https://doi.org/10.36315/2024v1end083
Education and New Developments 2024

EXPLORING THE EXISTENCE OF MATHEMATICS-SCIENCES ANXIOUS-ENDEMIC EQUILIBRIUM AMONG PRE-SERVICE PHYSICAL SCIENCES TEACHERS: A PATHWAY TO BUILDING RESILIENCE AMONG STEM STUDENTS

Sakyiwaa Boateng
Department of Mathematics, Science and Technology Education, Walter Sisulu University (South Africa)

Abstract

This study is part of a larger project that delves into the intricate dynamics surrounding the existence of Mathematics-Sciences Anxious-Endemic Equilibrium (MSAEE) among pre-service physical sciences teachers and its potential impact on fostering resilience among students pursuing STEM disciplines in South African universities. The South African international performance in mathematics and sciences has been of concern over the years. South Africa's maths and science learners have come to the international spotlight since it started participating in the Trends in International Mathematics and Science Study (TIMSS) for grades 4 and 8 learners in 1999 and 2003 and with grade 4 and 9 learners from 2011 to 2019. Notably, South African learners' performance at TIMSS for both mathematics and science has been very poor. Evidence from research indicates that a significant number of learners/students experience fear and exhibit subpar academic achievement in mathematics and science. While the origins of maths/science anxiety are still being debated, reducing math anxiety has been shown to enhance attainment and improvement in mathematical and science proficiency. Hence, there is a need to address these anxieties to improve learner performance in STEM subjects. The study utilised a mixed-methods approach, incorporating both quantitative surveys and qualitative interviews, to investigate the prevalence and features of MSAEE in pre-service physical sciences teacher education programmes. Statistical and thematic analyses were employed to identify patterns and relationships within the data. The findings indicated that the majority of respondents acknowledged experiencing some degree of maths/sciences anxiety. Another noteworthy characteristic was the phobia of mathematics/science examinations and the inclination to recoil when the moment arrived to attend a maths/science lecture, however, over time, participants developed an interest in these courses and shared their self-efficacies in the subjects as they build resilience in maths and science. Findings from the research contribute to the understanding of the complex interplay between mathematics and science anxiety, and the preparation of pre-service teachers to provide insights for educators, policymakers, and researchers interested in enhancing the quality of STEM education.

Keywords: *Anxiety, mathematics, pre-service teacher, resilience, science.*

1. Introduction

In the realm of education, particularly within the STEM (Science, Technology, Engineering, and Mathematics) fields, the mental well-being of pre-service teachers (PSTs) is of paramount importance. Among the myriad challenges they face, anxiety surrounding mathematics and sciences stands out as a significant concern (Hussein & Csíkos, 2023; Megreya et al., 2021). This anxiety not only impacts the PSTs themselves but also has implications for the future generations of STEM students they will educate. Thus, it is imperative to delve into the dynamics of this anxiety and explore potential pathways to address it effectively. In recent years, there has been a growing recognition of the intricate relationship between anxiety and academic performance (Demedts et al, 2022), particularly within mathematics and sciences education. This nexus is specifically pronounced among PSTs, who not only navigate their anxieties but also bear the responsibility of nurturing resilience among their future students in STEM disciplines. Understanding this dynamic is essential for crafting effective interventions that foster a balanced equilibrium conducive to learning and personal growth.

Despite the acknowledgement of the prevalence of mathematics and sciences anxiety among PSTs, there exists a noticeable gap in the literature concerning the specific intersectionality of this anxiety

within the context of physical sciences education. Previous research has predominantly focused on generalized STEM anxiety or has primarily centred on either mathematics or science anxiety individually (Hussein & Csíkos, 2023; Rozgonjuk et al., 2020). Thus, there is a dearth of comprehensive studies that specifically address the unique nature, extent, and underlying factors contributing to this equilibrium in mathematics and science anxiety. Furthermore, while existing literature has identified various factors contributing to STEM anxiety, there is a lack of in-depth exploration into the interconnectedness and equilibrium dynamics between mathematics and science anxiety among PSTs. Understanding these intricate relationships is crucial for developing targeted interventions that can effectively disrupt the anxious-endemic equilibrium and foster resilience among both PSTs and their future students.

Against this background, this study aims to bridge these gaps in the literature by exploring the existence of mathematics-sciences anxious-endemic equilibrium among PSTs. By doing so, it seeks to pave the way for the development of resilience-building strategies that can ultimately enhance the quality of STEM education and promote the mental well-being of all stakeholders involved.

This research seeks to address the following key questions:

1. Is there a prevalence of Mathematics-Sciences Anxious-Endemic Equilibrium among PSTs?
2. How does MSAEE influence the teaching practices and efficacy of PSTs?
3. What are the strategies and interventions implemented to alleviate MSAEE and promote resilience among PSTs and their future students?

2. Literature

Anxiety, particularly mathematics anxiety, significantly hinders confidence, mathematical capability, and participation in STEM fields (Wang et al., 2020). Mathematical models have shown that there are distinct equilibrium points associated with anxiety behaviour and performance in mathematics, one of which is free from math anxiety and the other is endemic to it (Nathan & Jackob, 2020). Research indicates that PSTs with high levels of mathematics anxiety may struggle with teaching mathematics effectively (Boyd et al., 2014), and may project this anxiety onto their future students (Mizala et al., 2015). However, the anxiety experienced by PSTs is not limited to mathematics; it extends to other subjects like physics and chemistry, influencing their overall teaching practices (Putra et al., 2021). On the other hand, the literature has shown that there is a negative correlation between mathematics anxiety and mathematics teacher efficacy (Swars et al., 2006). Additionally, factors such as content knowledge, attitude towards mathematics, and self-efficacy play a role in influencing mathematics anxiety and teaching practices (Aksu & Kul, 2019). It is therefore essential to address PSTs' anxiety to enhance their teaching practices.

The concept of academic resilience is particularly relevant in the context of STEM education, where students often face high levels of attrition and challenges (Morganson et al., 2015). Building resilience among students, especially those from disadvantaged backgrounds, is essential for promoting academic success and persistence in STEM majors (Kuldas et al., 2014) and supporting students' achievement in mathematics and other STEM subjects (Ghazzawi et al., 2021). In a study by Para and Johnstone-Wilder, (2023), they argued for the inclusion of such tools as the Growth Zone Model in classroom practice to help build students' resilience. Interventions such as improving PSTs' mathematical beliefs can help reduce mathematics anxiety and enhance their teaching efficacy (Yuniarti et al., 2019).

3. Methodology

This longitudinal study was framed within Action Research methodology to address PST anxieties in mathematics and science and promote positive change as they build their resilience in these subjects. The method entails an iterative process of strategizing, implementing, monitoring, and reflecting allowing PSSTs to collaboratively work towards resilience (Narayanamurthy et al., 2017). A whole class intervention was implemented in a third-year class of 29 PSTs who were majoring in Physical Sciences and Mathematics. The main instruments were the questionnaires, interviews and PSTs reflective dairies. The questionnaire was adopted from the Betz scale (1978) MAR-S scale to measure both PSTs' anxiety in mathematics and sciences.

4. Results

4.1. Demographic profile of pre-service teachers

The sample consists of a majority of male PSTs, with nineteen males and ten females. All participants were in their third year at the university, suggesting they have progressed through their

academic program and are approaching the completion of their teacher education. While specific ages may vary, their age ranges from 20 years to 23 years. These participants have already completed their second field placements in educational settings, gaining practical experience working with students under the supervision of an experienced teacher.

4.2. Prevalence of mathematics-sciences anxious-endemic equilibrium

Tables 1 and 2 show an analysis of PSTs' anxiety levels in mathematics, physics and chemistry.

Table 1. Descriptive analysis.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Physics	Female	10	28,80	2,616	,827	26,93	30,67	24	33
	male	19	29,63	2,733	,627	28,31	30,95	24	34
	Total	29	29,34	2,676	,497	28,33	30,36	24	34
Maths	Female	10	29,30	3,164	1,001	27,04	31,56	25	35
	male	19	30,47	2,674	,614	29,18	31,76	25	35
	Total	29	30,07	2,853	,530	28,98	31,15	25	35
Chemistry	Female	10	30,80	1,932	,611	29,42	32,18	28	34
	male	19	29,74	2,806	,644	28,38	31,09	25	35
	Total	29	30,10	2,554	,474	29,13	31,08	25	35

Table 2. ANOVA.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Physics	Between Groups	4,531	1	4,531	,624	,436
	Within Groups	196,021	27	7,260		
	Total	200,552	28			
Maths	Between Groups	9,025	1	9,025	1,114	,301
	Within Groups	218,837	27	8,105		
	Total	227,862	28			
Chemistry	Between Groups	7,405	1	7,405	1,141	,295
	Within Groups	175,284	27	6,492		
	Total	182,690	28			

The Table 1 and 2 provide means, standard deviations, and F values for between-group differences in the total MAR-S. A one-way analysis of variance (ANOVA) was conducted, and the findings are presented in Table 2. In all the cases, the p values are higher than 0.05 which means no significant difference in the variables was observed. Hence, the conclusion is that there is no difference in PSTs' anxiety levels in mathematics, physics and chemistry. This means that PSTs experience anxiety in maths, physics and chemistry.

4.3. MSAEE influence on the teaching practices and efficacy of PSTs

Understanding the impact of math and science anxiety on teaching practices and efficacy is crucial, particularly for PSTs during their teaching practice. This theme seeks to delve into the intricate relationship between math and science anxiety and teaching practices, exploring how these factors intersect and influence one another, as was observed in the classroom and noted during the interviews. One participant responded:

> "*Well, as a PST, I've realized that my own anxieties about math and science can sometimes trickle down into my teaching practices. When I feel anxious about a particular concept or topic, I notice that I may rush through explanations or avoid certain activities altogether. This has impacted my confidence and efficacy because learners pick up on my hesitancy and become unsure or disengage themselves. Therefore, I've been actively working on addressing my anxieties through the interventions that have been introduced to my class by my lecturer. I am also seeking support from my mentors to ensure I can confidently teach these two subjects.*" (PSTA).

This sentiment was also observed during the researcher's teaching practice observations. The author observed that most of the PSTs rush through explanations of the key concepts in maths and physical science often due to their anxiety about these concepts, probably because they have low content knowledge and lack confidence to teach those subjects. Another PST reiterated that:

"*I have found that my own math and science anxieties have influenced the way I plan and deliver lessons. When I am anxious about a particular mathematical concept, I spend excessive time preparing for that lesson, sometimes at the expense of other important topics. This can lead to a lack of balance in my teaching and affect my efficacy as a teacher because I might not cover all the necessary material adequately and stick to more traditional teaching methods rather than incorporating hands-on or inquiry-based learning activities."* (PSTD).

4.4. Strategies to alleviate MSAEE and promote resilience

This theme delves into the exploration of various strategies aimed at alleviating math and science anxiety while concurrently promoting resilience among PSTs during lectures. When asked about strategies to reduce anxiety levels among the participants, they gave varied responses including growth mindset, reflection, supportive environment and tailoring instructional approaches. Participants narrated:

> *"My lecturers emphasized the importance of adopting a growth mindset. They encouraged us to view challenges as opportunities for growth and learning, rather than obstacles to our success. As they promote a positive attitude towards learning and development, they cultivated resilience and confidence in our abilities to effectively learn math and science concepts during lectures.*" (PSTB).

> *"My lecturers prioritize creating a supportive learning environment to foster open communication, encouraging questions, and providing additional resources to address any gaps in understanding. By acknowledging our anxieties and providing a safe space for learning, they helped to build our confidence in math and science and efficacy during teaching practice.*" (PSTC).

> *"We have been exposed to varied instructional strategies tailored with emotional tools like the use of the Growth Zone Model, relaxation response and the Hand Model of the Brain. These strategies have been implemented during lectures as we break down complex topics into smaller, more manageable parts to help us navigate through challenging content." The relaxation response model makes me relax as I tackle challenging problem-solving. This has allowed me to persevere in solving problems in math and science"* (PSTA).

5. Discussion

This study delves into the intricate balance of anxiety experienced by PSTs in mathematics and sciences. Results across a wide range of previous studies have indicated that mathematics and science anxiety occur frequently among students of all grades and even at higher institutions of learning and that it is more likely to occur in females than in males. This study found that PSTs experience anxiety in both mathematics, physics and chemistry (math mean = 30.07, SD = 2.853, F=1.114; physics mean =29.34, SD =2,676, F=.624; chemistry mean =30.10, SD =2.554, F=1.141) and that their anxiety levels are comparable among the population sampled for the study. This finding corroborates with Putra et al., (2021) study which found that the anxiety experienced by PSTs is not limited to mathematics; it extends to other subjects like physics and chemistry, influencing their overall teaching practices.

In addition, this study found that PSTs' anxiety influenced their teaching practices and efficacy, especially during teaching practice sessions, undermining their effectiveness as teachers. The literature reviewed has shown that there is a negative correlation between mathematics anxiety and mathematics teacher efficacy (Swars et al., 2006). Additionally, factors such as content knowledge, attitude towards mathematics, and self-efficacy play a role in influencing mathematics anxiety and teaching practices among PSTs (Aksu & Kul, 2019). Moreover, several studies have argued that PSTs with high mathematics anxiety may project this anxiety onto their students, leading to lower academic expectations (Mizala et al., 2015). It is therefore essential to address pre-service teachers' anxiety to enhance their teaching practices.

Furthermore, in this study PSTs were exposed to varied instructional strategies tailored to emotional tools like the use of the Growth Zone Model, relaxation response and the Hand Model of the Brain. These strategies have been implemented during lectures as complex topics were broken down into smaller, more manageable parts to help PSTs navigate through challenging content. According to Para and Johnstone-Wilder (2023), these tools should be embedded in teacher practice to help address anxiety in the context of mathematics.

6. Conclusions and recommendations

This study explored the existence of Mathematics and Science anxious equilibrium among PSTs in Physical Sciences. The study highlights the significant but frequently disregarded issue of anxiety among PSTs teachers and its potential implications for STEM education. The study reveals a state of existence of anxious equilibrium among the PSTs towards mathematics and science, which has a

substantial impact on how they teach these subjects and, subsequently, their practices. By acknowledging and dealing with this balance, policymakers and teachers may create strategies to cultivate resilience among STEM students, promoting a nurturing learning atmosphere that encourages academic achievement and sustained involvement in science and mathematics disciplines. This study highlights the significance of advocating for the well-being of teachers and addressing anxiety-related difficulties in STEM education to foster a flourishing and inclusive learning environment for all students.

Acknowledgements

The author gratefully acknowledges the funding provided by the National Research Foundation (NRF) to conduct this study and WSU for providing funding to attend this conference

References

Aksu, Z., & Kul, Ü. (2019). The mediating role of mathematics teaching efficacy on the relationships between pedagogical content knowledge and mathematics teaching anxiety. *Sage Open*, *9*(3).

Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psychology*, *25*(5), 441-448.

Boyd, W., Foster, A., Smith, J., & Boyd, W. (2014). Feeling good about teaching mathematics: addressing anxiety amongst pre-service teachers. *Creative Education*, *05*(04), 207-217.

Demedts, F., Reynvoet, B., Sasanguie, D., & Depaepe, F. (2022). Unravelling the role of math anxiety in students' math performance. *Frontiers in Psychology*, *13*, 979113.

Ghazzawi, D., Pattison, D., & Horn, C. (2021). Persistence of underrepresented minorities in STEM fields: are summer bridge programs sufficient? *Frontiers in Education, 6*.

Hussein, Y., & Csíkos, C. (2023). The effect of teaching conceptual knowledge on students' achievement, anxiety about, and attitude toward mathematics. *Eurasia Journal of Mathematics Science and Technology Education*, *19*(2), em2226.

Kuldas, S., Satyen, L., Ismail, H. N., & Hashim, S. (2014). Greater cognitive effort for better learning: Tailoring an instructional design for learners with different levels of knowledge and motivation. *Psychologica Belgica*, *54*(4), 350-373.

Megreya, A. M., Szűcs, D., & Moustafa, A. A. (2021). The abbreviated science anxiety scale: psychometric properties, gender differences and associations with test anxiety, general anxiety and science achievement. *Plos One*, *16*(2), e0245200.

Mizala, A., Martínez, F., & Martínez, S. (2015). Pre-service elementary school teachers' expectations about student performance: how their beliefs are affected by their mathematics anxiety and student's gender. *Teaching and Teacher Education*, *50*, 70-78.

Morganson, V. J., Major, D. A., Streets, V. N., Litano, M. L., & Myers, D. P. (2015). Using embeddedness theory to understand and promote persistence in STEM majors. *The Career Development Quarterly*, *63*(4), 348-362.

Narayanamurthy, G., Gurumurthy, A., & Chockalingam, R. (2017). Applying lean thinking in an educational institute – an action research. *International Journal of Productivity and Performance Management*, *66*(5), 598-629.

Nathan, O. M., & Jackob, K. O. (2020). Mathematical modelling and analysis of mathematics anxiety behaviour on mathematics performance in Kenya. *Journal of Advances in Mathematics and Computer Science*, *35*(4), 46-62.

Para, T., & Johnston-Wilder, S. (2023). Addressing mathematics anxiety: a case study in a high school in Brazil. *Creative Education*, *14*(02), 377-399.

Putra, P., Ahmad, N., Wahyuni, S., & Narulita, E. (2021). Analysis of the factors influencing of pre-service science teacher in the conceptualization of STEM education: self-efficacy and content knowledge. *Jurnal Penelitian Pendidikan Ipa*, *7*(Special Issue), 225-230.

Rozgonjuk, D., Kraav, T., Mikkor, K., Orav-Puurand, K., & Täht, K. (2020). Mathematics anxiety among STEM and social sciences students: the roles of mathematics self-efficacy, and deep and surface approach to learning. *International Journal of STEM Education*, *7*(46).

Swars, S., Daane, C., & Giesen, J. (2006). Mathematics anxiety and mathematics teacher efficacy: what is the relationship in elementary preservice teachers? *School Science and Mathematics*, *106*(7), 306-315.

Yuniarti, S., Ishak, M., & Pang, V. (2019). The influences of mathematical beliefs on mathematics anxiety among pre-service elementary school teachers in East Borneo, Indonesia. *Borneo International Journal of Education (Bije)*, *1*, 75-90.