distribution. Therefore, A Mann-Whitney U was performed to evaluate whether mathematics anxiety and mathematical resilience levels differed by the Mathematics Anxiety Intervention Programme. The .05 alpha level was accepted as a criterion of statistical significance for all the statistical procedures performed.

Results

Table 2 shows the means of pre and post-test measurements of mathematics anxiety and mathematical resilience of experiment and control groups

	Math Anxiety		Mathematical Resilience	
Group	Pretest	Posttest	Pretest	Posttest
Experiment	39.2	28.0	105.3	110.2
	39	39	102	94

Table 2: Means of mathematics anxiety and mathematical resilience scores

Table 2 showed that mean score of math anxiety was calculated as 39.2 at pre-test for experiment group and 28.0 at post-test. Mean score of mathematical resilience was calculated as 105.3 at pre-test and 110.2 at post-test. On the other hand, mean score of mathematics anxiety was detected as 39 at pretest for control group and 39 again at post-test. Mean score of mathematical resilience was found as 102 at pretest and 94 at post-test with a decline. The Mann Whitney U results indicated that there is a statistically significant change in mathematics anxiety scores of experiment groups at the end of the group programme (U=16 and p=0.05). Since p > 0.5, it can be stated that mathematics anxiety intervention programme was found effective in reducing mathematics anxiety level of control group members. No change was detected in mean scores of control group. Additionally, a small change occurred in mathematical resilience scores of experiment group, however this is not statistically significant (U=65 and p=0.5).

Discussion and Conclusion

In this study, Mathematics Anxiety Intervention Programme was found effective in reducing mathematics anxiety levels of secondary school students. According to the oral assessments provided by the experiment group members at the tenth session, they found some session as more effective in reducing their mathematics anxiety. Namely, neuropsychological explanation of learning and the relationship between anxiety and learning; the role of unrealistic thinking or myths in mathematics anxiety, processing of traumatic experiences and mathematical resilience skills help student to overcome mathematics anxiety. They also revealed that they have not felt any fear when they volunteered to try to solve the problems at the board; spent much more time after they developed awareness about their feelings related with mathematics; remembered the hand model of the brain while feeling stress in case of offering a wrong solution and managed their feelings and huge improvements at math scores of some members

The Mathematics Anxiety Intervention Programme included ten sessions; each session lasts for two hours following the general rules of psychoeducational groups. However, at some sessions, the members were distracted and could not keep their focus because of length of the session. Therefore, the shorter version of sessions may be developed and applied. Although there was an improvement from pre to post-test scores, no statistically significant change has been measured at mathematical resilience scores. A possible explanation may be that the MR Scale may not be able to measure the mathematical resilient structure correctly. Because, in Turkish context most of the students are aware about the value of mathematics, a dimension of mathematical resilience. It is considered as a sign of being intelligent and a way to get higher education. However, this knowledge does not prevent them being highly anxious. Therefore, their MR scores may not change due to this reason. Similarly, students may consider the ineffective ways they used (ruminating, unrealistic thinking style, avoidance and so on…) as struggling, another dimension of MR and such perceptions may lead to high scores from the MR Scale.

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