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Enhancing Pre-Service Teachers' Resilience to Overcome Chemistry Anxiety: Self-Determination Theory Approach

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ABSTRACT: This study investigates the influence of Self-Determination Theory (SDT) as a construct to help pre-service teachers mitigate chemistry anxiety as they build resilience in the subject. The study was framed within the three key sub-constructs of autonomy, competence, and relatedness under SDT as a theoretical lens. The study employed sequential mixed methods research approaches and sampled pre-service teachers from two South African universities, one university being in the urban area and the second university in the rural area. Whole-class interventions were employed in each institution where the researchers incorporated a resilience toolkit over a semester. Questionnaires and interviews were the main instruments used to collect data. The data was analysed using descriptive statistics and thematic analysis. The study found that pre-service teachers generally experienced anxiety in chemistry, and that female pre-service teachers displayed statistically significant anxiety scores compared to males ($p = 0.018$); whereas the location of the university had no statistically significant influence on anxiety scores ($p = 0.896$). The study further found that the interventions improved emotional regulation, competence, and intrinsic motivation while fostering supportive peer networks. The study recommends integrating resilience-building strategies into science teacher training programs to equip pre-service teachers with skills to manage science anxiety effectively.

Keywords: Anxiety, chemistry, pre-service teachers, resilience, self-determination

INTRODUCTION

Globally, teacher education has increasingly recognized the importance of resilience among pre-service teachers due to an increased rise in the prevalence of psychological problems like anxiety among students in challenging courses such as mathematics and sciences. General anxiety is characterized by frequent apprehension about the negative consequences of past unpleasant experiences and future negative possibilities, feelings of nervousness, tenseness, or panic in response to a variety of situations, fear and apprehension regarding uncertainty, and presuming the worst." [1]. In this project, the researchers examined one form of educationally pertinent anxiety, science anxiety, that significantly impedes students' learning and academic success [2] . In addition, the researchers suggest that science anxiety can be mitigated by cultivating science resilience within the context of Self-Determination Theory (SDT) [3]. SDT is founded on the principle that it is crucial to address fundamental psychological needs in order to foster psychological safety, promote well-being, and prevent psychological damage by emphasizing autonomy, competence, and relatedness [4] . In this paper, the researchers present case studies that demonstrate how SDT explains science interventions to mitigate science anxiety and provide significant justification for the majority of the premises of the work on science resilience.

Science anxiety, akin to mathematics anxiety, encompasses the fears and apprehensions manifesting themselves during learning and engaging with scientific concepts and activities [5, 6]. The occurrence of this phenomenon is not restricted to specific age groups or academic levels; rather, it affects students across the entire educational spectrum, ranging from elementary school to higher education [5,7,8]. Specifically, chemistry anxiety has been widely acknowledged as a barrier to effective learning and teaching among pre-service teachers. This anxiety hampers their academic performance and affects their confidence and enthusiasm in teaching chemistry concepts that they perceive to be

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difficult. Several studies have been conducted on strategies to mitigate science anxiety and specifically with chemistry anxiety [9,10]. However, there are few studies that have been conducted to address chemistry anxiety at the university level. In addition, there have been numerous studies conducted globally on strategies to enhance students' understanding on content courses [8,11]. However, less attention has been given to psychological needs that may reduce anxiety and promote resilience and autonomy. Hence, SDT provides an appropriate framework for examining these issues. SDT underscores the significance of autonomy, competence, and relatedness in motivating individuals [9].

Literature review identified two critical gaps: Firstly, the insufficient research on the interplay between STD and academic anxiety in chemistry education. Despite the growing recognition of the importance of SDT in educational settings, particularly about motivation and teacher efficacy, research specifically addressing the interplay between SDT and academic anxiety within chemistry education remains sparse. Various studies highlight the relevance of emotional factors in learning, but few have holistically investigated how enhanced self-determination through autonomy and competence directly correlates with reduced anxiety levels in chemistry pre-service teachers [10]. Stapleton and others emphasize that a significantly high workload in teaching roles could intensify psychological distress, suggesting that a lack of autonomy might exacerbate anxiety [11]. This indicates a pressing need for research that concentrates on the specific emotional challenges faced by pre-service teachers, particularly in chemistry education.

While several studies [12, 13, 14] indicate that teachers' self-efficacy can mitigate anxiety related to inclusive education, there is a gap in evaluating whether similar self-efficacy constructs influence chemistry anxiety among pre-service teachers. Particularly, existing literature suggests reciprocal relationships between various emotional variables and performance efficacy, thereby encouraging the need for a more granular analysis of how SDT components can be leveraged to alleviate specific anxieties inherent in chemistry settings. The current body of literature primarily focuses on emotional intelligence and self-efficacy but falls short of integrating these with SDT in a scientific context to reduce chemistry anxiety. For example, studies exploring emotional intelligence's impact on self-efficacy indicate significant correlations [15], yet the application of these findings within the framework of chemistry education remains limited. Hence, exploring how constructs of SDT can act as mediators or moderators in reducing chemistry anxiety is vital, as existing knowledge largely overlooks these dimensions.

Secondly, there is a lack of contextual studies on self-determination theory in chemistry education. While the principles of SDT have gained traction in various educational contexts, the nuances of how these theories can be adapted and integrated into chemistry teacher training are insufficiently documented. There have been several studies [16, 17] that have assessed the importance of evaluating the SDT construct within the educational context. However, limited studies have been conducted to highlight the implications of SDT in the context of chemistry teacher education. Most of the studies conducted globally [16, 17] on SDT either focus on general education or are specific to STEM education and not specific to chemistry education in relation to student anxiety in the subject.

This study, therefore, fills the gap in the literature by enhancing pre-service teachers' resilience in chemistry courses through interventions using the constructs of the SDT framework. Previous research on resilience in education has primarily focused on high school students, with relatively few studies examining how resilience-building strategies might be employed in higher education, particularly in teacher preparation programs [18]. Furthermore, while the role of autonomy-supportive teaching environments has been studied in general education settings [19] here is a lack of empirical evidence on how these environments impact chemistry pre-service teachers.

The Self-Determination Theory (SDT)

SDT is a universal motivational theory that compares autonomous and controlled motivations in human behavior [20, 21]. Human motivation differs due to experiences and regulatory processes, and the extent of autonomy characterizes behavior [22]. Autonomous motivation is described as self-will and choice act (intrinsic), whereas controlled motivation is depicted as responding to pressure, an act of coercion (extrinsic) [20, 22]. Intrinsic motivation is propelled by personal interest, excitement and joy in a task instead of external rewards, whereas extrinsic motivation is an act of responding to separate outcomes, tangible or not; it is a goal-oriented behavior [9, 20, 21].

SDT is grounded in the belief that human motivation is contingent upon satisfying three fundamental psychological needs: autonomy, competence, and relatedness, which are essential for individuals' continuous development, veracity, and well-being [9, 20] Autonomy indicates that individuals tend to feel the need for their own decisions relating to their activities [23]. Competence implies that the individual possesses the necessary knowledge and skills to achieve in their activities in relation to the subject under consideration [24]. Relatedness implies that the individual has an inherent need to feel they are connected to other people in their environment and, as such, they feel supported in their workflow. Therefore, they develop a feeling and a sense of belonging in a community [20, 22, 25]. These

three needs are interrelated and collectively contribute to an individual's intrinsic motivation. In this context, pre-service teachers might feel a sense of belonging in a community where they work with their peers and their instructors to achieve a common goal. In this case, they might work harder to be recognize for their competency. In addition, pre-service teachers might also need to be on top of their game and work towards achieving success. This is of relevance to science education, as studies have indicated that because of the difficulties students experience in the science-related fields, there is a tendency for increased anxiety levels when it comes to studying chemistry [26].

The SDT highlights that when the psychological needs of students are fulfilled, their anxiety levels are drastically reduced. This is particularly relevant in science education and, as outlined in studies, has demonstrated that when students are given autonomy in their studies, they are more inclined to seek resources that will enhance their learning and improve their performance in the subject [27]. By making students have a sense of belonging, their engagement in the subject and their motivation levels increased. This sense of belonging also mitigates against their anxiety in their science courses. This is critical for overcoming anxiety related to science education.

The second psychological need is competency, which is relevant in helping students reduce their anxiety. As asserted in a study, instructors who provide positive feedback to students enable them to develop a sense of competence, which, of course, can help to reduce students' anxiety and their self-worth [28]. This is also in line with studies that indicate a strong association between student self-efficacy in the subject and their anxiety levels in an educational environment [28, 29].

The third construct of the SDT is the concept of relatedness. The sense of belonging of students makes them feel that they are supported, and that could enhance their learning and reduce their science anxiety. When students are supported in a learning environment and are engaged in a community where they feel a sense of mutual support, they work to enhance their learning outcomes [30]. This is in line with a study which shows that encouraging students to work together and establishing strong interpersonal relationships can enhance their learning outcomes as they reduce their anxiety [26].

On the other hand, numerous studies have investigated the integration of SDT in teacher education to reduce learner anxiety as they build their resilience in science education. One study [31] found that there was an improvement in the fulfilment of student needs as participants identified the causes of their anxiety as they made suggestions for nurturing their SDT needs in an educational context. In addition, Novak and others developed a science teaching anxiety scale and found that pre-service teachers who engaged in autonomy-supportive practices reported lower anxiety levels and higher self-efficacy in teaching science [32], This indicates that integrating SDT into teacher education programs can effectively address the emotional challenges faced by pre-service teachers in science disciplines. Furthermore, other strategies (e.g. collaborative learning) have been shown to enhance the fulfilment of SDT needs among pre-service teachers, reducing anxiety and increasing engagement [33]. These methods promote active learning and peer interaction, which are essential for fostering relatedness and competence.

Banerjee and Halder's study of how SDT motivates and influences teacher support found that students re-acquired competence through guidance and feedback; teacher autonomy enhanced students' sense of control by offering varied choices and rationalized tasks; and supporting relationships among students that promoted a sense of belonging [34]. In another study, Chan and others discovered that teaching styles that supported student autonomy by providing proper structure and encouraging participation effectively enhanced learning motivation, academic engagement and competence among preservice teachers [35]. This implies that providing autonomy support improved preservice teachers' motivations and engaged learning experiences. Hence, this study engages SDT and its elements to support preservice teachers' resilience against chemistry anxiety, particularly in concepts involving mathematical calculations.

Science Anxiety: Causes, Consequences and Mitigation Strategies

Science anxiety is defined as "a debilitating combination of fearful negative emotion and cognition in the context of science learning," [9]. Several studies have consistently indicated that math anxiety is a distinct construct that exhibits certain unique characteristics in contrast to other forms of anxiety in education [10, 36, 37]. This anxiety manifests as a fear or apprehension towards science learning and may manifest prior to or during the acquisition of scientific knowledge, significantly hindering students' academic performance and engagement [36]. Science anxiety is prevalent, with numerous studies showing that a significant proportion of students experience different levels of science anxiety [8, 9]

Several studies have further shown that there are several causes of students' anxiety in science, including negative past experiences with the subject, misconceptions, fear of science, low self-esteem, and rigid curricula which teachers present to the students [32, 38, 39]. These factors are often deeply rooted in the minds of the students as students begin to think whether they are worthy to pursue any

academic studies related to science [39]. Other studies have shown that students experience anxiety when they encounter any form of unfavorable interactions with their teachers, which also increases their anxiety levels in science [32]. When students feel they are not confident in what they study and the questions they respond to in science concepts, they develop low self-efficacy, leading to the anxiety they experience in the subject [24]. Of course, the subject content can also contribute to the anxiety that students experience in chemistry [32, 38], since chemistry requires students to think inductively when doing problem solving. That places cognitive load on students. Hence, leading to a profound impact on their anxiety about the subject.

Furthermore, several studies have also shown the relationship between student science anxiety and their performance in the subject, and their classroom engagements, as well as differences in gender in relation to anxiety [32, 40]. Other studies have also found that student anxiety can lead to their disengagement in the classroom, which often leads to their low performance in science [39, 40]. While other studies have shown a strong relationship between student anxiety and their attitude and interest in pursuing further studies in the sciences, often indicating that students with anxiety will be discouraged from pursuing further studies in science-related fields [32, 39, 40]. This is particularly concerning in STEM education, where a strong foundation in science is essential for future academic and career success in science-related fields [41]. For instance, in another study [42], investigated the correlation between chemistry test anxiety and student chemistry achievement using Pearson correlation from data collected with questionnaires from chemistry achievement items and test anxiety questionnaires. The study found that there was a negative correlation between students' chemistry achievement and their test anxiety. In addition, the study found that gender and the location of the school were controlled; there was no significant difference between test anxiety and students' chemistry outcomes. The study therefore suggested that teachers and all stakeholders of education should implement the affective, the cognitive, as well as the other domains as strategies to help students reduce their anxiety and improve on their performance in chemistry [42].

A similar study [43] investigated the gender differences in the relationship between anxiety, self-efficacy and students' learning outcomes in chemistry to determine if there is any association between these variables. The study found that the significance value is less than α (0,025). This shows that males have a lower contribution than females to the chemistry achievement outcomes [43]. Then again, Rozgonjuk found that the anxiety experienced by students is not associated with performance in a test or with a subject that is often associated with the outcome of a test [44]. However, this study did not find any significant association between gender and test performance. Nonetheless, it was observed that female students reported higher levels of science anxiety than males. In addition, the study found that females perceived the test items to be challenging and therefore required more time to complete the test.

Taken together, various mitigation strategies have been proposed and implemented to address the challenges of science anxiety. Interventions to reduce anxiety often focus on enhancing students' self-efficacy and providing supportive learning environments. For instance, pedagogical strategies such as concept mapping have been shown to help students better understand the relationships between scientific concepts, thereby reducing anxiety [45]. Moreover, fostering a growth mindset incorporates active learning techniques, such as collaborative group work and hands-on experiments, and supportive teacher-student relationships that create a safe and encouraging classroom environment [39]. This approach enhances students' comfort in expressing concerns and seeking assistance when necessary [32, 46]. Hence, the need to equip pre-service chemistry teachers to be aware of their anxiety in chemistry and that of their future classrooms.

Mathematical Resilience

Mathematical resilience is a pragmatic construct that was developed to characterize methods of working that would assist in the development of a positive stance of perseverance and self-safeguarding when learners engage with mathematical ideas. It is defined as "maintaining self-efficacy in the face of personal or social threat to mathematical well-being [47]. The term "mathematical resilience" allows instructors and students to assert, "I am striving to cultivate mathematical resilience, not mathematics anxiety," and subsequently act in a manner that fosters that resilience. Resilience-focused mathematics instruction has been extensively investigated [48]. Mathematical Resilience (MR) is the ability of students to maintain a positive mathematical attitude despite facing adversity [49]. Mathematical resilience can be characterized as a constructive strategy that empowers students to surmount emotional barriers in mathematics concepts, including anxiety and fear [50]. The student should be willing to discuss and reflect on mathematical barriers to enhance self-confidence and perseverance and develop resilience [50]. The same strategy to develop mathematical resilience is employed in this study to develop pre-service teachers' resilience in chemistry education.

There are varied components of MR across research, and six components were adopted in this study of developing resilience in a chemistry course [49, 50]. These include encouraging a growth

mindset (Mindset); promoting collaborative learning (relatedness); providing students opportunities to articulate and reflect their understanding (willingness and reflection); understanding the personal and practical value of mathematical concepts (value); creating a supportive community involving teachers and non-specialists (support); recognizing the struggle and effort are part of the learning process (struggle). Four attributes are the foundation of mathematical resilience. Three of these attributes are obviously in alignment with the three fundamental psychological requirements of SDT: personal value of mathematics (autonomy), growth mindset (competence), and community (relatedness).

Teaching strategies that reduce students' fear of chemistry concepts should be incorporated into students' resilience development. Such tools include the Growth Zone Model, Relaxation Response, the Hand Model of the Brain, and the ladder strategies employed in the research. To develop resilience, students' states of anxiety should be known by measuring anxiety using the modified version of the Betz questionnaire [51]. This paper measured student chemistry anxiety in the two universities for those enrolled in chemistry education courses.

RESEARCH METHODS

Materials and Tools

This study is a design-based intervention study, using action research. The researchers employed mixed methods within the pragmatic paradigm to examine the impact of the intervention on pre-service teachers' psychological needs for autonomy, competence, and relatedness. The study sampled pre-service teachers from two South African universities, one university being in the urban area and the second university in the rural area. Each researcher did a whole-class intervention at his/her university. The study purposefully sampled second-year students from two universities: University A = 116 (88 Female; 28 Male) and University B = 97 (38 Female; 59 Male). These pre-service teachers were registered for the second-year Chemistry 2 course and other major courses like Physics 2 and Mathematics 2. The content of the chemistry courses in both institutions covers concepts such as molecular geometry and bonding theories, inorganic chemistry, properties of gases, thermochemistry, chemical thermodynamics, organic chemistry, stoichiometry, and chemical equilibrium. One whole-class interventions were employed in each institution where the researchers incorporated a resilience toolkit over one semester in the chemistry lessons. Questionnaires and interviews were the main instruments used to collect data. The questionnaire items were adopted and modified from the Mathematics Anxiety Scale (MAS) [51], which has ten items on a five-point Likert scale. These questionnaire items have been designed to have items which identify the bidimensional effects for both positive and negative, toward mathematics. In other words, towards chemistry. The initial five items in the MAS were positively phrased, while the last five items were negatively phrased. The MAS questionnaire was formatted to comprise two components. Section A comprised enquiries regarding the demographic data of participants. Section B was the ten items of the MAS. The participants were directed to express their level of agreement with the items using a 5-point scale, where 1 signifies significant disagreement, 2 denotes disagreement, 3 indicates neutrality, 4 represents agreement, and 5 reflects strong agreement. The independent variable in this study was gender, and the dependent variable was the chemistry anxiety scores. The research attained a response rate of 78 per cent. The interview questions were designed to capture on pre-service psychological needs after the interventions.

The MAS questionnaires were distributed to the pre-service teachers prior to the intervention. The post-intervention qualitative data, involving semi-structured interviews, were collected to explore participants' experiences of resilience and autonomy in their personal growth and development. It provided a more nuanced understanding of how participants internalised and applied resilience strategies. The researchers were granted ethical clearance by the research ethics committees of their respective universities. Consent was sought from the participants who voluntarily opted into the study, and each participant was assigned a pseudonym. Confidentiality and anonymity were guaranteed to protect participants' data and privacy.

The intervention

The study incorporated the Growth Zone Model (GZM), the Hand Model of the Brain (HMB), and the Relaxation Response Model (RRM) as interventional tools implemented to reduce pre-service teachers' chemistry anxiety, foster resilience, and enhance cognitive and emotional regulation in chemistry learning over one semester to cover the chemistry units; *Molecular Geometry and Bonding Theories; Basic Introductory Inorganic Chemistry; Characteristics of Gases; and Thermochemistry*. The intervention comprises the following phases:

Phase 1: Orientation and Skill Building (Weeks 1-2)

The lecturers (who are the researchers) provided workshops on the GZM, HMB, and RRM. The GZM framework is introduced to help pre-service teachers identify and navigate through three zones (the Comfort Zone, the Growth Zone and the Anxiety Zone). The HMB is a visual tool to help pre-service teachers understand the relationship between their emotions and brain function. Pre-service teachers were trained to recognize signs of flipping their fists (losing emotional control) and strategies to regain focus. The RRM was incorporated to teach pre-service teachers how to activate their parasympathetic nervous system to reduce anxiety by practicing relaxation exercises. The pre-service teachers participated in hands-on activities to understand these models.

Phase 2: Topic-Specific Implementation (Weeks 3-10)

Each lecturer integrates the models into their teaching as follows: Molecular Geometry and Bonding Theories (GZM: The lecturers started with basic concepts like Lewis structures and progressed to hybridization and molecular orbital theory. HMB: Pre-service teachers identify when concepts feel overwhelming and use self-regulation strategies. RRM: Guided relaxation sessions before group discussions). Basic Introductory Inorganic Chemistry (GZM: Lecturers break down periodic trends and reactions into manageable sub-units. HMB: Role-playing to simulate anxiety scenarios in problem-solving. RRM: Use of calming techniques before individual tasks).

Characteristics of Gases: (GZM: lecturers facilitated the gradual transition from gas laws to kinetic molecular theory. HMB: Self-awareness practices during chemistry problem-solving activities. RRM: Daily mindfulness exercises).

Thermochemistry (GZM: lecturers scaffold concepts of energy changes, enthalpy, and Hess's Law. HMB: Journaling emotions during practice activities. RRM: Breathing exercises before any tasks).

Phase 3: Reflection and Assessment (Weeks 11-12)

Pe-service teachers complete their journal reflections on their cognitive and emotional regulation during a reflection session to evaluate the impact of GZM, HMB, and RRM on their learning and anxiety levels. Pre-service teachers were also interviewed. One week after the intervention, interviews were conducted with the participants. 20 second-year pre-service chemistry teachers from two higher education institutions participated in the interviews. These included 10 students from each of the two second-year chemistry education classes at the selected institutions. Participants with varying levels of chemistry anxiety and who consented to be interviewed were purposively selected. Participants were aged between 19 to 23 years. The researchers were sensitive to the gender of the participants. The interviews were conducted over a week. Scheduling was flexible to accommodate students' academic commitments. Each interview lasted approximately 30–45 minutes, with variations depending on the depth of responses provided by participants. The interview protocol was designed to explore student teachers' experiences with coping strategies and the perceived role of self-determination theory components in mitigating anxiety.

Method of Quantitative and Qualitative Analysis

The researchers employed descriptive statistics and thematic analysis to analyse the data. The data were analysed using the statistical software. Data items 2, 3, 4, 6, and 7 were documented utilizing reverse scoring. This was executed to ensure uniform question directionality. A high total score on the MAS would signify a considerable perception of high anxiety levels. A low aggregate score would signify a low anxiety level. In addition, a thematic analysis [52] was utilized for the post-intervention qualitative data to examine the three principal constructs of SDT: competence, autonomy, and relatedness. The patterns in the data were identified to explain how the interventions impacted pre-service teachers' sense of autonomy, competency, and relatedness.

RESULT AND DISCUSSION

Result of Qualitative Analysis

Participants' perceptions of resilience and autonomy

The Self-Determination Theory (SDT) posits that fulfilling three basic psychological needs (competence, autonomy, and relatedness) is fundamental to nurturing motivation and well-being among students. The results of the study align closely with these constructs, providing a framework for understanding how resilience-building strategies can mitigate chemistry anxiety among pre-service teachers.

Gradual Development of Competence

The study's findings indicate that pre-service teachers experienced a gradual development of competence as they engaged with complex chemistry concepts. Two pre-service teachers narrated:

> *At first, I felt overwhelmed by the chemistry concepts, especially stoichiometry and reaction mechanisms. However, the GZM helped me break down the tasks into manageable steps,*

and I started to feel more confident. The relaxation exercises also calmed me down before tackling problems, which made it easier to focus and apply what I had learned, and that enhanced my competency in chemistry (PST6A).

A second pre-service teacher indicated that*:*

When my lecturer introduced the GZM, my classmates and I began to engage with the tool, which made me realise that it's okay to feel challenged as long as I keep progressing. The visualisation techniques and relaxation practices reduced my anxiety significantly, allowing me to approach chemistry concepts with a clearer mind. Over time, I could see myself mastering topics that I had previously avoided (PST43B).

These findings show that there is a gradual increase in students' development of competencies and reduced anxiety as a result of the intervention. This is in alignment with the SDT constructs, which align with SDT's assertion that competence is cultivated through the experience of overcoming challenges and engaging in optimally difficult tasks. As participants stepped outside their comfort zones and applied the GZM, they reported increased confidence in their abilities to problem solving tasks. This is consistent with the literature, which emphasizes that competence is not merely an inherent trait but a skill that develops through practice and feedback [9, 10].

Increased Emotional Awareness and Regulation

When the pre-service teachers were asked about their emotional awareness and self-regulation, they highlighted that there has been an improvement in their awareness of self, which directly aligns with SDT psychological need of autonomy. Two pre-service teachers have this to say:

The GZM tool has indeed assisted me in keeping calm whenever I make a mistake. Using the tool, I could identify what I could control, and by taking small, manageable steps, I started to trust my own decisions more. I feel like I am in charge of my learning, which has reduced my anxiety about learning chemistry concepts (PST73A).

PST2A concurred with PST23A:

I have used the RRM techniques to calm my nerves, and I realized how much my emotions affected my chemistry learning. Taking time to calm down and refocus made it easier for me to manage challenging situations in the classroom. I feel more confident approaching chemistry problems, which aligns with my learning style. It is like I have developed my own way of dealing with the anxiety of chemistry (PSTB94).

These findings directly connect to the SDT construct of autonomy by emphasising pre-service teachers' growing ability to self-regulate and make independent, effective decisions in their professional development as chemistry teachers. This finding is supported by research indicating that emotional regulation is crucial for maintaining autonomy, as it allows individuals to make deliberate choices rather than being overwhelmed by external pressures [11, 19, 20]. The Relaxation Response Model, employed as part of the intervention, contributed to this increased emotional awareness. This aligns with the broader literature on SDT, emphasizing that autonomy is enhanced when individuals can effectively regulate their emotions and make choices that align with their values and goals [17, 22, 23].

Improved Cognitive Regulation

The study also found that pre-service teachers effectively regulated their thoughts and emotions, engaged deeply in tasks, and persisted in facing challenges. The GZM and the RRM provided the strategies that supported the development of competence and autonomy among the participants. Two pre-service teachers commented:

I used to get overwhelmed when I did not understand a chemistry concept during the lesson, but the approach my lecturer uses has taught me to break any unit and task into smaller, manageable steps. The RRM helped me calm my mind and focus whenever I felt anxious (PST10A).

Another pre-service teacher has this to say:

*I calm down, which resonates in my mind all the time. During lessons, I realized I could control my emotions better using the RRM we learned. I used deep breathing exercises to reduce my anxiety before I tackled any problem-solving activity given to the class to solve as an individual. The GZM encouraged me to set realistic goals and reflect on my progress, which gave me a sense of accomplishment (*PST8B).

These responses show that the intervention strategies improved pre-service teachers' competence and autonomy, which aligns with SDT. This study's finding also corroborates the findings from the literature, which showed that when individuals feel capable of regulating their cognitive processes, they are more likely to experience intrinsic motivation and engage in self-directed learning [9, 20]. This

underlines the importance of incorporating resilience-building strategies into teacher training programs, as they can significantly enhance pre-service teachers' psychological resources [27].

Result of Quantitative Analysis

The statistical analysis of the pre-test anxiety questionnaires was conducted to inform the nature and depth of the intervention strategies. The dependent variable was the anxiety levels of pre-service teachers, and the two categorical independent variables were the universities and gender.

Statistical analysis

The statistical analysis tested two null hypotheses:

1. The distribution of anxiety levels is equal across categories of university.
2. The distribution of anxiety levels is equal across categories of gender.

To test the hypothesis, the data for the two universities was subjected to a two-way ANOVA univariant analysis. From analysis, descriptive mean score values, the Levene test, and the test between subjects' effects were scrutinized for inferences.

TABLE 1. Comparison of mean score values per university and gender

University	Gender	Mean Score	Std. Deviation	N
A	Female	2.3068	.76351	88
	Male	2.0000	.76980	28
	Total	2.2328	.77300	116
B	Female	2.2632	.44626	38
	Male	2.0847	.42702	59
	Total	2.1546	.44112	97
Total	Female	2.2937	.68197	126
	Male	2.0575	.55733	87
	Total	2.1972	.64325	213

The results in Table 1 exhibit a slight difference in anxiety levels between the two universities under consideration (University A; mean = 2.2328 & University B mean = 2.1546). The preservice teachers at University A generally experienced higher anxiety levels than their counterparts at University B. Furthermore, the mean score results indicate that preservice female teachers have higher anxiety levels compared to their male counterparts across Universities A and B.

To compare the standard deviation scores between the two universities, Levene's Test of Equality of Error Variances test the null hypotheses, and the error variance of the anxiety levels is equal to the independent variables, as shown in Table 2. The assumption of sample homogeneity of variances was violated, since the equality of error variances was significant ($p < 0.001$).

TABLE 2. Levene's Test of Equality of Error Variances[a,b]

		Levene Statistic	df1	df2	Sig.
Chem Anxiety Score	Based on Mean	12.159	3	209	<.001
	Based on Median	7.081	3	209	<.001
	Based on the Median and with adjusted df	7.081	3	183.021	<.001
	Based on trimmed mean	11.258	3	209	<.001

a. Dependent variable: Chemistry_Anxiety_Score

b. Design: Intercept + University + Gender + University * Gender

TABLE 3. Independent-Samples Mann-Whitney U Test for gender and universities.

	Gender	University
Total N	213	213
Mann-Whitney U	4438.5	5567.5
Test Statistic	4438.5	5567.5
Standard Error	440.894	446.687
Standardised Test Statistic	-2.365	-0.131
Asymptotic Sig.(2-sided test)	0.018	0.896

Since the two samples (universities A & B) under consideration are unrelated, the Mann-Whitney U Test was employed. The Mann-Whitney U test is a nonparametric test that analyses the statistical significance difference between two independent sample distributions [53]. It is the alternative analysis test when the data is not equal and not normally distributed [54]. Table 3 gives a summary of the results of the Mann-Whitney test for gender and the two universities' anxiety scores.

The result score by gender shows a statistically significant difference in the distribution of anxiety scores/levels between genders (z = -2.365, p = 0.018). Therefore, the null hypothesis stating that the distribution of the anxiety scores is equal across genders was rejected. The results strongly suggest that there is a statistically significant gender impact on the anxiety levels of the preservice teachers in this research. The results for the Mann-Whitney U test for university comparison (z = -0.131, p = 0.896) indicate that there was no statistically significant difference in anxiety scores. Therefore, we fail to reject the null hypothesis that the distribution of anxiety scores is the same across categories. Hence, the university attended by the preservice teachers does not statistically have an impact on the participants' anxiety scores. To further support the notion that the university attended has no bearing on the participants' anxiety score, the mean ranks are examined in Figure 1.

Figure 1 depicts that University A (116 participants) attained a mean rank of 107.50, whereas University B (116 participants) achieved a mean rank of 106.40. University A exhibits a marginal advantage of mean ranking values over University B, suggesting that University A's preservice teachers perform slightly better than their counterparts in University B on the measured variables. The frequency distribution indicated in Figure 1 illustrates that the anxiety scores are spread equally across the universities. This further suggests that the universities attended by the preservice teachers may not be the primary contributors to student anxiety scores.

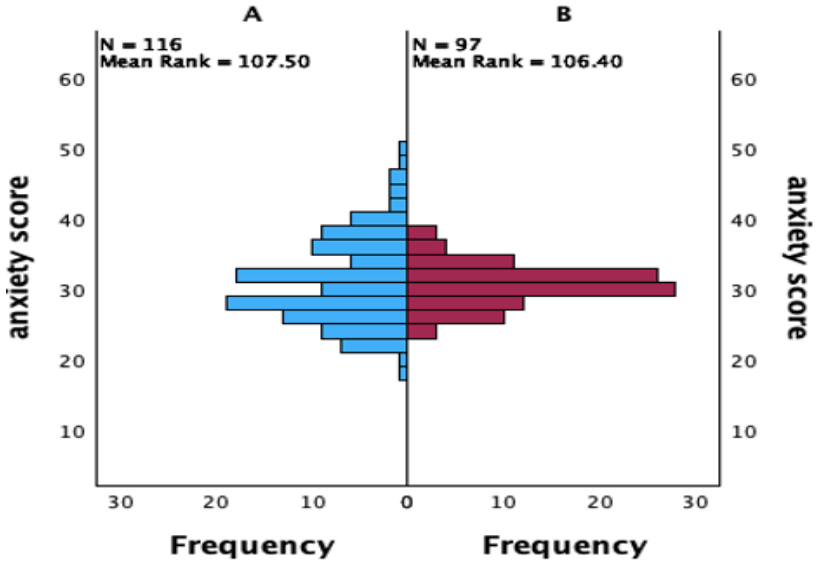


FIGURE 1. Independent -Samples Mann-Whitney U Test for the two universities.

Integrating the findings from the anxiety mean score values and the Mann-Whitney U Test, it is apparent that female preservice teachers have higher anxiety levels than their male counterparts. The location or university attended has no statistical significance in preservice teachers' anxiety levels. Hence, much focus should be on mitigating female teachers' high levels of anxiety scores. The results of this study reveal that female participants tend to be affected by chemistry anxiety and are likely to show low engagement in chemistry-related activities [32]. Fia and others argue that disengagement in science subjects results in a negative feedback loop, preventing the students from meaningfully engaging in conceptual learning [40]. Hence, during the intervention, it is important to institute supportive teaching strategies that develop female preservice teachers' self-efficacy and autonomy to develop resilience against anxiety and subject aversion. Since resilience is not an innate trait [55], the intervention should institute strategies that encourage coping approaches, increase emotional regulation and focus on resilience-building activities to minimize chemistry anxieties, particularly in female preservice teachers [55]. To reduce chemistry anxieties in female students, collaborative learning that incorporates mixed genders will be of great importance, as male students have less likelihood of being affected by the subject's complexities and developing fear. We argue that creating

positive collaborative environments can develop the skills and confidence necessary to maintain resilience in subjects such as chemistry.

CONCLUSION

The paper investigated the application of SDT to lower the chemistry anxiety among chemistry preservice teachers from two universities by promoting their autonomy, competence, and relatedness to develop science resilience. Quantitative findings revealed that female preservice teachers exhibited higher anxiety levels than male preservice teachers, and the difference was statistically significant. However, the location of the university yielded a non-statistically significant difference in preservice teachers' anxiety scores. Suggesting that location has no bearing on the participants' anxiety levels. Targeted structured interventions such as the Hand Model of the Brain, Growth Zone Model and Relaxation Response Model were critical in the development of preservice teachers' competence, improved emotional alertness and increased regulated cognition. The investigation revealed that promoting a supportive, autonomous and collaborative learning environment effectively mitigates chemistry anxiety and fosters a positive approach towards the teaching and learning process of complex scientific concepts. The integration of the three SDT principles into teacher education training programs can enable preservice teachers to develop the necessary psychological aptitude to confront and overcome the challenges of teaching complex subjects that often evoke high levels of anxiety, such as chemistry.

We recommended that teacher training programs integrate SDT principles to enhance autonomy, competence, and relatedness to increase resilience among preservice teachers through structured intervention courses or programs that foster self-regulation and emotional awareness. There is a need to design and implement interventions that are gender sensitive to address female preservice teachers' unique challenges and promote their engagement and confidence development in teaching chemistry. We further recommend that preservice teacher programs incorporate collaborative learning activities that help construct supportive networks, as this promotes the sharing of experiences, discussion of challenging tasks, and co-construction of knowledge to reduce feelings of isolation and increased anxiety. Additionally, the study recommends the integration of coping strategies, emotional regulation and a growth mindset in resilience-building activities that include relaxation techniques, simulation experiences and micro-teaching into the curriculum. Furthermore, the incorporation into the teacher education training of mentorship programs and peer support groups that enable preservice teachers to continuously develop their teaching efficacy is encouraged.

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