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Examining gendered patterns in mathematics and science anxiety levels among physical science pre-service teachers

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Abstract

Mathematics and science anxiety among pre-service teachers is an important issue, particularly when considering its potential impact on their ability to teach mathematics and science effectively. This study explores the levels of mathematics and science anxiety among pre-service teachers and investigates if there are gendered patterns within this context. The study employs a quantitative research approach to collect and analyze data from a sample of pre-service teachers enrolled in science education program at one university in South Africa. The research design involves a non-experimental descriptive study approach, utilizing survey instruments to gather data on the responses of 29 female and 39 male pre-service teachers specializing in physical science education. The science-math anxiety scale questionnaire was employed to measure the levels of math, chemistry, and physics anxiety. A self-designed questionnaire was also developed to collect demographic information from pre-service teachers. The data was examined using statistical package for the social sciences, specifically version 29.0. Descriptive statistics were utilized to characterize the overall levels of math, chemistry, and physics anxiety in the sample. To explore gendered patterns, non-parametric statistics were employed to compare the mean of math, chemistry, and physics anxiety scores between male and female pre-service teachers. The study's findings revealed high levels of mathematics and chemistry anxiety among the participants, and especially among female pre-service teachers. The findings of this study have practical implications for teacher education programs aiming to create inclusive and supportive environments for pre-service teachers. Understanding the gendered nature of mathematics and science anxiety can inform the development of targeted interventions and pedagogical strategies that address the specific needs of male and female pre-service teachers. Ultimately, this study contributes to the ongoing discourse on math and science anxiety, emphasizing its relevance in the unique context of math and science education and the gendered dynamics that may shape pre-service teachers' experiences and, consequently, their effectiveness as future math and science teachers.

Keywords: anxiety, chemistry, mathematics, physical sciences, pre-service teachers, science

INTRODUCTION

Howie (2003) and Mullis et al. (2020) have expressed concerns about the poor academic performance of South African students in mathematics and sciences, since South Africa gained independence. This issue is widely recognized as a national crisis, drawing attention from both educational institutions and private sectors (Ubah et al., 2020). Each year, the Department of Basic Education (DBE) (2011, 2021, 2022) releases technical and diagnostic reports that provide an analysis of the secondary school exit exams and grade 12 results. The minimum threshold for learners to gain a certificate of completion is set at 30% for all subjects, with the exception of languages, which need a minimum score of 40%. The technical reports published by DBE (2011, 2021,

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Contribution to the literature

- The study makes a substantial contribution to the existing literature by emphasizing the intricate ways in which gender impacts anxiety levels in STEM education settings and presents empirical evidence about the disparity in anxiety levels between male and female pre-service teachers.
- The study offers to fill a major knowledge gap by examining how these anxieties are expressed and their possible effects on teaching effectiveness and career continuance. This provides teachers with the essential confidence and abilities to create a more inclusive and supportive learning environment.
- Moreover, the study provides crucial information for policymakers and educational stakeholders to develop specific initiatives to reduce anxiety and promote gender equality in STEM education. This not only enhances the scholarly discussion on gender and education but also establishes a basis for future investigations into the intersectional elements that impact preservice teachers' anxiety and performance.

2022) about the performance of grade 12 learners continue to indicate a dismal performance in these two subjects. Generally, the two patterns of results for the two subjects exhibit properties of a normal distribution curve, where there are percentage achievement decreases from average performance to higher achievements. Over the five years, an average of 12.6% of learners passed mathematics, and an average of 18.5% passed physical sciences with a pass percentage above 60%. These learners qualify to take STEM-associated bachelor's degrees if they meet the requirements and have minimum entry scores. Mji and Makgato (2006) highlighted a critical concern regarding the insufficient number of students qualified to enroll in universities and pursue STEM fields in South Africa due to the low status of mathematics and science literacy in the country's curriculum. This issue has important implications for the future workforce and the country's ability to compete globally in STEM (Ramonyai et al., 2022). Furthermore, the challenges faced by South African universities in recruiting STEM students have been linked to the broader issues of low performance to the existing educational landscape (Konyana, 2023). These challenges contribute to the limited pool of qualified individuals entering STEM fields, exacerbating the shortage of skilled professionals in critical areas of science and technology. Despite efforts by South African universities to implement extended degree programs to support students in transitioning to tertiary education, the weak outcomes of the education system continue to hinder the preparation of students for advanced studies in STEM fields (Mlachila & Moeletsi, 2019).

Similarly, South Africa's international performance in mathematics and sciences has been of concern over the years. South Africa's mathematics and science learners have come to the international spotlight since the trends in international mathematics and science study for grade 4 and grade 8. The national average for South Africa's mathematics and science success scores increased from "extremely low" in 1995, 1999, and 2003 to "low" in 2011 and 2015 (Mullis et al., 2020). According to Mullis et al. (2020), South Africa's mathematics and science performance scores, which were categorized as "extremely low" in 1995, 1999, and 2003, improved to a "low" level in 2011 and 2015. Mullis et al. (2020) argue that South Africa has a comparatively lower performance in mathematics and science when compared to the other nations. In their study, Sithole et al. (2017) observed that 45 percent of first-year students had severe difficulty with mathematics, which is crucial to competencies in STEM programs, and they blame the high dropout rate in STEM degrees on not understanding mathematics.

High dropout rates observed in STEM degree programs in numerous nations worldwide are frequently ascribed to new undergraduate students' inadequate mathematics and scientific readiness (Deeken et al., 2020). In the South African context, to improve the rate at which STEM students continue their studies, it is important to address the underlying reasons for the high failure rate in mathematics and science disciplines at the secondary school level.

According to Elias and Arnold (2006), developing students' emotional features is just as important as the growth of their cognitive characteristics in the teaching-learning process.

However, researchers assert that cultivating emotional attributes associated with math and science has been emphasized as crucial in education (Adolphus & Otuturu, 2022). Research also indicates that the emotional aspect plays a crucial role in math and science education, not only for academic success and cognitive skill development but also for instilling moral and ethical values in students and nurturing favorable attitudes towards social matters (Khalil et al., 2014). Hence, it is important to include emotional and cognitive traits to enhance math and science education. Anxiety is one of the emotional traits that impact the math and science learning process.

Anxiety is the psychological condition experienced by an individual when confronted with a situation that is perceived as challenging or threatening, resulting in a sense of unease and restlessness (Mallow, 2006). These situations elicit emotional and physiological stimulation in individuals (Hodgin, 2014). Research has demonstrated that math and science anxiety is the

apprehension and fear individuals experience towards math and science concepts which manifests as feelings of nervousness, tension, and fear, which at higher levels can hinder students' capacity to effectively solve math and science-related problems (Ganley et al., 2019; Horne, 2022). A high level of anxiety has been revealed to interfere with cognitive processing by impairing the continuing activity in the working memory, which in turn affects performance in timed and high-pressure situations (Ashcraft, 2002; Ashcraft & Moore, 2009).

Despite the importance of math and science in academic and professional pursuits, many pre-service teachers experience high levels of anxiety when faced with math and science-related problems (Megreya & Al-Emadi, 2023). This phenomenon poses a substantial obstacle to achieving successful learning and proficiency in math and science, potentially leading to negative outcomes such as low performance, avoidance of math and science-related tasks, and a decline in overall academic self-efficacy (Avci & Kirbaslar, 2017). Understanding the many and varied elements of student anxiety in math and science is crucial for developing targeted interventions and creating a supportive learning environment to support students' achievement in STEM. Against this background, the objective of this study is to examine the levels of math and science anxiety among pre-service teachers and to determine how their math and science anxiety levels are gendered. By identifying and conducting a comprehensive inquiry into the various degrees of anxiety, teachers, researchers, and policymakers can gain valuable insights into the underlying factors that contribute to math and science anxiety. This will facilitate the development of evidence-based interventions to alleviate this issue.

The study is guided by the following questions:

1. "What is the assessed level of mathematics and science anxiety among second-year pre-service physical science teachers?"
2. "To what degree in mathematics and science anxiety influenced by gender among second-year pre-service physical science teachers?

The study is guided by the following hypotheses:

1. **Null hypothesis (H_o).** There is no statistically significant difference in chemistry, mathematics, and physics anxiety between male and female physical sciences pre-service teachers in science education programs.
2. **Alternative hypothesis (H_1).** There is a statistically significant difference in the chemistry, mathematics, and physics anxiety levels between male and female physical sciences pre-service teachers in science education programs.

LITERATURE REVIEW

Conceptualizing Mathematics and Science Anxiety

Mathematics anxiety involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations" (Richardson & Suinn, 1972, p. 551). At first, mathematics anxiety was conceptualized as a one-dimensional notion. However, later investigations indicated that it is actually a multidimensional concept (Kazelskis, 1998).

This phenomenon is characterized by emotional distress and physiological reactions, such as sweating, rapid heartbeat, and intrusive thoughts, that disrupt cognitive resources required for math problem-solving (Beilock & Maloney, 2015). Research indicates that math anxiety can manifest in various forms, including worry, discomfort, and fear related to mathematical concepts, theories, formulas, problem-solving, and assessments (Prasetyo et al., 2023). Studies have shown that mathematics anxiety affects students' learning and performance in math courses, potentially limiting their future opportunities in the field (Akbayir, 2019; Arianto et al., 2021). Research has indicated that teachers' anxiety towards mathematics can have an influence on students' academic performance in mathematics and their evaluation of their teachers' attitudes towards the subject (Ramirez et al., 2018; Schaeffer et al., 2021). This underscores the need of tackling teachers' anxiety issues in educational environments.

On the other hand, science anxiety is defined as "a debilitating combination of fearful negative emotion and cognition in the context of science learning" (Bryant et al., 2013, p. 432). Science anxiety can be defined as the apprehension and stress that can arise prior to or during the process of learning science (Bryant et al., 2013; Mallow, 2010). However, it should be noted that science anxiety is distinct from performance or test anxiety, as well as math anxiety. Various factors have been proposed as potential causes of science anxiety, including gender appropriateness parental expectations and teachers' perspectives and attitudes (Cherian & Siweya, 1996; Uçak & Say, 2019). Several anecdotal studies suggest that students are exposed to negative notions about science during their academic years (Mallow, 2006). Nevertheless, the existing body of work on science anxiety levels among students mostly centers around understanding the adverse emotions linked to the process of acquiring science knowledge. In other studies, a positive correlation was shown between high science anxiety and low levels of science success, science vocabulary understanding and self-efficacy (Ardasheva et al., 2018; Griggs et al., 2013). Moreover, studies have demonstrated that students pursuing the arts track have high levels of both science anxiety and math anxiety in comparison to their counterparts in the sciences track

(Megreya & Al-Emadi, 2023). This implies the existence of subject-specific disparities in anxiety levels among students. Research has also investigated the influence of instructional cognitive load on students' anxiety levels and their psychological orientations (Adolphus & Otuturu, 2022; Martin et al., 2021). It is essential to comprehend the components that contribute to science anxiety and their impact on students' learning experiences. This understanding is critical for establishing successful strategies to reduce anxiety and foster positive emotional traits in science education.

The issue of math and science anxiety among pre-service teachers is an important concern in the field of education, with implications for teacher efficacy and student learning outcomes. Studies have indicated that pre-service teachers often exhibit higher levels of math anxiety compared to other undergraduate majors, which may lead them to actively avoid math coursework (Park, 2024). Additionally, research has shown that pre-service teachers with high math anxiety levels may perform poorly in math teaching (Alico et al., 2017), underscoring the importance of addressing anxiety issues early in teacher training programs. Moreover, the relationship between math anxiety and students' math achievement has been explored, indicating that low math anxiety pre-service teachers may exhibit higher confidence in teaching primary mathematics and science (Garcia & Bana, 2022). Furthermore, studies have shown that teacher confidence and math anxiety are negatively correlated, emphasizing the importance of nurturing teacher confidence to mitigate math anxiety among pre-service teachers (Lau et al., 2022). In their study, Efe and Efe (2016) conducted a comparative study of anxiety levels among pre-service science teachers in Switzerland and Turkey. They discovered notable disparities based on gender, country, and age, suggesting that cultural and demographic factors can influence science anxiety in pre-service teachers. Similarly, research conducted by Kurbanoğlu and Akin (2010) identified multiple factors contributing to chemistry laboratory anxiety. These factors include previous negative encounters in science classes and being taught by anxious science teachers. Putra et al. (2021) highlighted that the anxiety among pre-service science teachers might impact their competence in teaching science in the classroom. This emphasizes the need to address science anxiety to maintain a high standard of science education.

Gender Differences in Mathematics and Science Anxiety

Gender differences in math and science anxiety levels among students have been a subject of interest in academic research. Several studies have delved into this topic, shedding light on the disparities that exist between male and female students when it comes to anxiety related to mathematics (Delage et al., 2022; Morán-Soto & Peña, 2022; Mweni et al., 2023; Richland et al., 2020). The findings from these studies consistently point towards a trend where female students tend to experience higher levels of mathematics anxiety compared to their male counterparts. This gender gap in mathematics anxiety seems to manifest early on, even at the secondary school level, indicating that female students may face more anxiety when engaging in math-related tasks, especially as educational demands increase (Morán-Soto & Peña, 2022). Moreover, research has shown that while there may not always be statistically significant differences in mathematical performance between genders, females often exhibit more negative attitudes towards mathematics and higher levels of test anxiety (Richland et al., 2020). This suggests that the disparity in mathematics anxiety levels between male and female students could be attributed to factors beyond just performance, such as attitudes and perceptions towards the subject. Studies have indicated that female students, in comparison to males, may have debilitating causal attribution patterns, perceive mathematics as a male-dominated domain, and exhibit higher levels of anxiety towards mathematics, which can negatively impact their academic performance (Mweni et al., 2023). This suggests that addressing mathematics anxiety, particularly among female students, could be crucial in improving overall achievement in the subject.

On the contrary, studies such as Asikhia's (2021) have identified gender differences in mathematics anxiety, with findings indicating that male students may experience higher levels of mathematics anxiety compared to their female counterparts. This insight into gender-specific variations in anxiety levels can inform targeted strategies to alleviate anxiety and create a more inclusive learning environment for all students.

Research on gender differences in science anxiety suggests that there may be variations in how males and females experience anxiety in science-related academic settings. Some studies show that science anxiety varies based on gender, and female students are more anxious (Ardasheva et al., 2018; Mallow, 2006). Conversely, a study found a direct relationship between gender and science anxiety among fifth-grade students, indicating that boys experienced higher levels of science anxiety compared to girls (Megreya et al., 2021). However, there was no gender disparity in self-efficacy towards science. Some studies have indicated that female students are more prone to experiencing heightened levels of anxiety in STEM classroom environments (Rozgonjuk et al., 2020). Other studies investigating the impact of gender on science anxiety found no substantial disparity between female and male students' levels of science anxiety (Avci & Kirbaslar, 2017; Kahyaoğlu et al., 2019). Nevertheless, some studies have failed to identify any gender-related impact on science anxiety among university students (Şahin, 2014). In their study, Cotner et al. (2020) discovered that there were slight differences between genders in the levels of reported test anxiety.

However, they did not find any specific impact of test anxiety on performance in a biology class based on gender. While some research studies have found variations in science anxiety between genders, other investigations have not observed any notable disparities.

THEORETICAL FRAMEWORKS

The Implicit Theory of Intelligence

The study was framed within the implicit theory of intelligence, a mindset theory (MT), as one of its theoretical frameworks. Psychologist Dweck (2012a) is credited with formulating MT. In the 1970s, she began researching mindsets after observing the distinct ways in which young individuals reacted to challenges and setbacks. Dweck (2012a) found that whereas certain children consciously evaded barriers, others eagerly pursued them. Dweck and her colleague Mary Bandura ultimately investigated whether an individual's reaction to challenges is influenced by their perception of failure, specifically their belief in the fixed nature of talent. Put simply, the question is whether failure serves as a demotivating or inspiring force for individuals. This revelation prompted Dweck and her colleagues to undertake extensive research, investigating these underlying concepts in several domains, including interpersonal relationships and academic and professional achievement. Dweck and Legget (1988) introduced the MT, also referred to as the implicit theory of intelligence. This theory posits that individuals can adopt one of two attitudes towards intelligence: a fixed or entity mindset, or a growth or incremental mindset.

Advocates of entity theory argue that nature predetermines intellect as an immutable attribute. In contrast, advocates of the incremental approach assert that intelligence is a malleable and expandable characteristic that may be developed by training (Dweck & Legget, 1988; Yeager & Dweck, 2020). According to mindset theorists, the underlying beliefs about intelligence may greatly influence one's drive to study. These theorists argue that one's notions about intelligence can affect one's motivation, attitude, and conduct. As argued by Shenk (2010), attitudes towards intelligence may greatly influence performance, regardless of the factual nature of intelligence. Success is contingent upon one's underlying viewpoint; when students adopt the belief that intelligence is pliable (a growth mindset), they are more inclined to see the need to exert effort, commitment, and passion in pursuing knowledge.

The fundamental principle of MT is that intellect can be enhanced and cultivated through exertion. Individuals with a fixed perspective on intellect tend to shy away from challenges or quickly surrender in the face of adversity. In addition, such individuals will ignore adverse remarks and perceive the effort as futile. Conversely, students with a growth mindset have a solid motivation to acquire knowledge and develop themselves. They embrace difficult tasks, persist in the face of obstacles, internalize feedback, and perceive effort as an essential element of progress. Despite facing challenges and setbacks in various math and science topics, student teachers with a growth attitude towards mathematics will be motivated and make progress in their learning of the subject. Considering performance drivers, such as attitudes, problems, hurdles, effort, and success, can elucidate the factors influencing motivation and desire to study among students. The principles facilitate comprehension of individuals' cognitive processes and behavioral patterns when they are required to succeed.

Pre-service teachers' implicit theory of intelligence will impact their inclination to develop resilience against the backdrop of mathematical anxiety. The implicit theory of intelligence adopted by preservice teachers is important in shaping their abilities to build resilience to overcome mathematical anxiety. The theory has the potential to influence their perceptions of students' capabilities and can intrinsically motivate and effect strategies that overcome mathematical anxiety. A conceptual understanding of the growth mindset, as suggested by the implicit theory of intelligence, can lead to more robust teaching methods and support systems that enhance students' resilience.

METHODOLOGY

This paper emanates from a large project with the mathematics resilience network (Southern Africa Branch), which aims, through action research, to develop anxiety-informed practices among STEM lecturers and their students in five universities. This paper reports on one university in South Africa. Justifying the suitability of a quantitative research strategy for this study is its emphasis on quantifying and evaluating numerical data (Fischer et al., 2014). The objectives of this study involve determining the level of math and science anxiety and evaluating gender differences, both of which can be quantified through structured measurements. This design provides a systematic and structured approach to collecting and analyzing data, allowing for statistical comparisons and the generalizability of findings to larger populations.

The present study adopts a quantitative exploratory and descriptive approach. An exploratory design is characterized by its primary focus on acquiring ideas and insights (De Vos et al., 2011). The choice of an exploratory and descriptive research design in a quantitative study offers a robust framework for investigating and understanding complex phenomena in students' anxiety. An exploratory approach allowed the researchers to delve into the multifaceted aspects of anxiety, uncovering underlying patterns and potential

variables that influence anxiety levels. In addition, the descriptive research design provides a systematic and standardized approach to measure and characterize the extent of anxiety quantitatively, offering a detailed portrayal of anxiety levels among the study population. This approach is essential for capturing the prevalence and nuances of anxiety within the specific context under study, such as among students and within math and science discipline. Moreover, integrating exploratory and descriptive approaches aligns with the call for interdisciplinary research, integrating insights from diverse math and science areas to enrich the understanding of anxiety in educational and social contexts.

Sample

The target population was university undergraduate students. The study participants were 2nd year undergraduate pre-service teachers from one university in South Africa, who were either majoring in physical sciences (option A or option B) or mathematics (option A and B) but had registered for mathematics 2 and physics 2/chemistry 2 for the 2023 academic year. Most importantly, these courses were compulsory for students to fulfil their curriculum requirements and were necessary prerequisites for other courses in the curriculum. All 87 pre-service teachers in the class were invited to participate in the study, and 68 of them answered. There were 29 females and 39 males.

Data Collection Tools and Data Collection Procedure

The researchers adapted the science-math anxiety scale questionnaire (S-MASQ) from Betz's (1978) original version. The Betz (1978) S-MASQ scale has gained considerable recognition for effectively determining the extent of anxiety related to mathematics and science. It has also played a crucial role in establishing the connection between anxiety and academic performance and career decisions. Studies conducted by Betz (2004) and Megreya et al. (2021) have documented this recognition. Various studies have used this tool to measure math and science anxiety, providing valuable insights into the psychological and emotional aspects of learning mathematics and science (Megreya et al., 2021; Pizzie & Kraemer, 2019). The scale has also been adapted and modified to suit specific research contexts, such as the modified abbreviated math anxiety scale (m-AMAS) and the abbreviated science anxiety scale (ASAS), demonstrating its versatility and applicability in diverse research settings (Megreya et al., 2021; Pizzie & Kraemer, 2019). The instrument exhibits strong test-retest, ensuring consistency and reliability in measuring anxiety scores over time.

The instrument consists of 10 Likert-type items, each offering five response alternatives that range from 1 (strongly disagree) to 5 (strongly agree). There are five items with positive wording and five ones with negative wording. The questionnaires were administered to the pre-service teachers after obtaining ethical clearance and participants' consent. The instrument consists of two parts. Section A contained questions focusing on the demographic information of participants. Section B was based on the standardized survey (S-MASQ). The participants were instructed to indicate their level of agreement with the items using a 5-point scale, where 1 represents strongly disagreement, 2 represents disagreement, 3 represents neutrality, 4 represents agreement, and 5 represents strong agreement. The independent variable in this study was gender, while the dependent variable was the S-MASQ scores. The study achieved a response rate of 78 percent.

Data Analysis

The data was analyzed using the statistical package for the social sciences, specifically version 29.0. The data items 2, 3, 4, 6, and 7 were recorded using reverse scoring. This was done to maintain consistent question directionality. A high aggregate score on the S-MASQ would indicate a substantial degree of perceived high level of anxiety. In contrast, a low aggregate score would indicate a low perceived anxiety.

At first, an assessment was carried out to confirm the accuracy, dependability, and conformity of the data. An analysis of descriptive statistics was conducted to ascertain the frequency distribution of the average scores. Diverse statistical models were utilized to evaluate the influence of the independent variable (gender) on the dependent variable (anxiety levels in chemistry, math, and physics). The study utilized descriptive statistics and the Mann-Whitney U test to compare the anxiety levels of two independent variables, male and female.

Validity and Reliability

The S-MASQ has demonstrated satisfactory internal consistency and test-retest reliability in previous studies (Dew et al., 1984; Johnston-Wilder et al., 2014; Pajares & Urdan, 1996). Internal validity in quantitative research is ensured by limiting any confounding factors that might provide alternative interpretations for the observed results (Cohen et al., 2017). The S-MASQ questionnaire, which has been standardized, already meets the requirements for content and construct validity. One researcher was present throughout the questionnaire administration to address any doubts the respondents may have had. One researcher administered information sheets to inform the participants about "the purpose of the study, study methods, time required to participate, their right to ask questions or withdraw at any time and" that there are no "potential risks or benefits" in taking part (López-Alvarado, 2017, p. 3) so that the participants could make informed decisions if to participate or not.

Table 1. Demographic profile of pre-service teachers

Variable	Frequency	Percentage (%)
Gender		
Female	29	42.6
Male	39	57.4
Total	68	100
Age		
18-19	25	36.7
20-21	32	47.1
22 and above	11	16.2
Total	68	100

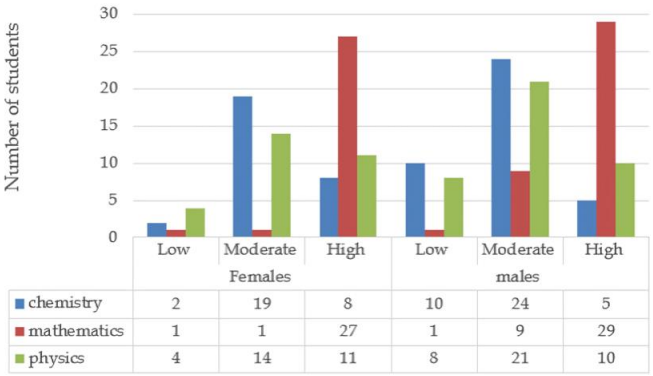

Figure 1. Pre-service teachers' anxiety levels per subject (Source: Authors' own elaboration)

RESULTS

Response Rate

The analysis of the questionnaires revealed a high proportion of responses from the research participants. Upon finalizing the data-gathering phase, the final tally of completed questionnaires amounted to 68. The research had a population size of 87, resulting in a response rate of 78%. Due to the characteristics of the data collection, the data is shown as trends and analyzed using inferential methods. Initially, a distinct description of the data is provided for each metric, namely chemistry, mathematics, and physics anxiety levels and gender disparities. The focus here is on how variables are distributed based on the students' anxiety levels.

Background Profile of Pre-Service Teachers

Demographic data about the respondents shows that 39 (57.4%) were males and 29 (42.6%) were females. The majority, 32 (47.1%) of the participants, were in the 20-21 years category (**Table 1**).

Prevalence of Math and Science Anxiety Among Pre-Service Teachers

Table 2 shows a summary of descriptive statistics calculated for the level of anxiety in mathematics, chemistry, and physics among 2nd year pre-service teachers. The observations for chemistry had an average of 30.22 (standard deviation [SD] = 3.29, SE_M = 0.40, min = 23.00, max = 38.00, skewness = 0.12, kurtosis = 0.23, mode = 30.00, median [Mdn] = 30.00). The observations for physics had an average of 30.44 (SD = 3.11, SE_M = 0.38, min = 24.00, max = 37.00, skewness = -0.24, kurtosis = -0.68, mode = 33.00, Mdn = 31.00). The observations for mathematics had an average of 34.97 (SD = 3.68, SE_M = 0.45, min = 25.00, max = 42.00, skewness = -0.64, kurtosis = 0.45, mode = 36.00, Mdn = 35.00). If the absolute value of the skewness is larger than 2, the variable is regarded as having asymmetry with respect to its mean. When the kurtosis is greater than or equal to 3, the variable's distribution deviates notably from a normal distribution in its propensity to generate outliers (Westfall & Henning, 2013). **Table 2** contains the summary statistics.

Table 2 further demonstrates that the degrees of anxiety related to chemistry varied between a minimum value of 23 and a maximum value of 38. The levels of anxiety related to physics varied between a minimum of 24 and a maximum of 37. The range of math anxiety scores varied between 25 and 42. The scores were utilized to ascertain the pre-service teachers' varying anxiety levels in chemistry, mathematics, and physics. More precisely, scores falling within the range of 24 to 27 were categorized as indicating low levels of anxiety, scores ranging from 28 to 32 were categorized as indicating moderate levels of anxiety, and scores ranging from 33 to 42 were categorized as indicating high levels of anxiety. **Figure 1** illustrates the distribution of anxiety related to chemistry, mathematics, and physics among pre-service teachers, categorized accordingly.

From **Figure 1**, it is observed that 12 (17.7%) of the participants have low anxiety levels in chemistry, 43 (63.2%) participants have moderate anxiety levels in chemistry and 13 (19.1%) participants have high anxiety levels in chemistry. This implies that 56 (82.4%) of participants have between moderate and high anxiety levels in chemistry. The graph in **Figure 1** further illustrates that 2 (2.9%) of the participants have low anxiety levels in math, 10 (14.7%) participants have moderate anxiety levels in math, and 56 (82.4%) participants have high anxiety levels in math. This implies that 66(97%) of participants have between moderate and high anxiety levels in math. This shows that math is the subject in which most participants experience higher levels of anxiety.

Table 2. Descriptive statistics

Variable	Mean	SD	n	SE_M	Min	Max	Skewness	Kurtosis	Mode	Mdn
Chemistry	30.22	3.29	68	0.40	23.00	38.00	0.12	0.23	30.00	30.00
Physics	30.44	3.11	68	0.38	24.00	37.00	-0.24	-0.68	33.00	31.00
Math	34.97	3.68	68	0.45	25.00	42.00	-0.64	0.45	36.00	35.00

Additionally **Figure 1** shows that 12 (17.7%) of the participants have low anxiety levels in physics, 35 (51.4%) participants have moderate anxiety levels in physics and 21 (30.9%) participants have high anxiety levels in physics. This implies that 56 (82.4%) of participants have between moderate and high anxiety levels in physics. A further noteworthy characteristic was that a considerable proportion of participants experienced moderate to high levels of chemistry (n = 56; 82.4%), math (n = 66; 97%) and physics (n = 56; 82.4%) anxiety. It is worth commenting that in mathematics, almost all participants (66 out of 68) showed moderate or High anxiety and had a predisposition to experience discomfort when confronted with math-related activities. Hence, anxiety in mathematics is commonly high in this group of pre-service teachers. Furthermore, it is worth noting that there is a statistically significant difference between levels of anxiety per subject. Therefore, it is evident that the participants experienced different anxiety levels under different situations and tasks. In particular, mathematics anxiety is statistically significantly higher than in physics or chemistry. There is no statistically significant difference in anxiety between physics and chemistry.

Gender Patterns of Math and Science Anxiety Among Pre-Service Teachers

We utilized diverse statistical models to evaluate the influence of the independent variable (gender) on the dependent variables (anxiety levels in chemistry, math, and physics). The statistical analysis used in this study was the Mann-Whitney U test, which was used to compare two independent variables (male and female) on a continuous variable (the scores for chemistry, math, and physics anxiety).

Hypothesis testing

The null hypothesis (H_o). There is no statistically significant difference in the levels of anxiety related to chemistry, mathematics, and physics between male and female pre-service teachers specializing in physical sciences education program.

Alternative hypothesis (H_1). There is a statistically significant difference in the levels of anxiety related to chemistry, mathematics, and physics between male and female pre-service teachers specializing in physical sciences within science education program.

A two-tailed Mann-Whitney two-sample rank-sum test was performed to see if there were any statistically significant differences in mathematics scores based on Gender. The two-tailed Mann-Whitney two-sample rank-sum test is a substitute for the independent samples t-test. However, it does not rely on the same assumptions (Conover & Iman, 1981). The Mann-Whitney U test is a non-parametric test employed to compare two independent groups with ordinal data that is not normally distributed. The test is useful when the assumptions of the parametric t-test are violated. The non-parametric test allows a strong comparison of anxiety scores between genders without the need for the data to satisfy strict parametric assumptions.

Table 3. Two-tailed Mann-Whitney test for math by gender

Variable	Female		Male		U	z	p
	Mean rank	n	Mean rank	n			
Math	43.34	29	27.92	39	822.00	-3.20	.001

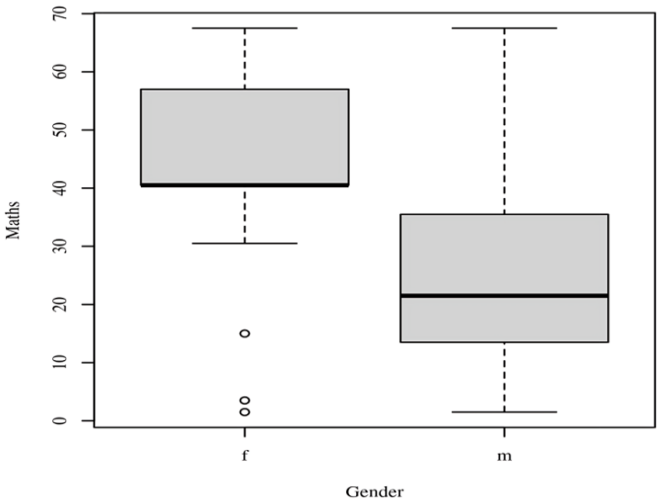

Figure 2. Ranks of math by gender (Source: Authors' own elaboration)

The female group consisted of 29 observations, while the male group had 39 observations. The two-tailed Mann-Whitney U test yielded a statistically significant result with an alpha value of .05. The test statistic U was 822, the z-score was -3.20, and the p-value was .001. The average mean rank for the female group was 43.34, while the average mean rank for the male group was 27.92. This indicates that the distribution of mathematics scores among female students was noticeably distinct from the distribution of mathematics scores among male students. The Mdn age for females (Mdn = 36.00) was substantially higher than the Mdn age for males (Mdn = 34.00). The outcome of the two-tailed Mann-Whitney U test is displayed in **Table 3**. **Figure 2** displays a boxplot illustrating the rankings of mathematics according to gender.

Figure 2 displays a boxplot that visualizes the distribution of mathematical anxiety levels among males and females. **Figure 2** illustrates that girls exhibit higher levels of mathematics anxiety compared to boys. This indicates a notable disparity in anxiety levels between females and when it comes to mathematics. Females exhibit higher levels of anxiety in mathematics compared to males.

A two-tailed Mann-Whitney two-sample rank-sum test was performed to investigate if there were any statistically significant differences in physics

Table 4. Two-tailed Mann-Whitney test for physics by gender

Variable	Female		Male		U	z	p
	Mean rank	n	Mean rank	n			
Physics	37.36	29	32.37	39	648.50	-1.04	.300

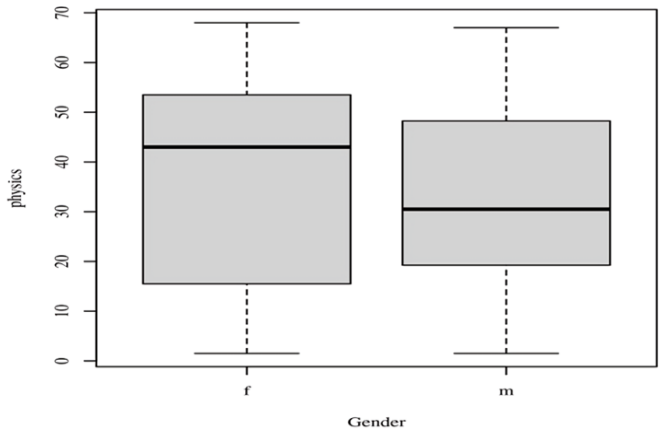

Figure 3. Ranks of physics by gender (Source: Authors' own elaboration)

Table 5. Two-tailed Mann-Whitney test for chemistry by gender

Variable	Female		Male		U	z	p
	Mean rank	n	Mean rank	n			
Chemistry	39.95	29	30.45	39	723.50	-1.97	.049

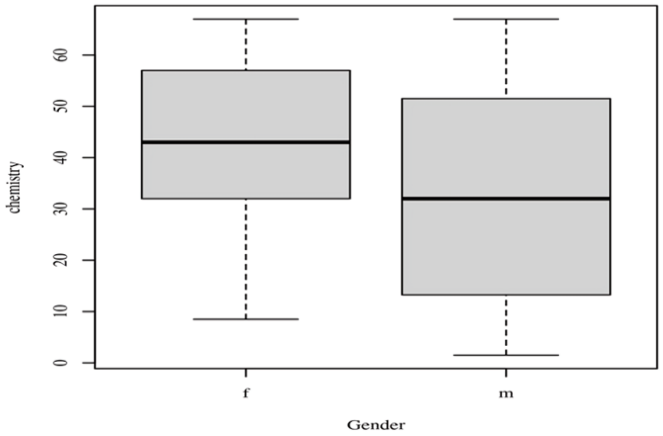

Figure 4. Ranks of chemistry by gender (Source: Authors' own elaboration)

performance across different genders. The group labelled as "female" consisted of 29 observations, while the group labelled as "male" consisted of 39 observations. The outcome of the two-tailed Mann-Whitney U test did not yield a statistically significant result, given an alpha level of .05. The test statistics were, as follows: U = 648.5, z = -1.04, p = .300. The mean rank for the female group was 37.36, while the mean rank for the male group was 32.37. This indicates that there was no statistically significant difference between the distribution of physics scores for females (Mdn = 32.00) and males (Mdn = 30.00). The outcome of the two-tailed Mann-Whitney U test is displayed in **Table 4**. **Figure 3** displays a boxplot illustrating the rankings of physics according to gender.

Figure 3 displays a boxplot that visualizes the distribution of physics anxiety levels among males and females. **Figure 3** indicates that the distribution of physics scores for the female group was not substantially distinct from the distribution of physics scores for the male group. This indicates that there is no statistically significant difference in anxiety levels between females and males in physics.

A two-tailed Mann-Whitney two-sample rank-sum test was performed to investigate if there were any statistically significant differences in chemistry based on gender. The female group consisted of 29 observations, while the male group consisted of 39 observations. The two-tailed Mann-Whitney U test yielded a statistically significant result with an alpha value of .05. The test statistics were U = 723.5, z = -1.97, and p = .049. The mean rank for the female group was 39.95, while the mean rank for the male group was 30.45. This indicates that the distribution of chemistry scores among females was noticeably distinct from the distribution of chemistry scores among males. The Mdn value for the variable female (Mdn = 31.00) was significantly higher than the Mdn value for the variable male (Mdn = 30.00). The outcome of the two-tailed Mann-Whitney U test is displayed in **Table 5**. **Figure 4** displays a boxplot illustrating the rankings of chemistry according to gender.

Figure 4 shows a boxplot that visualizes the distribution of chemistry anxiety levels among males and females. The data shown in **Figure 4** indicates that females exhibit higher levels of chemistry anxiety compared to males. This indicates a notable statistically significant difference in anxiety levels between females and males in chemistry. Females show higher levels of anxiety chemistry compared to males. This indicates that the distribution of chemistry scores among females was considerably statistically significant different from the distribution of chemistry scores among males.

DISCUSSION

This study examined the level of anxiety related to chemistry, mathematics, and physics, as well as its association with gender, among a group of pre-service teachers in their second year of study. The study was based on the Implicit Theory of Intelligence, which is a theoretical foundation for understanding mindset. Dweck (2012b) developed this hypothesis in order to explain the varying ways in which people react to challenges and setbacks. Despite the small sample size of 68 pre-service teachers, the summary of descriptive statistics reveals that among 2nd - year pre-service teachers, the average level of anxiety in mathematics,

chemistry, and physics was 30.22 in chemistry (SD = 3.29, SEM = 0.40, min = 23.00, max = 38.00, skewness = 0.12, kurtosis = 0.23, mode = 30.00, Mdn = 30.00). The physics observations had a mean of 30.44, with a standard deviation of 3.11. The standard error of the mean was 0.38. The minimum value observed was 24.00, while the maximum value was 37.00. The skewness of the data was -0.24, indicating a slight leftward skew. The kurtosis was -0.68, suggesting a platykurtic distribution. The mode of the data was 33.00, and the Mdn was 31.00. The average score for the mathematics observations was 34.97, with a standard deviation of 3.68. The standard error of the mean was 0.45. The minimum score was 25.00, while the maximum score was 42.00. The skewness of the distribution was -0.64, and the kurtosis was 0.45. The mode of the distribution was 36.00, and the Mdn was 35.00. This finding indicates that the participants experience different levels of anxiety in these subjects.

This finding corroborates previous research indicating a high incidence of anxiety symptoms, chemistry, math, and physics, among students (Khafizova et al., 2024; Li et al., 2022; Megreya et al., 2024; Para, & Johnston-Wilder, 2023). An additional noteworthy finding was that a considerable proportion of participants, experienced moderate to high levels of anxiety in chemistry (82.4%), math (97%), and physics (82.4%) when their scores were utilized to assess the different degrees of anxiety in these subjects. Notably, mathematics anxiety was the highest among this group, with 97% of participants reporting high levels of anxiety. Hence, it is evident that pre-service teachers experienced different levels of anxiety when faced with different scenarios and activities. This finding is consistent with the study conducted by George and Mitchell (2022), which discovered a considerable degree of high level of mathematics anxiety among the student population. While anxiety levels did not vary between chemistry and physics, the participants reported experiencing moderate to high levels of anxiety in both disciplines. Mallow (2006) found that students with high levels of anxiety towards science are more inclined to avoid science and STEM-related disciplines. This finding supports another study conducted by Dowker et al. (2016) that demonstrates a notable discrepancy in the occurrence of science anxiety. Consequently, pre-service teachers may have different levels of science anxiety, which could potentially impact their comprehension and approach to STEM instruction. According to the study conducted by Putra et al. (2021), there is a correlation between science anxiety among pre-service science teachers and their ability to effectively teach science in the classroom. This underscores the necessity of tackling science anxiety to uphold the caliber of science education in South Africa. According to the Theory of mindset, students deliberately avoid problem-solving, while others actively seek out chances for problem-solving. This suggests that there are variations in anxiety levels among students that are particular to certain subjects. When assisting pre-service teachers in enhancing their confidence and effectiveness in teaching science, it is crucial to take these elements into account.

Another key finding from the study was the gender patterns of anxiety among the participants. The study found that the mean rank in math for females was 43.34 and the mean rank for males was 27.92. This suggests that the distribution of math for females was significantly higher than that of males. This implies that there is a statistically significant difference in anxiety levels between females and males in math. Females are more anxious in math than males. Similarly, the mean rank in physics for the group female was 37.36 and the mean rank for the group male was 32.37. This suggests that the distribution of physics for group female (Mdn = 32.00) was not significantly different from the distribution of physics for the male This implies that there is no statistically significant difference in anxiety levels between females and males in physics. In chemistry, the study found that the mean rank for the group female was 39.95 and the mean rank for the group male was 30.45. This suggests that the distribution of chemistry for the group female was statistically significantly different from the distribution of chemistry for the male category. This suggests that the distribution of chemistry for the female group was statistically significantly different from that for the male category. Females are more anxious in chemistry than males. This implies that there is a significant difference in anxiety in math, chemistry and physics and that this group of students experienced higher levels of math anxiety than in physics and chemistry.

The results align with previous research on gender disparities in mathematics (Delage et al., 2022; Morán-Soto & Peña, 2022; Mweni et al., 2023; Richland et al., 2020). The results of these research consistently indicate a pattern in which female students routinely exhibit higher levels of mathematics anxiety in comparison to their male peers. The presence of a gender disparity in mathematics anxiety is evident from an early stage, including at the secondary school level. This suggests that female students may experience higher levels of anxiety when participating in math-related activities (Morán-Soto & Peña, 2022).

However, the study also revealed that females experience higher levels of anxiety in chemistry compared to males. This finding aligns with other research findings that demonstrate a gender-based variation in science anxiety, with female students exhibiting higher levels of anxiety (Akgun et al., 2007; Anderson & Clawson, 1992; Ardasheva et al., 2018; Mallow, 2006). Moreover, studies have indicated that female students are more prone to experiencing high levels of anxiety in STEM (Rozgonjuk et al., 2020). In contrast, the study conducted by Megreya et al. (2021)

revealed a positive association between gender and science anxiety among fifth graders. Their findings imply that boys experience higher levels of science anxiety compared to girls, but there is no gender disparity in self-efficacy towards science.

The findings of our study anchor on the fact that fundamental beliefs of intelligence influence gender differences in mathematics and science anxieties. The higher anxiety scores recorded in female preservice students in mathematics and chemistry could be attributed to societal stereotypes and internalized beliefs about their abilities in STEM subjects, which fortify a fixed mindset instead of a growth mindset. It is important to implement intervention strategies that foster the development of a growth mindset to benefit female students in alleviating STEM anxiety and enhancing teaching effectiveness in STEM subjects. The results of this study are critical because they contribute to our knowledge of math and scientific anxiety at the college level and emphasize the importance of addressing this anxiety among future teachers.

CONCLUSION

In conclusion, this quantitative study provides a thorough analysis of math and science anxiety levels among pre-service teachers, specifically emphasizing gender-based trends. The study's primary findings suggest that pre-service teachers encountered different levels of math and science anxiety, ranging from moderate to severe. These findings could greatly impact the future of mathematics and science education in South Africa. This study also highlights the statistically significant differences in levels of mathematics and science anxiety between male and female pre-service teachers. It is not advisable to make sweeping generalizations based solely on the findings of a single study. However, it can be confidently stated that the present study effectively achieved its goal of investigating the associations between the variables in question and may have some implications to warrant future research.

Nevertheless, the presence of mathematics and science anxiety continues to be a major obstacle for both male and female students when it comes to pursuing professions in STEM. The combination of these factors and the relatively low status associated with teaching as a profession among young South Africans is likely to deter scientifically inclined individuals from pursuing a career in STEM. Consequently, the potential ramifications of this might have momentous and widespread effects. If a teacher has math and science anxiety, it may result in their future students having a detrimental math and science education experience, potentially discouraging them from choosing math and science electives in high school and beyond in further education and training.

Recommendations

This study is limited to students in one higher education institution in South Africa doing physics, chemistry and mathematics (excluding biology) and used one data collection tool. Conducting similar studies with different data collection tools and samples is recommended.

This study enhances the current body of research by offering valuable insights into the gendered aspect of mathematics and science anxiety among pre-service teachers focusing on math and science education in South Africa. Analyze these trends to provide insights that might guide specific interventions and support mechanisms in teacher education programs. Moreover, pinpointing the elements linked to math and science anxiety might help formulate approaches to boost pre-service teachers' self-assurance when it comes to teaching math and science.

The math and science curricula delineate the specific areas of information and abilities that students are expected to learn. Nevertheless, emotional traits such as fear, and drive are not explicitly encompassed. Affective traits significantly impact math and science learning, which is widely recognized. Hence, it is imperative to incorporate emotional attributes into the science curriculum to address anxieties that students might experience in math and science.

The results of this study have practical implications for programs that educate math and science teachers. Curriculum planning and professional development activities can incorporate strategies that specifically target gender-based differences in math and science anxiety. Establishing a nurturing and all-encompassing educational setting that considers the unique challenges encountered by male and female pre-service teachers in handling math and science anxiety is crucial for their prospective achievement in teaching math and science.

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Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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