Chapter # 17

STRATEGIES FOR DEVELOPING MATHEMATICS AND SCIENCE RESILIENCE IN PRE-SERVICE TEACHERS TO ADDRESS MATHS AND SCIENCE ANXIETY IN SOUTH AFRICAN SCHOOLS

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ABSTRACT
This chapter explores strategies to foster resilience among pre-service mathematics and science teachers education to reduce maths and science anxiety within South African schools. Pre-service teachers often face high levels of maths-science-related anxiety, which can impact their effectiveness and confidence in teaching these subjects. Developing resilience is crucial to helping them cope with the challenges of teaching. This project examines various resilience-building strategies and practical teaching experiences and the integration of anxiety-reducing techniques within teacher training curricula for mathematics and sciences. The Self-Determination Theory underpins this study. The study employs a participatory action research approach, collecting qualitative insights from focus group interviews and reflective journals. This study employed action research to design cycles of whole class (n=29) intervention based on three tools designed by Johnson-Wilder and the mathematical resilience network team, and the emotional grid to support pre-service teachers in building resilience in math/science as they prepare for fieldwork. Data was analysed through thematic content analysis. The findings revealed that maths/science anxiety may be successfully reduced through the effective use of emotional tools. These findings suggest a new method of utilising the affective domain in teachers' training in South Africa for educational transformation.

Keywords: resilience, maths anxiety, science anxiety, pre-service teachers, teacher education.

1. INTRODUCTION

Education systems globally face the challenge of preparing future teachers to navigate the complexities of teaching mathematics and science effectively, particularly in contexts where anxiety towards these subjects among both students persists (Fitriati, Rosli, Iksan, & Hidayat, 2024; Wallace, 2015). In South Africa, as in many parts of the world, the effective teaching and learning of mathematics and science are crucial for developing a skilled workforce and a scientifically literate society (Jojo, 2019; Lelliott, 2014). However, despite efforts to improve educational outcomes in these subjects, challenges persist, particularly regarding pre-service teachers' (PSSTs) preparedness to teach mathematics and science effectively. One significant barrier to successful teaching and learning in these disciplines is the prevalence of math and science anxiety among students and teachers (Griggs, Rimm-Kaufman, Merritt, & Patton, 2013; Megreya, Szűcs, & Moustafa, 2021). In South Africa, where mathematics and science education outcomes have long been a concern (Reddy et al., 2020), addressing the anxiety levels associated with these subjects is paramount for enhancing teaching and learning experiences. Pre-service teacher education

programs play a crucial role in shaping teachers' competencies and attitudes towards mathematics and science instruction. However, there is a need to ensure that these programs not only equip future teachers with subject knowledge but also foster resilience to confront challenges inherent in teaching these subjects.

Mathematics and science anxiety, characterized by feelings of fear, tension, and apprehension when engaging with mathematical and science concepts, can significantly impede academic performance and professional efficacy. PSSTs who experience high levels of anxiety in mathematics and science may struggle to convey these subjects effectively in classrooms, perpetuating a cycle of anxiety and underachievement among students (Gresham, 2018). Addressing math and science anxiety among PSSTs is therefore paramount for enhancing the quality of mathematics and science education in South African schools. Moreover, cultivating resilience in PSSTs can empower them to navigate the challenges associated with teaching these subjects, fostering confidence and effectiveness in the classroom. This study investigates strategies for developing resilience among PSSTs while simultaneously addressing mathematics and science anxiety levels in South African schools. By exploring the intersection of resilience development and anxiety mitigation within the context of pre-service teacher education, this study seeks to contribute insights into effective pedagogical approaches and support mechanisms for preparing teachers to excel in teaching mathematics and science.

The following research question guides the study:

(1) How do resilience-building strategies impact pre-service teachers' confidence and anxiety levels in mathematics and science as they prepare for teaching in South African schools?

2. BACKGROUND

Mathematics anxiety and science anxiety are two distinct yet interrelated phenomena that significantly impact students' academic performance and engagement in STEM (Science, Technology, Engineering, and Mathematics) fields. Both forms of anxiety manifest as feelings of tension, apprehension, and fear related to the respective subjects, but they arise from different contexts and can affect students in unique ways. Math anxiety is defined as a feeling of tension and apprehension that interferes with math performance ability, the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations (Khasawneh, Gosling, & Williams, 2021). Mathematics anxiety is characterized by a fear of performing mathematical tasks, leading to avoidance behaviours and a lack of confidence in one's mathematical abilities (Sokolowski & Ansari, 2017). This anxiety can stem from various sources, including negative past experiences with mathematics, societal stereotypes, and the high-stakes nature of math assessments. Studies indicate that mathematics anxiety is prevalent among students and can negatively correlate with their self-efficacy and performance in mathematics (Megreya & Al-Emadi, 2024; Megreya, Hassanein, Al-Emadi, & Szűcs, 2025). For instance, Daker, Gattas, Sokolowski, Green, and Lyons, (2021) found that first-year students' math anxiety predicted their avoidance of STEM fields and underperformance throughout their university studies, independent of their actual math ability. This suggests that even students who possess the necessary skills may refrain from pursuing STEM careers due to debilitating anxiety. Conversely, science anxiety refers to the apprehension and stress associated with learning and performing science-related tasks. Fia, Ayarkwa, and Obuobi-Ayim (2022) defined science anxiety as emotions that obstruct students' interest and engagement in scientific learning, ultimately hindering their scientific skills and knowledge development.

It encompasses a range of emotions, including fear of failure in scientific experiments, anxiety about understanding complex scientific concepts, and apprehension regarding participation in science classes. Avcı and Kırbaşlar (2017) highlighted that students' anxiety levels in science were significantly related to their academic performance, indicating that higher anxiety could lead to lower achievement in science subjects. While both mathematics and science anxiety share common features, such as the emotional distress associated with academic performance, they differ in their specific triggers and manifestations. The implications of these anxieties are profound, as they can lead to a cycle of avoidance and underachievement in both subjects. For instance, Megreya and Al-Emadi (2024) found that both math and science anxiety negatively correlated with students' self-efficacy in these domains, suggesting that anxiety can diminish students' confidence and willingness to engage with challenging material. This avoidance can further perpetuate feelings of inadequacy and reinforce negative beliefs about one's abilities in mathematics and science.

However, the emotional and psychological aspects contributing to mathematics and science anxiety are multifaceted, necessitating a comprehensive exploration of the underlying mechanisms that influence these feelings. Research indicates that mathematics anxiety is not merely a transient emotional response but a complex interplay of cognitive, emotional, and social factors that can significantly impact students' academic performance and career choices in STEM fields (Buckley, Reid, Goos, Lipp, & Thomson, 2016; Moustafa, Porter, & Megreya, 2019). Understanding these dimensions can provide educators and policymakers insights into effective interventions that can alleviate anxiety and foster resilience among pre-service teachers. Factors such as gender stereotypes and societal expectations can exacerbate feelings of inadequacy and anxiety, particularly among female students and those from underrepresented ethnic backgrounds (Pelch, 2018; Rozgonjuk, Kraav, Mikkor, Orav-Puurand, & Tähtet, 2020). Research has consistently shown that female students tend to report higher levels of mathematics anxiety compared to their male counterparts, which can be attributed to societal pressures and the internalization of negative stereotypes regarding their mathematical abilities (Pelch, 2018; Rozgonjuk et al., 2020). This highlights the need for educational interventions focusing on individual coping strategies and challenges and changing the broader cultural narratives surrounding mathematics/science and gender. In addition to cognitive and cultural factors, the emotional support systems available to students can significantly influence their experiences of anxiety. Research suggests that supportive teacher-student relationships can mitigate the effects of anxiety, fostering a positive learning environment that encourages risk-taking and resilience (Dowker, Sarkar, & Looi, 2016; McLean, Janssen, Espinoza, Johnson, & Jiménez. 2023). Teachers who model positive attitudes towards mathematics and provide constructive feedback can help students reframe their perceptions of mathematics as a subject that can be mastered with effort and practice rather than an insurmountable challenge (Dowker et al., 2016; McLean et al., 2023). Hence, Barroso et al. (2021) study supports the need for interventions to mitigate anxiety and enhance math/science achievement.

2.1. Theoretical Framework

Self-Determination Theory (SDT) (Ryan & Deci, 2018) offers a blueprint for understanding the motivational basis of personality and social behaviour and the relation of basic psychological needs to well-being, psychological flourishing, and high quality of life. SDT posits that three innate psychological needs motivate individuals to grow and change: autonomy, competence, and relatedness. These needs are crucial in fostering resilience,

especially in high-anxiety contexts such as learning challenging subjects. Research indicates that emotional intelligence, motivation, and resilience significantly influence academic performance and the adoption of healthy lifestyle habits among adolescents, which can be extrapolated to PSSTs (Trigueros, Cangas, Bermejo, García, & Liriaet, 2019). This connection underscores the importance of fostering emotional intelligence and motivation through SDT principles, thereby enhancing resilience. For instance, when PSSTs perceive their learning environment as supportive of their autonomy, they are more likely to engage deeply with the material, which can mitigate feelings of anxiety associated with learning mathematics and science. Moreover, the interplay between teacher resilience and professional development is critical. Studies have shown that supporting beginning teachers in addressing their specific needs can significantly contribute to their overall professional development (Kim, 2024). This suggests that interventions grounded in SDT could be tailored to enhance the resilience of PSSTs by providing them with opportunities to develop their competencies in a supportive environment. For example, creating collaborative learning experiences that foster relatedness among peers can enhance their sense of belonging and reduce anxiety. In addition, the motivational climate within educational settings plays a significant role in shaping PSSTs' engagement and resilience. Studies have shown that a positive motivational climate, characterized by supportive teaching styles, can enhance academic engagement and resilience among PSSTs (López-García, Poyatos, Burgueño, & Granero-Gallegos, 2022).

Competence refers to the feeling of being effective in one's activities. A strong sense of competence in mathematics and science education can significantly reduce anxiety and improve performance (Termizi & Mahmud, 2022). In this study, the interventions highlighted coping strategies that built competence through mastery experiences and highlighted the importance of practical teaching experiences in building confidence and reducing anxiety among PSSTs. The third component of SDT, relatedness, emphasizes the importance of social connections and support in the learning process. This study created a supportive learning community among PSSTs that nurtured them through classroom activities, thereby reducing feelings of isolation that often accompany anxiety. Research has shown that when students feel connected to their peers and instructors, they are more likely to engage in learning activities and persist in the face of challenges (Daker et al., 2021). Therefore, implementing collaborative learning strategies and peer support systems in teacher training programs can enhance relatedness and contribute to resilience against anxiety in mathematics and science.

2.2. Methodology

2.2.1. The Research Process and Analysis

The study employed a Participatory Action Research (PAR) approach to design a whole-class intervention (MacDonald, 2012). PAR allows for a high degree of participant engagement throughout the research process, promoting a sense of ownership and commitment among those involved (MacDonald, 2012). This study is an active collaboration of eight lecturers who teach Mathematics, Science and Technology. However, this chapter reports on interventions at one university where the Growth Zone Model (GZM), the Hand Model of the Brain (HMB) and Relaxation Response Model (RRM) tools (Johnston-Wilder, Lee, & Mackrell, 2021) were embedded into classroom practices to promote math and science resilience among third-year university students. The sample consists of one whole class of nineteen (19) males and ten (10) females. In the first cycle of interventions, a series of training sessions which were embedded into their physical

sciences teaching II curriculum were conducted for PSSTs, focusing on resilience-building strategies and addressing anxiety in teaching mathematics and science. These workshops helped PSSTs to identify anxiety triggers related to assessments and practice cognitive reappraisal techniques. For instance, before a major mathematics formal task, PSSTs participated in a session where they learned to replace thoughts like *I'm going to fail* with *This anxiety shows I care and am prepared to tackle the challenge*. Follow-up surveys indicated reduced exam-related anxiety. These sessions facilitate discussions and activities to enhance learning and teaching effectiveness and confidence in the subject they will teach in the future. At the same time, during physics III, chemistry III, and mathematics III content lessons, the lecturers engaged in a series of interventions with the three tools as PSSTs learned physics, chemistry, and mathematics concepts, usually beginning with brief mindfulness exercises, such as deep breathing or guided visualization, to create a calm, focused learning environment. For example, a chemistry lecturer incorporates a 3-minute breathing exercise before starting complex organic chemistry lessons.

All the tools were provided to the PSSTs for engagement purposes. PSSTs maintain a weekly reflection journal documenting their learning experiences, challenges, strategies to overcome difficulties, and personal growth insights. For instance, after a challenging lesson on chemical equilibrium, a pre-service teacher reflects on the misconceptions encountered and how reworking problems with peer support helped improve understanding. This process helps normalize struggles as part of the learning journey.

Qualitative data was collected at the end of the first semester through focus group discussions, reflective journals and individual interviews. The qualitative data was analysed using thematic analysis as guided by Clarke and Braun's (2016) framework. Quality assurance measures were established by returning the captured responses to the participants for member checking.

2.2.2. Research Findings

Participants Profile

The sample consists of 19 males and 10 females. All PSSTs were in their third year at the university, suggesting they have progressed through their academic program and were approaching the completion of their teacher education. While specific ages may vary, PSSTs in their third year at university typically range from early 20 years to 25 years, although there may be some variation due to individual circumstances. Each PSST brings unique strengths and qualities to the classroom, whether it be leadership abilities, subject matter expertise, creativity, or a passion for working with learners.

In discussing these findings within the framework of SDT, it becomes clear that interventions such as the GZM, HMB and RRM play a pivotal role in fulfilling three essential SDT needs: autonomy, competence, and relatedness, which are necessary for nurturing intrinsic motivation and resilience in learning mathematics and science. Three themes emerged in the data analysis: motivation for learning complex concepts, cultivating confidence and personality development all in relation to autonomy, confidence and relatedness.

Theme 1: Motivation for Learning Complex Concepts

SDT posits that individuals are more motivated to engage in activities when they feel competent, autonomous, and connected to others. Participants' reflections on the interventions highlight how these tools helped them manage anxiety and build confidence, a shift that aligns with increased competence, which is one of SDT's core needs. By recognizing and confronting their discomfort within the GZM framework, participants began to view math and science as areas for potential growth rather than fear, thereby

nurturing intrinsic motivation. For example, PSST9's recognition that growth lies outside their comfort zone is emblematic of SDT's emphasis on resilience through self-determined learning.

Some participants narrated:

I have struggled with anxiety in math and science for as long as I can remember. The Growth Zone Model has given me a framework to understand that it is okay to feel uncomfortable and that growth happens outside of my comfort zone. It is still a work in progress, but I am seeing improvements in my confidence and performance (PSST9).

For the first time in my life, I am no longer anxious when I have maths and science tests. I could not believe it when my lecturer announced test dates for Chemistry III and Mathematics III (PSST29).

Ah, indeed, the GZM has really helped me. I just move my pebbles to appropriate levels during lectures. That engages me actively in the lesson. When I am in my comfort zone, I begin to smile about myself and my achievements. I know within me that I can do this (PSST18).

Theme 2: Cultivating Confidence

The participants' increased confidence indicates a strengthened sense of competence fostered by the interventions. PSST1 reflective responses indicated exemplified shifts in self-perception, driven by repetitive affirmations that empower them to tackle complex content. This internal motivation for competence fosters resilience and positions them as proactive learners who will, in turn, inspire similar resilience in their future students. Furthermore, PSSTs' use of mindfulness techniques reflects SDT's emphasis on autonomy, as these strategies allow them to self-regulate and remain autonomously engaged in the learning process. Two PSSTs responded:

The interventions have improved my confidence in math/science. The thought of having "I can do maths" I can do chemistry" lingers in my mind each time the lecturers teach complex concepts. I keep saying this to myself to help me get through to each lesson. That has been helpful (PSST1).

My confidence in mathematics, chemistry and physics has improved drastically. Quantum mechanics at the third-year level was very challenging. Now, with the relaxation model, I can breathe in and breathe out as if I am releasing too much information out of my system so I can absorb more… hahaha. But now I'm very confident in myself (PSS4).

Incorporating mindfulness activities into math/science lessons helped PSSTs stay calm and focused on the task at hand. Techniques such as mindful breathing allowed them to approach math/science with a calm and centred mindset.

Theme 3: Personality Development

Through the use of GZM and related strategies, participants report personal growth and an anxiety reduction, embodying SDT's concept of relatedness, the idea that feeling connected to a community (in this case, through shared growth in resilience-building tools) enhances motivation. The GZM empowers participants like PSST20 and PSST15 by reframing discomfort as part of the learning journey, thus allowing them to see personal progress rather than focusing solely on achievement.

"I've been amazed by the impact of incorporating coping strategies based on the GZM, HMB, and RRM in our lectures. I have been empowered to approach science and mathematics with a growth mindset, knowing that my abilities are not fixed and that they can improve with effort and perseverance. As a result, I have seen a noticeable reduction in my anxiety levels and a corresponding increase in my academic achievement (PSST20).

The GZM has been a game-changer for me in tackling my anxiety around math and science. I understand that discomfort is a natural part of growth, and I've been able to push through challenging concepts with more confidence. It's not about being perfect but about progressing, and that mindset shift has made all the difference (PSST15).

2.3. Discussions

Mathematics and science anxiety can be significant barriers to effective teaching and learning among PSSTs. These anxieties not only impact the teachers themselves but also have cascading effects on the confidence and achievement of their future students. To address this issue, it is essential to explore strategies that not only reduce anxiety but also cultivate resilience and motivation in PSSTs towards these subjects. This explored how integrating intervention strategies using the GZM, the HMB and RRM vis-a-vis informed by the SDT can help reduce mathematics and science anxiety among PSSTs while simultaneously building their resilience towards these subjects. The SDT posits that when individual needs are satisfied, individuals experience greater intrinsic motivation, well-being, and optimal functioning. Applying the principles of SDT to the context of PSSTs facing mathematics and science anxiety offers a promising avenue for intervention, which improves students' learning and reduces anxieties as they work towards building resilience. The first theme focused on motivation to learn complex concepts in math and science. The study found that the participants believed that the tools helped alleviate their doubt and anxiety with mathematics and science as they studied complex concepts in the subjects. This finding aligns with the study by Barroso et al. (2021), who support the need for interventions to mitigate anxiety and enhance math/science achievement. The second theme focused on cultivating a sense of confidence as they build resilience. The study found that the interventions provided a starting point for their confidence in the subjects as they have developed knowledge of the subject with understanding and would be able to assist their future learners to develop confidence in mathematics and science. Research supports students' emotional well-being and resilience in science education. Some of its indicators include thinking patterns, self-confidence, having support, optimism, perseverance, and being able to have self-control in difficult situations (Hakim & Murtafiah, 2020; Johnston-Wilder et al., 2021). The third theme focused on participants' personality development. The findings show that implementing coping strategies based on the intervention models has been incredibly effective in helping PSSTs manage anxiety in science and mathematics. SDT highlights the significance of intrinsic motivation, autonomy, and competence in fostering positive outcomes in educational settings (Johnston-Wilder et al., 2021). Following a cycle of interventions, PSSTs can effectively integrate the GZM, HMB, and RRM into their teaching practice to reduce anxiety in science and mathematics topics and build resilience in these subjects.

Although studies have shown that gender differences, ethnicity, and socioeconomic status significantly influence how individuals experience and manage anxiety (Li et al., 2023; Skagerlund, Östergren, Västfjäll, & Träff, 2019; Zhang, Zhao, & Kong, 2019), it becomes evident that resilience strategies cannot adopt a one-size-fits-all approach. Instead, instructions must be specifically tailored to address different demographic groups' distinct challenges. In light of this, incorporating resilience strategies that build confidence and foster supportive mentorship is crucial for PSSTs. Research highlights that reflective practices that encourage self-awareness and personal growth, alongside peer support networks, can also significantly alleviate anxiety (Prachagool, Nuangchalerm, Juhji, & Thavornsil, 2021). Such strategies help enhance the overall resilience of PSSTs, preparing them to navigate the challenges of their future teaching careers effectively.

While the sample size might limit the transferability of findings, it is sufficient to identify recurring themes and patterns relevant to the research objectives.

3. FUTURE RESEARCH DIRECTIONS

The long-term impact of this study would be the engagement of the PSSTs after they have entered the teaching profession, encouraging them to engage in reflective practices on how resilience strategies have helped them manage their anxiety in the classroom over time.

Future research could explore the long-term impact of resilience-building interventions, such as the GZM and RRModel, on PSSTs' efficacy in real classroom settings. Investigating how these tools influence their teaching practices over time would provide valuable insights into sustained effects on anxiety management and resilience. Resilience strategies could be integrated into long-term professional development programs. For example, including resilience-building modules in in-service teacher training or workshops after graduation could help assess if these strategies lead to continued teacher growth and lower anxiety levels during their careers. Further studies might examine the potential of integrating additional frameworks like SDT-based mentorship programs that foster autonomy, competence, and relatedness within teacher training curricula. Expanding this research to other educational contexts, such as early-career in-service teachers or secondary students, could offer a broader understanding of how resilience-building strategies reduce anxiety and promote confidence in STEM fields. Finally, future studies might analyze the role of cultural factors in South Africa that impact how PSSTs experience and respond to interventions to ensure these tools are culturally adaptive and effective in diverse settings.

4. CONCLUSION

This study explores strategies to enhance resilience and reduce anxiety levels among PSSTs in mathematics and science within the context of South African schools. An important issue emphasised in the study is the significance of reducing anxiety levels among PSSTs in mathematics and science. Moreover, the motivating climate in educational environments significantly influences PSSTs' engagement and resilience. Research indicates that a favourable motivational climate, defined by encouraging pedagogical approaches, might improve academic engagement and resilience in PSSTs (López-García et al., 2022). Using SDT principles, educators can cultivate an environment that enhances intrinsic motivation, promoting resilience in overcoming adversities.

Studies have demonstrated that anxiety may have a substantial effect on both the effectiveness of instruction and the academic achievements of students. Hence, it is important to implement interventions that target the reduction of anxiety levels and the enhancement of resilience in PSSTs to enhance educational practices and optimise student learning experiences. Nonetheless, the study recommends integrating experiential learning methodologies into teacher training programmes and implementing mentoring programmes and support structures that can foster resilience and mitigate anxiety levels among PSSTs. Through the provision of experienced mentors, resources, and advice, PSSTs can receive the necessary assistance to effectively negotiate the difficulties associated with teaching and learning mathematics and science.

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