Developing Mathematical Resilience: Effective Strategies to Alleviate Mathematics Anxiety among Secondary School Students in Kalomo District, Zambia.

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ABSTRACT

Mathematics anxiety is a pervasive barrier to student engagement, academic achievement, and participation in STEM disciplines, particularly in resource-constrained educational settings. This study investigates the prevalence of mathematics anxiety among secondary school students in Kalomo District, Zambia, and evaluates the effectiveness of four resilience-building interventions: Growth Mindset Training, Peer-Assisted Learning, Teacher-Scaffolded Problem Solving, and Technology-Enhanced Learning. Using an Explanatory Sequential Mixed-Methods Design, the study collected quantitative data from 375 students and qualitative insights from 25 students and 12 mathematics teachers through interviews, focus groups, and classroom observations. Findings reveal that 47.2% of students exhibited high levels of mathematics anxiety, with female students disproportionately affected (62.1% vs. 37.9%). Paired t-tests confirmed significant reductions in anxiety across all interventions ($p < 0.001$), with Technology-Enhanced Learning (Cohen's $d = 3.49$) and Growth Mindset Training (Cohen's $d = 3.09$) demonstrating the strongest effects. ANOVA results indicated statistically significant differences among intervention groups ($F = 4.89$, $p = 0.003$), with Technology-Enhanced Learning outperforming Peer-Assisted Learning ($p < 0.05$). Furthermore, a moderate negative correlation between mathematical resilience and anxiety ($r = -0.421$, $p < 0.001$) highlights the role of resilience-building interventions in fostering confidence and engagement. Qualitative findings underscore the critical role of teacher scaffolding, peer collaboration, and mindset development in mitigating anxiety and improving learning persistence. These insights reinforce the need for integrated educational policies that combine growth-mindset reinforcement, teacher professional development, and digital learning accessibility to enhance mathematics learning in low-resource contexts. The study contributes to global discourse on mathematics education equity, offering empirically grounded, scalable interventions for addressing mathematics anxiety. Future research should explore the longitudinal impact of these strategies on student performance, STEM retention, and career aspirations in numeracy-intensive fields.

Keywords: Mathematics anxiety, mathematical resilience, STEM education, growth mindset, technology-enhanced learning, peer-assisted learning, teacher scaffolding.

INTRODUCTION

Mathematics anxiety is a significant psychological barrier that affects students' ability to engage with and succeed in mathematical tasks. Research suggests that high levels of anxiety lead to avoidance behaviours, reduced mathematical performance, and negative self-perceptions, particularly among secondary school students (Ashcraft & Moore, 2009; Mutambo et al., 2021). This challenge is even more pronounced in rural contexts such as Kalomo District, Zambia, where students face additional socio-economic and pedagogical challenges. Despite growing global interest in mathematics resilience, limited research has explored effective strategies for fostering this resilience in low-resource educational settings.

In Zambia, mathematics anxiety remains a pressing concern, especially in rural districts such as Kalomo, where students face a combination of socio-economic, psychological, and pedagogical challenges that hinder their mathematical proficiency. Previous studies indicate that the fear of failure, negative classroom experiences, and

limited access to supportive learning environments contribute significantly to students' anxiety toward mathematics (Mutambo et al., 2021). Without effective intervention, this anxiety can lead to avoidance behaviors, diminished self-efficacy, and long-term academic struggles, further widening the gap in mathematical competence among learners.

To address this issue, the concept of mathematical resilience has emerged as a critical framework for fostering positive attitudes and perseverance in mathematics learning. Mathematical resilience refers to students' ability to overcome anxiety and persist in mathematical tasks despite challenges (Johnston-Wilder & Lee, 2010). Developing this resilience involves implementing targeted strategies that reduce anxiety, build confidence, and create a supportive learning culture that enables students to engage with mathematics more effectively.

This study explores the effectiveness of various pedagogical, psychological, and contextual strategies in alleviating mathematics anxiety among secondary school students in Kalomo District, Zambia. Specifically, it examines the role of teacher interventions, peer support, growth mindset approaches, and the integration of technology in fostering mathematical resilience. By identifying evidence-based strategies that enhance students' confidence and engagement in mathematics, this research aims to contribute to the growing discourse on mathematics education in Zambia and provide practical insights for educators and policymakers seeking to improve students' mathematical outcomes. While previous studies on mathematics anxiety have explored various mitigation strategies, limited research has focused on their effectiveness in rural African contexts, particularly in Zambia. Additionally, few studies integrate a comprehensive approach that combines pedagogical, psychological, and technological interventions to develop mathematical resilience."

Therefore, this study aims to investigate the impact of targeted pedagogical, psychological, and contextual strategies in reducing mathematics anxiety and fostering mathematical resilience among secondary school students in Kalomo District, Zambia. Specifically, it seeks to: (i) assess the prevalence of mathematics anxiety among students, (ii) evaluate the effectiveness of teacher and peer interventions, and (iii) explore the role of mindset development.

Problem Statement

Mathematics anxiety is a persistent psychological and cognitive barrier that negatively affects students' engagement, performance, and long-term success in mathematics (Ashcraft & Krause, 2007; Maloney & Beilock, 2012). It is characterized by feelings of tension, apprehension, and fear when confronted with mathematical tasks, often leading to avoidance behaviours, reduced self-efficacy, and underachievement (Dowker et al., 2021). This phenomenon is particularly detrimental in secondary education, where students are expected to develop higher-order mathematical competencies essential for academic progression and future careers, particularly in STEM-related fields (Beilock & Willingham, 2014; Carey et al., 2022). Despite growing international recognition of mathematics anxiety as a critical educational issue, its prevalence and impact remain significantly high in developing countries, including Zambia, where contextual challenges such as poor teacher preparation, inadequate learning resources, and socio-cultural perceptions of mathematics exacerbate the problem (Mutambo et al., 2021; Ministry of General Education, Zambia, 2020).

In Zambia's rural secondary schools, such as those in Kalomo District, the issue is even more pronounced due to limited access to trained mathematics teachers, large class sizes, exam-driven learning approaches, and a lack of interventions designed to address students' emotional and cognitive struggles with mathematics (World Bank, 2021). Studies indicate that students in rural areas often internalize negative beliefs about their mathematical abilities, resulting in learned helplessness, disengagement, and persistent underperformance in mathematics examinations (Mutambo et al., 2021; OECD, 2023). Despite the documented evidence of the detrimental effects of mathematics anxiety, there remains a significant gap in research on how to cultivate mathematical resilience—a crucial psychological trait that enables students to persist in mathematics despite challenges (Johnston-Wilder & Lee, 2010; Sharma & Sharma, 2023).

While existing interventions globally have focused on anxiety-reduction techniques such as relaxation strategies, mindset interventions, and peer tutoring, there is limited empirical evidence on holistic, resilience-building approaches that combine pedagogical, psychological, and technological strategies, particularly in low-resource

educational settings like Kalomo District (Ramirez et al., 2018; Zhang et al., 2022). Moreover, few studies have investigated the intersection of teacher pedagogies, student motivation, and the role of digital learning tools in fostering sustainable resilience in mathematics learning in Zambia. This lack of contextualized, evidence-based interventions leaves students without the necessary coping mechanisms to navigate mathematical challenges, perpetuating low achievement levels and negative attitudes toward mathematics. Addressing this research gap is critical to ensuring equitable access to quality mathematics education, improving students' problem-solving abilities, and ultimately increasing Zambia's participation in STEM-driven economic development.

This study, therefore, seeks to investigate and evaluate effective strategies for alleviating mathematics anxiety and fostering mathematical resilience among secondary school students in Kalomo District, Zambia. Specifically, it explores teacher-centered instructional strategies, peer-assisted learning models, cognitive and emotional coping mechanisms, and the integration of technology-enhanced learning tools. By generating empirical evidence on the effectiveness of these interventions, this research will provide valuable insights for education policymakers, curriculum designers, and mathematics educators in Zambia and beyond. The findings will contribute to the broader discourse on mathematics education reform in sub-Saharan Africa, offering practical recommendations for enhancing student engagement, confidence, and performance in mathematics.

Research Objectives

To assess the prevalence of mathematics anxiety among secondary school students in Kalomo District, Zambia.

To evaluate the effectiveness of teacher-led instructional strategies in reducing mathematics anxiety among secondary school students.

To examine the influence of mindset development on mathematical resilience among secondary school students.

Research Questions

What is the prevalence of mathematics anxiety among secondary school students in Kalomo District, Zambia?

How effective are teacher-led instructional strategies in reducing mathematics anxiety among secondary school students?

How does mindset development influence mathematical resilience among secondary school students?

Significance of the Study

Mathematics anxiety remains a critical challenge affecting students' academic performance, confidence, and long-term engagement with mathematics. This issue is particularly pronounced in low-resource educational settings, such as Kalomo District, Zambia, where students face limited access to trained mathematics teachers, inadequate instructional support, and socio-cultural barriers that reinforce negative perceptions of mathematics. Despite increasing global recognition of mathematics anxiety as a barrier to learning, there is limited empirical research on resilience-based interventions tailored to rural African education systems. This study is significant in multiple ways, offering contributions to educational practice, psychological theory, policy development, and global mathematics education research.

This study provides evidence-based strategies for mitigating mathematics anxiety and developing mathematical resilience among secondary school students. By evaluating the effectiveness of teacher-led instructional strategies, peer-assisted learning models, and mindset development interventions, the study generates insights that can enhance teaching methodologies and improve student engagement in mathematics classrooms. The findings will support mathematics educators by equipping them with practical tools and approaches to foster a more inclusive and supportive learning environment that empowers students to persist in mathematical learning despite challenges. This research extends the theoretical discourse on mathematics resilience, particularly in under-researched contexts like rural Sub-Saharan Africa. It contributes to educational psychology by exploring the role of growth mindset, self-efficacy, and motivation in reducing mathematics anxiety and enhancing persistence in learning. While previous studies have primarily focused on mathematics anxiety as a cognitive

and emotional barrier, this study shifts the focus toward resilience-building interventions, offering a novel perspective on how students can develop adaptive coping mechanisms in mathematics learning.

Mathematics education reforms in Zambia have primarily focused on curriculum content and assessment structures, with less emphasis on addressing the psychological and emotional barriers that hinder student achievement. This study's findings will provide empirical evidence to inform policy decisions related to teacher training, curriculum design, and student support programs. By highlighting effective strategies for reducing mathematics anxiety, the study offers practical recommendations for integrating resilience-focused teaching methodologies into Zambia's education system, ensuring that students are better equipped to engage with mathematics confidently. Most existing research on mathematics anxiety and resilience has been conducted in Western and Asian contexts, with limited studies focusing on African educational settings. This study addresses this research gap by examining context-specific interventions suited for rural secondary schools in Zambia. The findings will provide valuable insights applicable to other developing countries facing similar educational challenges, thereby contributing to the global discourse on inclusive and effective mathematics education.

With the increasing adoption of digital learning tools in education, this study also explores the potential role of technology in fostering mathematical resilience. The findings may inform the development of interactive learning platforms, gamified mathematics interventions, and teacher support systems that integrate digital resources to create engaging and anxiety-reducing mathematics learning environments.

LITERATURE REVIEW

The literature review focuses on mathematical resilience as a means of overcoming mathematics anxiety in secondary school students, particularly within the context of Kalomo District, Zambia. It explores how Resilience Theory provides a framework for understanding why some students persist in mathematical learning despite anxiety, while others disengage. The review underscores that mathematics anxiety is not merely an emotional response but a multi-dimensional issue involving cognitive, emotional, and behavioural components that negatively impact students' mathematical performance, engagement, and long-term attitudes toward the subject.

Theoretical Framework: Developing Mathematical Resilience to Overcome Mathematics Anxiety in Secondary School Students in Kalomo District

Mathematics anxiety remains one of the most significant psychological and cognitive barriers to student success in mathematics. It manifests in avoidance behaviours, negative self-perceptions, and, ultimately, diminished academic performance. This anxiety is not merely a reaction to challenging mathematical tasks but a deep-seated fear that influences students' long-term engagement with the subject. Studies have shown that students who cultivate mathematical resilience—the ability to persist in learning despite challenges—are better equipped to manage anxiety and develop a sense of confidence in their mathematical abilities.

Resilience in mathematics education goes beyond mere perseverance; it involves the adoption of adaptive coping mechanisms, self-regulation strategies, and positive emotional responses to failure. In rural educational settings such as Kalomo District in Zambia, where students often face additional structural and pedagogical challenges, mathematical resilience becomes even more critical. Resource constraints, limited teacher-student interaction, and larger class sizes compound the difficulties associated with mathematics anxiety, making resilience a necessary condition for success. This study employs Resilience Theory as a lens to explore the relationship between mathematics anxiety and mathematical resilience, identifying key factors that influence students' ability to engage productively with mathematics despite their anxieties.

Theoretical Foundation: Resilience Theory in Mathematics Education

In mathematics education, Resilience Theory explains why some students persist despite difficulties, while others disengage due to mathematics anxiety (Masten, 2001; Johnston-Wilder & Lee, 2010). Masten defines resilience as a process of positive adaptation in the face of adversity, which is particularly relevant in

mathematics education, where many students perceive failure as an indication of fixed ability rather than an opportunity for growth. Mathematical resilience draws from this broader concept of resilience and applies it specifically to the learning of mathematics. Students who exhibit mathematical resilience demonstrate emotional regulation, persistence in problem-solving, and a belief in their own capacity to improve. Johnston-Wilder and Lee have identified three fundamental components of mathematical resilience: the development of a growth mindset, the cultivation of mathematical agency, and the creation of a supportive learning environment. These elements work together to shape how students interact with mathematics, influence their perception of their own mathematical abilities, and ultimately determine their capacity to overcome anxiety and engage effectively with the subject.

A growth mindset, as articulated by Dweck, plays a central role in fostering mathematical resilience. Students with a growth mindset believe that mathematical ability is not a fixed trait but rather a skill that can be developed through effort and persistence. This perspective is particularly important in mitigating the negative effects of mathematics anxiety, as it encourages students to reframe challenges as opportunities for learning rather than indicators of failure. In addition to mindset, mathematical agency—the sense of ownership and control over one's learning—is a crucial factor in building resilience. Students who believe they have the capacity to influence their own learning outcomes are more likely to persist in problem-solving and less likely to disengage when faced with difficulties.

Equally important is the role of the learning environment in shaping students' mathematical resilience. A classroom culture that encourages risk-taking, embraces mistakes as a natural part of the learning process, and fosters peer collaboration creates conditions that support resilience. Teachers play a pivotal role in establishing such an environment by providing constructive feedback, using pedagogical strategies that reduce anxiety, and creating opportunities for students to engage in collaborative learning. Research indicates that students who learn in environments that normalize struggle and celebrate effort demonstrate higher levels of resilience and lower levels of mathematics anxiety.

The Interplay Between Mathematics Anxiety and Mathematical Resilience

Mathematics anxiety and mathematical resilience exist in a dynamic relationship, where the presence of one often influences the development of the other. Students with high levels of mathematics anxiety tend to develop avoidance behaviors, which further reinforce negative self-perceptions and increase their reluctance to engage with mathematical tasks. Conversely, students who cultivate mathematical resilience are more likely to persist despite challenges, develop adaptive coping strategies, and experience a greater sense of confidence in their mathematical abilities.

This study proposes a conceptual model that situates mathematical resilience as a mediating factor in the relationship between mathematics anxiety and academic performance. Within this model, mathematics anxiety serves as an initial barrier to engagement, leading to fear-driven avoidance and negative emotional responses. However, when students are exposed to intervention strategies that promote resilience—such as mindset training, peer-assisted learning, and teacher-led scaffolding—the negative effects of anxiety can be mitigated. These interventions provide students with the emotional and cognitive tools necessary to regulate anxiety, reframe their understanding of failure, and build persistence in mathematical problem-solving.

Interventions for Enhancing Mathematical Resilience

A growing body of research suggests that mathematical resilience can be cultivated through targeted educational interventions. One of the most effective approaches is the creation of mistake-friendly classrooms, where students are encouraged to see errors as valuable learning experiences rather than indicators of incompetence. By shifting the emphasis from correct answers to problem-solving processes, teachers can help students develop a more positive relationship with mathematics. Peer-assisted learning strategies have also been shown to enhance mathematical resilience by fostering a sense of collective problem-solving and reducing the social stigma associated with struggling in mathematics. When students work collaboratively, they not only gain exposure to diverse problem-solving approaches but also develop confidence through shared learning experiences.

In addition to classroom-based strategies, emotional regulation training plays a critical role in helping students manage mathematics anxiety. Interventions based on self-efficacy theory suggest that students benefit from structured opportunities to experience incremental successes in mathematics. By gradually increasing the complexity of mathematical tasks and providing positive reinforcement along the way, educators can help students build confidence and develop a sense of control over their learning outcomes.

Contextual Considerations: The Role of Mathematical Resilience in Rural Education

In rural districts such as Kalomo, where students often face heightened challenges due to limited access to resources and large class sizes, the development of mathematical resilience is particularly crucial. Students in these settings may have fewer opportunities for individualized support, making it essential for educational interventions to incorporate resilience-building strategies that empower students to become self-directed learners. The application of Resilience Theory in this context provides a valuable framework for understanding how students navigate the compounded challenges of mathematics anxiety and resource constraints.

This study examines how targeted interventions—such as teacher training programs, peer mentorship initiatives, and culturally responsive pedagogical approaches—can support the development of mathematical resilience in rural classrooms. By applying resilience-based educational strategies, it is possible to create a learning environment that not only mitigates mathematics anxiety but also fosters long-term engagement and success in mathematics. Mathematical resilience is a critical factor in overcoming mathematics anxiety and fostering sustained engagement with the subject. By applying Resilience Theory to mathematics education, this study seeks to illuminate the mechanisms through which students develop persistence, regulate anxiety, and build confidence in their mathematical abilities. In contexts where mathematics anxiety is prevalent, particularly in rural and resource-limited settings, resilience-based interventions offer a promising pathway for improving student outcomes.

This conceptual framework positions mathematical resilience as a transformative force in mathematics education, shifting the narrative from one of anxiety and avoidance to one of growth, persistence, and success. Through a deeper understanding of the interplay between mathematics anxiety and resilience, this study contributes to the ongoing discourse on educational psychology and mathematics pedagogy, offering insights that have the potential to inform both policy and classroom practice.

Conceptualizing Math Anxiety and Resilience

Mathematics anxiety is a deeply ingrained issue that affects individuals across different age groups and educational contexts, shaping their attitudes, behaviours, and overall engagement with mathematical tasks. It extends beyond momentary nervousness, manifesting as a persistent sense of fear, worry, and apprehension that disrupts cognitive functioning and negatively impacts learning outcomes. This anxiety is not merely an emotional response; rather, it operates on multiple levels, encompassing emotional, cognitive, and behavioural dimensions. Emotionally, students experience heightened stress and avoidance tendencies when confronted with mathematical problems, leading to increased physiological responses such as elevated heart rates and anxious rumination. Cognitively, math anxiety erodes self-efficacy, reinforcing negative self-perceptions about one's mathematical abilities and feeling a self-perpetuating cycle of underachievement. Behaviourally, individuals affected by math anxiety are likely to withdraw from mathematics-related activities, avoid academic pathways that involve quantitative reasoning, and develop a learned helplessness that further diminishes their engagement with the subject (Zhang, 2023; Luttenberger et al., 2018).

A fundamental factor in the development of math anxiety, particularly among children, is the influence of parental attitudes toward mathematics. The home environment plays a pivotal role in shaping early attitudes toward learning, and parental anxieties about mathematics can be implicitly transmitted to children. Studies have shown that parents who experience high levels of math anxiety often unconsciously model their fears, inadvertently discouraging their children from engaging confidently with mathematics. The nature of parental involvement is also crucial in this dynamic. Parents who exert excessive control over their children's math learning—rather than fostering autonomy-supportive learning environments—can contribute to the development of anxiety by making mathematics seem more stressful and intimidating than it actually is. Conversely, well-

intentioned but highly anxious parents who frequently assist with homework may unintentionally heighten their child's anxiety rather than alleviate it. Research confirms that children of math-anxious parents tend to perform worse in mathematics, particularly when these parents are heavily involved in their children's math-related tasks (Oh et al., 2022; Retanal et al., 2021; Maloney et al., 2015). This suggests that it is not simply parental involvement, but the quality and nature of this involvement, that influences math anxiety and achievement outcomes. A parent who expresses confidence and frames math as a problem-solving adventure fosters a markedly different perception than one who signals nervousness, frustration, or avoidance. Thus, the role of parents in mitigating or exacerbating math anxiety underscores the importance of fostering positive, encouraging, and autonomy-supportive mathematical interactions at home (Casad et al., 2015; Haque & Farhana, 2017).

Teachers similarly play a crucial role in shaping students' mathematical attitudes and experiences. A math-anxious teacher, consciously or unconsciously, may transmit their own discomfort with mathematics to students, reinforcing negative perceptions and creating a less supportive learning environment. The influence of teacher anxiety extends beyond individual classrooms, as it can reinforce broader societal stereotypes about mathematics ability. For instance, studies indicate that female teachers with high levels of math anxiety are more likely to unintentionally reinforce gendered beliefs about mathematical competence, subtly discouraging female students from pursuing mathematics with confidence. This dynamic contributes to the well-documented gender gap in STEM fields, as early exposure to math-anxious teaching can lead girls to internalize the notion that mathematics is inherently difficult or reserved for a select group of "naturally gifted" individuals (Beilock et al., 2010). Furthermore, math-anxious teachers may be less inclined to adopt innovative or student-centered teaching strategies, relying instead on rote memorization or procedural learning, which has been shown to exacerbate anxiety rather than alleviate it. When teachers lack confidence in their mathematical abilities, they may project their insecurities onto their students, creating an environment where mistakes are feared rather than viewed as opportunities for learning (Luo et al., 2023; Ramirez et al., 2018). Given the critical role of teachers in shaping mathematical mindsets, professional development programs that focus on reducing teacher math anxiety and equipping educators with effective pedagogical strategies are essential in addressing this issue at a systemic level.

Another major contributor to mathematics anxiety is the complex relationship between self-efficacy and performance. Students who lack confidence in their mathematical abilities often experience a self-fulfilling prophecy, where anxiety leads to avoidance, reduced effort, and ultimately lower achievement, which in turn reinforces their initial self-doubt. This interplay creates a cyclical pattern in which students develop a learned helplessness toward mathematics, believing that they are inherently "bad at math" and that no amount of effort will change their abilities (Ashcraft & Kirk, 2001; Zhang et al., 2019). Self-efficacy, or the belief in one's capacity to succeed in specific tasks, has been identified as a crucial psychological construct in mitigating mathematics anxiety. When students believe they can improve their mathematical skills through effort and practice, they are more likely to engage in problem-solving, persist through difficulties, and ultimately perform better. Conversely, students with low self-efficacy are more likely to disengage at the first sign of struggle, further reinforcing their anxiety. The literature highlights that students who have had repeated negative experiences with mathematics—such as repeated failures, harsh criticism, or pressure to perform—are more likely to experience anxiety that persists into adulthood (Ashcraft & Moore, 2009). This indicates that interventions aimed at increasing self-efficacy, such as incremental learning, positive reinforcement, and mastery-based learning approaches, are particularly effective in breaking the cycle of math anxiety.

The interplay between math anxiety, parental influence, teacher attitudes, and self-efficacy highlights the complexity of this issue and the need for multi-faceted interventions. Simply addressing one dimension, such as providing extra tutoring to anxious students, may not be sufficient if their broader learning environment continues to reinforce negative attitudes toward mathematics. Effective interventions should focus on both individual and systemic factors. At the parental level, equipping caregivers with strategies to foster a growth mindset and a positive approach to mathematics can prevent the transmission of anxiety across generations. Within the educational sphere, teacher training programs that focus on reducing math anxiety among educators and promoting resilience-based teaching strategies can have a far-reaching impact on student outcomes. Additionally, fostering self-efficacy through structured, supportive learning experiences—where students

experience incremental successes and develop confidence in their mathematical abilities—can serve as a powerful countermeasure to math anxiety.

Ultimately, mathematics anxiety is not an inherent trait but a learned response, shaped by social influences, educational experiences, and individual psychological factors. Understanding its multidimensional nature provides valuable insights into how it can be addressed effectively. By creating environments that normalize struggle, encourage persistence, and frame mathematics as an accessible and rewarding discipline, students can develop resilience and overcome their fears. Addressing the roots of math anxiety requires a shift in perspective—one that moves away from seeing mathematical ability as a fixed trait and toward recognizing it as a skill that can be developed with the right support, encouragement, and mindset.

Empirical Studies on Math Anxiety and Resilience

Mathematics anxiety is a widespread challenge that affects students globally, disrupting their ability to engage confidently with mathematical concepts. This issue is particularly pronounced in African educational contexts, where systemic constraints, including resource limitations, teacher shortages, and large class sizes, often exacerbate the anxiety students experience in learning mathematics. While mathematics anxiety manifests as a cognitive, emotional, and behavioral response that hinders mathematical engagement, research has increasingly highlighted the role of resilience in counteracting its negative effects. Resilience, understood as the ability to persist in learning despite difficulties, has emerged as a crucial factor in shaping students' mathematical experiences. Empirical studies suggest that fostering resilience can mitigate the adverse impacts of mathematics anxiety, enabling students to develop adaptive coping strategies that improve both their academic performance and overall learning attitudes.

A growing body of research underscores the significance of resilience in mathematics education across different cultural contexts. Liu's longitudinal study on college students emphasizes the role of resilience in online mathematics learning, demonstrating that students with higher resilience exhibit greater engagement and academic success in digital learning environments (Liu, 2024). This finding is particularly relevant in an era where digital education is expanding, as it suggests that resilience not only buffers students against anxiety but also facilitates adaptability to evolving learning modalities. Ersozlu et al. further contribute to this discourse by exploring cross-cultural differences in mathematics anxiety, revealing that resilience is not a universal construct but is shaped by cultural and educational contexts (Ersozlu et al., 2022). Their comparative analysis of students in Australia and Russia highlights variations in how resilience is cultivated and its impact on mathematical achievement, underscoring the need for context-sensitive educational interventions. These studies reinforce the notion that resilience-building strategies must be adapted to the specific challenges and expectations of different educational systems.

In Africa, where mathematics anxiety is often compounded by structural challenges such as limited instructional resources and teacher-centered pedagogies, resilience emerges as an essential attribute for student success. Awofala's research on Nigerian students establishes a strong correlation between mathematical resilience and academic performance, demonstrating that students who develop resilience are better equipped to overcome mathematics-related stress and perform well in assessments (Awofala, 2021). This aligns with Akkan's systematic review, which identifies key dimensions of mathematical resilience, including cognitive and affective factors, and provides actionable recommendations for educators seeking to cultivate resilience in students (Akkan, 2024). The African educational context, characterized by diverse socio-economic backgrounds and varying levels of instructional quality, necessitates resilience-building approaches that are not only pedagogically sound but also culturally relevant. The ability of students to persist in learning despite external barriers is particularly crucial in environments where academic support structures may be limited.

To address mathematics anxiety effectively, resilience-building must be integrated into teaching and learning practices. Johnston-Wilder et al. propose a comprehensive toolkit designed to support teachers, learners, and parents in fostering mathematical safeguarding and resilience (Johnston-Wilder et al., 2020). This toolkit highlights the importance of psychological support, equipping students with coping strategies that allow them to navigate mathematical challenges with greater confidence. The role of educators in creating resilience-friendly learning environments is further emphasized in Tambunan's analysis, which underscores the impact of teacher

performance on student resilience and mathematical literacy (Tambunan, 2021). A teacher's approach to mathematics instruction can either reinforce anxiety or foster a sense of self-efficacy, making professional development in resilience-based teaching methodologies a crucial aspect of educational reform.

Beyond teacher-led interventions, innovative pedagogical strategies offer promising avenues for resilience development. Sari's research on flipped learning demonstrates how active engagement and problem-solving approaches contribute to mathematical resilience by encouraging students to take ownership of their learning (Sari, 2023). Unlike traditional lecture-based instruction, which often induces passive learning and increases anxiety, flipped learning fosters a student-centered approach where learners interact with mathematical concepts at their own pace. This pedagogical shift not only enhances understanding but also builds confidence, reducing the fear associated with making mistakes. Similarly, Oszwa's ecological model of mathematical resilience advocates for a holistic perspective, integrating environmental, instructional, and psychological factors to create a supportive learning ecosystem (Oszwa, 2022). This model suggests that resilience is not developed in isolation but emerges from a network of influences, including classroom culture, peer interactions, and access to learning resources.

The implications of these findings extend beyond academic discourse and call for systemic changes in mathematics education. Schools and educational policymakers must recognize that addressing mathematics anxiety requires more than remedial interventions; it demands a paradigm shift in how mathematics is taught and perceived. Embedding resilience-building practices within curricula, fostering positive mathematical mindsets, and providing educators with the necessary training to support anxious learners are crucial steps toward creating a more inclusive and effective learning environment. Moreover, parental engagement initiatives should focus on equipping caregivers with strategies to support mathematical resilience at home, ensuring that students receive consistent reinforcement across different learning spaces.

The interplay between mathematics anxiety and resilience presents a compelling area of research that holds significant potential for transforming mathematics education. By prioritizing resilience as a fundamental component of mathematical instruction, educators and policymakers can create learning environments where students feel empowered rather than intimidated by mathematical challenges. The development of resilience is not merely about improving test scores; it is about fostering a mindset that allows students to approach problem-solving with confidence, adaptability, and persistence. A sustained commitment to resilience-building in mathematics education will not only alleviate anxiety but also cultivate a generation of learners who view mathematics as an accessible and valuable skill rather than an insurmountable obstacle.

Gaps in Existing Literature

The existing body of research on developing mathematical resilience and alleviating mathematics anxiety among secondary school students presents notable gaps, particularly in socio-cultural contexts like Kalomo District, Zambia. While a substantial body of literature has explored the impact of mathematics anxiety on student performance, self-efficacy, and career aspirations, much of this research has been conducted in Western or more developed educational systems. The applicability of such findings to the Zambian context remains uncertain, as the cultural, pedagogical, and systemic differences between these educational environments are significant. The absence of localized research constrains a deeper understanding of how factors such as societal expectations, teacher-student interactions, and parental involvement shape mathematics anxiety and resilience among Zambian students (Zakaria et al., 2012; Brewster & Miller, 2023).

One of the most pressing concerns in the literature is the lack of targeted intervention strategies that are culturally relevant and contextually appropriate for Zambia. Research has demonstrated that interventions such as mindfulness practices, cognitive-behavioral approaches, and resilience-building programs have been effective in alleviating mathematics anxiety in other settings (Brunyé et al., 2013; Ola-Oluwa, 2021). However, these interventions are often designed within educational systems that have well-established psychological support structures and resources, making direct application to Zambia's educational landscape challenging. Studies suggest that effective interventions in the Zambian context would need to integrate parental involvement and community engagement, as these factors play a significant role in shaping students' attitudes towards mathematics (Choi & Han, 2020; Casad et al., 2015). The role of parents in either exacerbating or alleviating

mathematics anxiety cannot be overlooked, as parental attitudes toward mathematics influence children's self-perceptions and learning behaviors. In Zambia, where education is often a collective effort involving extended families and community structures, interventions should incorporate culturally attuned parental education programs that encourage supportive rather than pressurizing approaches to mathematics learning.

Beyond parental influence, gender disparities in mathematics anxiety remain a significant issue that requires targeted attention. Research has consistently shown that female students report higher levels of anxiety towards mathematics compared to their male counterparts, a trend that ultimately affects their academic performance and career aspirations in STEM fields (Goetz et al., 2013; Wang et al., 2015). The cultural reinforcement of gender norms in education, particularly in Zambia, can further exacerbate this disparity, discouraging girls from pursuing mathematics-intensive fields. Although global studies have examined interventions aimed at boosting female students' confidence in mathematics, there is limited research on gender-sensitive strategies that account for Zambia's unique socio-cultural dynamics. Addressing these disparities requires interventions that go beyond classroom instruction and tackle deep-seated societal perceptions about gender and mathematical ability. Programs that provide mentorship, showcase successful female mathematicians, and create supportive peer-learning environments could serve as potential strategies to foster resilience and confidence among female students.

Another critical area that remains underexplored in the literature is the integration of indigenous knowledge and culturally relevant pedagogies into mathematics education. There is growing recognition that the way mathematics is taught influences students' engagement, perception, and overall anxiety levels. Conventional mathematics curricula often present the subject in an abstract, decontextualized manner that may feel disconnected from students' lived experiences (Kadonsi, 2023). In contrast, culturally responsive teaching approaches that incorporate indigenous mathematical concepts and real-world applications relevant to students' communities have been shown to enhance engagement and reduce anxiety. The integration of local practices—such as traditional measurement systems, counting methods, and problem-solving approaches used in everyday life—could make mathematics more accessible and meaningful to students in Kalomo District. By bridging the gap between cultural identity and academic content, such pedagogical strategies could foster deeper mathematical resilience and a more positive learning experience.

The need for localized research that explicitly addresses these gaps is evident. While broader studies provide valuable insights into the nature of mathematics anxiety and resilience, they often lack the depth needed to inform practical, context-specific interventions in Zambia. The challenge is not only to understand how mathematics anxiety manifests in this specific educational setting but also to develop actionable strategies that align with the realities of Zambia's schooling system, socio-economic conditions, and cultural expectations. Future research must focus on designing, implementing, and evaluating interventions that cater to Zambia's diverse student population, considering variations in rural and urban schooling environments, teacher training capacities, and resource availability.

A comprehensive approach to addressing mathematics anxiety in Kalomo District should therefore encompass multiple levels of intervention. At the pedagogical level, innovative teaching methodologies that align with students' cultural backgrounds and lived experiences should be explored. At the institutional level, teacher training programs must be strengthened to equip educators with the skills to recognize and address mathematics anxiety while fostering resilience in students. At the community level, parental education initiatives and mentorship programs should be developed to create a more supportive learning environment, particularly for female students. Finally, at the research level, empirical studies tailored to Zambia's context should be prioritized to inform evidence-based policy recommendations.

Ultimately, the intersection of mathematics anxiety and resilience is a crucial area of inquiry that requires a localized and multi-dimensional approach. By incorporating cultural insights, addressing gender disparities, leveraging community involvement, and integrating indigenous pedagogies, Zambia can move towards a more inclusive and effective mathematics education system. A shift from merely acknowledging the existence of mathematics anxiety to actively developing and implementing resilience-building strategies will not only improve student outcomes but also contribute to long-term educational equity and economic empowerment in the region.

METHODOLOGY

The Methodology section outlines the research design, study population, sampling methods, data collection techniques, data analysis strategies, and ethical considerations used in this study. It employs an Explanatory Sequential Mixed-Methods Design, integrating both quantitative and qualitative approaches to examine the relationship between mathematics anxiety and mathematical resilience among secondary school students in Kalomo District, Zambia. This two-phase design allows the study to quantify the prevalence of mathematics anxiety and resilience before exploring the underlying cognitive, emotional, and environmental factors that influence students' experiences. The methodology ensures empirical rigor, contextual depth, and practical applicability, making the study's findings relevant for educational policymakers, teachers, and researchers seeking to improve mathematics education in low-resource settings.

Research Design

The Explanatory Sequential Mixed-Methods Design was selected for this study as it facilitates a comprehensive, two-phase investigation into the relationship between mathematics anxiety and mathematical resilience among secondary school students in Kalomo District, Zambia. This design is particularly well-suited for understanding both the prevalence and underlying causes of mathematics anxiety, ensuring that findings are empirically grounded and contextually meaningful.

In Phase One (Quantitative Component), the study establishes a statistical foundation by measuring mathematics anxiety levels, resilience factors, and academic performance using standardized psychometric instruments. This phase provides objective, generalizable insights into how mathematics anxiety manifests within the student population and identifies patterns that warrant further exploration. However, while quantitative data can reveal correlations and prevalence rates, it does not explain the underlying cognitive, emotional, and environmental factors influencing students' experiences. To address this limitation, Phase Two (Qualitative Component) is designed to delve deeper into the findings from the quantitative phase by gathering rich, narrative-based insights through semi-structured interviews, focus group discussions, and classroom observations. This phase allows the study to explore students' perceptions, coping mechanisms, and the role of teacher interventions in fostering mathematical resilience. By integrating numerical data with qualitative interpretations, the research gains a more nuanced understanding of how students navigate mathematics anxiety and develop resilience in real-world educational settings (Creswell & Plano Clark, 2018).

A single-method approach would be inadequate for capturing the complex interplay between cognitive, emotional, and environmental influences on mathematics anxiety. A purely quantitative study might provide broad statistical relationships but would lack depth in explaining the "why" and "how" behind the observed trends. Conversely, a purely qualitative study would offer rich personal narratives but could not provide statistical validation and generalizability across the broader student population. By combining both approaches, the mixed-methods design enhances research validity through triangulation, ensuring that the findings are both statistically reliable and practically relevant to educational interventions. This research design is particularly relevant for education in developing contexts such as Zambia, where students in rural schools face unique socio-economic and pedagogical challenges that require both empirical measurement and qualitative exploration. The integration of quantitative data for evidence-based analysis and qualitative insights for contextual interpretation ensures that the study's findings are not only academically rigorous but also actionable for policymakers and educators seeking to enhance mathematics education in low-resource environments.

Study Population

This study examines secondary school students and mathematics teachers in Kalomo District, Zambia, a population selected due to the critical role secondary education plays in shaping mathematical competence, confidence, and long-term engagement with STEM disciplines. Research has consistently shown that mathematics anxiety peaks during secondary school years, as students transition from foundational arithmetic to more abstract mathematical reasoning (Ramirez et al., 2018). This stage is particularly significant because mathematical resilience—the ability to persist in learning despite challenges—is often developed in response to

the cognitive and emotional demands imposed by more advanced mathematical concepts. Given that mathematics achievement at this level directly influences students' academic trajectories and career choices, understanding the mechanisms through which resilience is built and sustained is fundamental to improving mathematics education outcomes.

Beyond student experiences, mathematics teachers play an equally significant role in fostering resilience in mathematics learning. Empirical studies indicate that teachers' instructional strategies, feedback mechanisms, and classroom culture strongly influence students' ability to cope with mathematical anxiety (Boaler, 2016). By examining mathematics teachers in Kalomo District, this study aims to uncover how pedagogical practices, teacher perceptions, and classroom support structures impact students' development of resilience. The inclusion of teachers as part of the study population is essential for identifying effective intervention strategies that can be embedded within classroom instruction to mitigate the effects of mathematics anxiety.

The selection of Kalomo District as the study site is particularly significant due to the structural and socio-economic challenges that characterize rural education in Zambia. Research on mathematics education in low-resource settings suggests that students in rural schools often experience additional barriers such as limited access to qualified teachers, insufficient instructional materials, large class sizes, and socio-cultural beliefs that reinforce negative attitudes toward mathematics (World Bank, 2021). These conditions exacerbate mathematics anxiety and learning difficulties, making the development of resilience particularly crucial. Investigating how students in such environments develop mathematical resilience offers valuable insights into context-specific strategies that address structural inequities and promote inclusive, high-quality mathematics education.

To ensure a focused and methodologically sound investigation, this study will include secondary school students in Grades 10 to 12 who have been enrolled in either government or private secondary schools in Kalomo District for at least two academic years. Students at this level have been exposed to sufficient mathematical instruction, allowing for meaningful assessment of anxiety levels, coping mechanisms, and resilience-building strategies. In addition, mathematics teachers with at least one year of teaching experience at the secondary school level in Kalomo District will be included, as they provide critical perspectives on instructional strategies, student engagement, and the effectiveness of interventions aimed at reducing mathematics anxiety.

To maintain research validity and ensure alignment with study objectives, certain groups will be excluded. Students below Grade 10 will not be included, as they may not have been sufficiently exposed to complex mathematical concepts that typically trigger mathematics anxiety. Teachers who do not specialize in mathematics will also be excluded, as their insights would not align with the study's focus on resilience-building within mathematics instruction. Furthermore, students with severe learning disabilities affecting mathematical comprehension will not be included unless specialized interventions addressing their unique needs are incorporated into the research scope.

By focusing on secondary school students and mathematics teachers in Kalomo District, this study ensures a holistic investigation into the development of mathematical resilience and its impact on reducing mathematics anxiety. The findings will contribute to evidence-based educational policies, teacher training initiatives, and curriculum reforms aimed at enhancing mathematics learning experiences in rural Zambia. Additionally, the study will provide insights that inform future research on resilience-building in mathematics education across similar socio-economic contexts in sub-Saharan Africa.

Sample Size

The sample size for this study was determined using a combination of statistical power analysis and purposive sampling techniques to ensure both quantitative generalizability and qualitative depth. Given that this research employs an Explanatory Sequential Mixed-Methods Design, the quantitative phase required a statistically representative sample to establish measurable patterns in mathematics anxiety and resilience, while the qualitative phase was designed to generate in-depth, contextual insights into students' lived experiences, coping mechanisms, and the role of instructional strategies.

For the quantitative phase, the sample size was determined using Cochran's formula for finite populations, a widely accepted method in educational research for estimating appropriate sample sizes based on confidence level, margin of error, and expected response variance. Given that Kalomo District has an estimated secondary school student population of 3,500, and assuming a 95% confidence level, a 5% margin of error, and an estimated response variance of 50%, the minimum required sample size was calculated as 350 students. To mitigate potential non-responses or incomplete surveys, the final sample was adjusted to 375 students, ensuring sufficient statistical power for quantitative analysis.

For the qualitative phase, a purposive sampling approach was employed to select a subset of participants whose perspectives would provide rich, contextualized insights into the findings from the quantitative phase. A total of 25 students were selected based on their mathematics anxiety and resilience scores, ensuring variation across low, moderate, and high resilience levels. In addition, 12 mathematics teachers were included to provide insights into pedagogical strategies and classroom-based resilience interventions. To capture institutional perspectives, five school administrators were selected to offer insights into school-level policies and systemic support mechanisms for mathematics education.

The final qualitative sample size was determined based on data saturation principles, wherein additional interviews and focus groups did not yield new emergent themes. Previous research in educational psychology suggests that a qualitative sample size between 20 and 50 participants is sufficient for thematic saturation in studies examining learning behaviours and instructional dynamics (Guest, Bunce, & Johnson, 2006). The selection of 42 participants was therefore adequate to ensure comprehensive coverage of key themes while maintaining methodological rigor.

The chosen sample sizes for both phases align with best practices in mixed-methods educational research. The quantitative sample provides a statistically sound basis for identifying patterns in mathematics anxiety and resilience, while the qualitative sample ensures that the findings are contextually grounded in students' and teachers' lived experiences. This integration strengthens the validity, reliability, and applicability of the study's findings, ensuring that insights generated from the research are both empirically robust and practically meaningful for improving mathematics education in Zambia's rural school system.

Data Collection Methods

To ensure a comprehensive understanding of mathematics anxiety and resilience among secondary school students in Kalomo District, Zambia, this study adopted a mixed-methods approach, integrating both quantitative and qualitative data collection techniques. This combination allowed for a deeper exploration of the factors influencing mathematics anxiety while also ensuring that findings were measurable, replicable, and enriched by real-life experiences.

Structured surveys were administered to a representative sample of students to capture their levels of mathematics anxiety, coping mechanisms, and overall resilience. The survey incorporated a range of question formats, including Likert-scale items and structured prompts, to gauge emotional responses to mathematics and the effectiveness of various intervention strategies. To enhance reliability and validity, the survey was based on well-established instruments such as the Mathematics Anxiety Rating Scale (MARS) and the Mathematical Resilience Scale (MRS), both of which have been extensively validated in educational psychology research. Before being distributed to participants, the survey underwent pilot testing to refine question clarity and ensure response accuracy.

To complement the quantitative data gathered through surveys, semi-structured interviews were conducted with students, mathematics teachers, and school administrators. These interviews were designed to uncover deeper insights into the causes of mathematics anxiety, the effectiveness of teacher interventions, and the role of peer support and digital learning tools in fostering resilience. The flexible structure of these interviews allowed participants to elaborate on their experiences while ensuring consistency in data collection. Students shared their personal struggles and coping mechanisms, while teachers and administrators reflected on the broader instructional and institutional factors influencing mathematics learning. Participants were selected through

purposive sampling to ensure a diverse representation of perspectives across different academic performance levels and school environments. All interviews were audio-recorded, transcribed verbatim, and analyzed thematically using NVivo software, following Braun and Clarke's six-step framework for thematic analysis.

In addition to surveys and interviews, non-participant classroom observations were conducted to provide a real-time perspective on how mathematics anxiety manifests in learning environments. These observations focused on student engagement, teacher-student interactions, and anxiety-related behaviors such as avoidance, hesitation, or visible frustration during problem-solving tasks. A structured observation protocol was used to ensure consistency in data collection across different classrooms. Attention was given to the instructional strategies employed by teachers, the extent to which students actively participated in mathematical discussions, and the role of peer interactions in either alleviating or exacerbating anxiety. Observations were carried out across multiple sessions in both government and private schools to ensure variability in teaching approaches and classroom settings. This contextualized perspective enriched the survey and interview findings, allowing for a more comprehensive analysis of mathematics anxiety and resilience in diverse educational settings.

To provide an objective measurement of mathematics anxiety and resilience levels, the study incorporated standardized psychometric instruments, including the Mathematics Anxiety Rating Scale (MARS) and the Mathematical Resilience Scale (MRS). These tools were used in a pre-test and post-test format to assess changes in students' anxiety levels following the implementation of intervention strategies. The collected data were analyzed using statistical techniques such as paired t-tests and ANOVA to determine whether there were significant differences in anxiety levels across various intervention groups. By integrating standardized measurement tools with qualitative insights, the study ensured a robust and multidimensional approach to understanding mathematics anxiety.

The use of multiple data collection methods strengthened the credibility of the study by allowing for triangulation of findings. Surveys provided broad, quantifiable trends, while interviews offered in-depth personal narratives that added depth to the statistical results. Classroom observations captured the learning environment in its natural form, helping to contextualize the experiences shared in interviews and survey responses. Meanwhile, standardized mathematics anxiety scales ensured precise measurement of anxiety levels before and after interventions. This holistic approach provided a nuanced understanding of how students experience and cope with mathematics anxiety, while also shedding light on the effectiveness of various interventions in fostering resilience.

Data Analysis Techniques

To ensure a rigorous and comprehensive examination of the data collected, this study employed both quantitative and qualitative analysis techniques. The quantitative data derived from surveys and standardized mathematics anxiety scales were analyzed using Statistical Package for the Social Sciences (SPSS), while the qualitative data from interviews and classroom observations were subjected to thematic analysis. The integration of these analytical methods provided a multidimensional understanding of the factors influencing mathematics anxiety and resilience among secondary school students.

Quantitative data were analyzed using descriptive and inferential statistical techniques to identify trends, patterns, and relationships in the dataset. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize the overall distribution of mathematics anxiety levels among students. To compare pre-test and post-test anxiety scores following various intervention strategies, paired t-tests were conducted, assessing whether the differences in mean scores were statistically significant. The assumption of normality was checked using Shapiro-Wilk tests and histogram visualizations to confirm whether the anxiety score distributions met the conditions required for parametric testing. Where normality was violated, Wilcoxon signed-rank tests were used as a non-parametric alternative.

To determine whether there were significant differences in anxiety reduction across the different intervention groups, one-way analysis of variance (ANOVA) was performed. Before conducting ANOVA, assumptions of

homogeneity of variance (Levene's test) and independence of observations were checked to ensure validity. In cases where homogeneity of variance was violated, Welch's ANOVA was used as an alternative. If a significant main effect was found, post hoc tests such as Tukey's HSD or Games-Howell tests were conducted to identify specific group differences. Additionally, correlation analyses (Pearson's or Spearman's rank correlation, depending on normality conditions) were used to examine relationships between students' mathematics anxiety levels, resilience scores, and demographic factors such as gender, school type, and grade level.

For qualitative data obtained from interviews and classroom observations, thematic analysis was employed following Braun and Clarke's (2006) six-phase framework. This process involved data familiarization, initial code generation, theme identification, theme refinement, and final interpretation. NVivo software was used to facilitate data coding and pattern recognition, ensuring a systematic and reproducible approach to theme development. The credibility of the thematic analysis was enhanced through inter-coder reliability checks, where multiple researchers reviewed and refined coding to ensure consistency and minimize bias.

To further strengthen the robustness of findings, triangulation was employed by cross-referencing results from statistical analysis with qualitative insights from interviews and observations. This integration of quantitative and qualitative findings provided a more holistic interpretation of the factors influencing mathematics anxiety and resilience. The combination of rigorous statistical analysis, thematic exploration, and data triangulation ensured that the study produced reliable, valid, and insightful conclusions regarding effective strategies for reducing mathematics anxiety among secondary school students.

Ethical Considerations

This study adhered to strict ethical guidelines to ensure the rights, dignity, and well-being of all participants were safeguarded throughout the research process. Ethical approval was obtained from the relevant institutional review board and educational authorities before data collection commenced. The study followed established ethical principles, including informed consent, anonymity, confidentiality, and voluntary participation, in alignment with research ethics protocols for studies involving human participants. Before participation, all students, teachers, and school administrators were fully informed about the purpose of the study, the procedures involved, potential risks and benefits, and their rights as participants. Written informed consent was obtained from all participants, and in the case of students who were minors, additional parental or guardian consent was secured. Participants were assured that their involvement in the study was entirely voluntary, and they had the right to withdraw at any stage without any negative consequences.

To protect anonymity and confidentiality, no personally identifiable information was collected or recorded. Participants were assigned coded identifiers to ensure that survey responses, interview transcripts, and observational notes could not be traced back to specific individuals. All data were stored in password-protected electronic files, and access was restricted to authorized research personnel only. Direct quotes from interviews used in the study's findings were carefully anonymized to prevent any unintentional identification of participants. The study also ensured adherence to the principle of non-maleficence, meaning that no participant was subjected to harm, distress, or undue pressure. Given the sensitive nature of discussing mathematics anxiety, participants were encouraged to share their experiences at their comfort level, and interviews were conducted in a respectful and non-judgmental manner. Teachers and school administrators were consulted to ensure that data collection activities did not interfere with regular academic activities.

Throughout the study, ethical compliance was maintained in accordance with institutional guidelines and international ethical research standards, such as those outlined in the Belmont Report (1979) and the American Psychological Association (APA) ethical principles. At the conclusion of data collection, participants were debriefed, and any concerns they had regarding the research process were addressed. The findings were shared with participating schools in a summarized format, ensuring that insights from the study contributed to practical improvements in mathematics education while respecting participant confidentiality.

RESULTS

This section presents the findings of the study based on the quantitative and qualitative data collected. The results are structured according to the study objectives, which guided the data analysis and presentation. The study aimed to:

Assess the prevalence of mathematics anxiety among secondary school students in Kalomo District.

Evaluate the effectiveness of teacher-led instructional strategies in reducing mathematics anxiety.

Examine the influence of mindset development on mathematical resilience among secondary school students.

The findings are organized into descriptive statistics, an analysis of mathematics anxiety levels, an evaluation of resilience-building strategies, and thematic insights from qualitative data.

Descriptive Statistics

The study surveyed 375 secondary school students and conducted interviews and focus group discussions with 25 students and 12 mathematics teachers. The demographic breakdown of the student participants is presented in Table 1.

Table 1: Demographic Characteristics of Student Participants

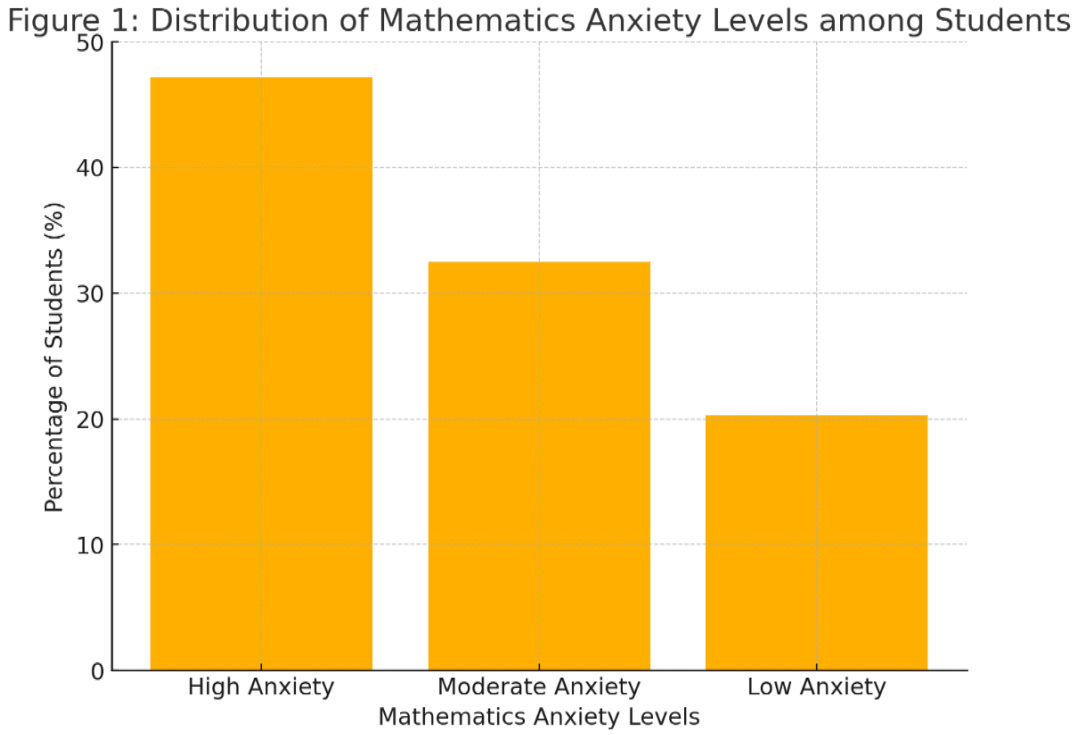
Characteristic	Frequency (n)	Percentage (%)
Gender		
Male	180	48.0%
Female	195	52.0%
Grade Level		
Grade 10	125	33.3%
Grade 11	130	34.7%
Grade 12	120	32.0%
School Type		
Government	285	76.0%
Private	90	24.0%
Government	285	76.0%

The study involved a total of 375 student participants, categorized based on gender, grade level, and school type. The gender distribution of the participants was fairly balanced, with 180 males (48.0%) and 195 females (52.0%). This indicates a slight predominance of female participants in the study. The participants were drawn from three different grade levels. Grade 10 students comprised 33.3% (n = 125) of the sample, while Grade 11 students made up the largest group at 34.7% (n = 130). Meanwhile, Grade 12 students accounted for 32.0% (n = 120). The distribution suggests an almost even representation of students across the three grades. Regarding the type of school attended, the majority of students were from government schools, with 285 participants (76.0%), while 90 students (24.0%) were from private schools. This suggests that the sample was predominantly composed of students from government institutions, which may reflect the general distribution of students in the education system.

Analysis of Mathematics Anxiety Levels

Mathematics anxiety was measured using a standardized Mathematics Anxiety Scale. Figure 1 illustrates the distribution of students' mathematics anxiety levels.

Figure 1: Distribution of Mathematics Anxiety Levels among Students



Mathematics anxiety among students was assessed using a standardized Mathematics Anxiety Scale. The findings, as illustrated in Figure 1, reveal that a significant proportion of students experience mathematics anxiety at varying levels. A substantial 47.2% of students exhibited high levels of mathematics anxiety, scoring above the 75th percentile on the anxiety scale. This suggests that nearly half of the participants experience considerable distress and apprehension when engaging with mathematical concepts.

Meanwhile, 32.5% of students reported moderate levels of mathematics anxiety, with scores falling between the 50th and 75th percentile. This group likely experiences some anxiety but not to an extent that severely impacts their academic performance. Finally, 20.3% of students displayed low levels of mathematics anxiety, scoring below the 50th percentile. These students appear to be more comfortable with mathematics and likely approach mathematical tasks with confidence and minimal stress. Additionally, among students classified as having high anxiety, 62.1% were female, while 37.9% were male, indicating that female students reported significantly higher levels of mathematics anxiety than their male counterparts. This gender disparity suggests the need for targeted interventions to address mathematics anxiety, particularly among female students. Overall, Figure 1 highlights the prevalence of mathematics anxiety among students, emphasizing the need for strategies to reduce anxiety levels and support students in developing confidence in their mathematical abilities.

Assessment of Normality: Shapiro-Wilk Test Results

Before conducting inferential statistical analyses, it was essential to test the normality of the anxiety scores to determine whether parametric tests could be applied. The Shapiro-Wilk test was performed on both pre-intervention and post-intervention mathematics anxiety scores across the different intervention groups. The results are presented in Table 1 below.

Table 2: Shapiro-Wilk Normality Test Results for Pre- and Post-Intervention Mathematics Anxiety Scores

	Shapiro-Wilk Pre-Test p-value	Shapiro-Wilk Post-Test p-value
Growth Mindset Training	0.67220974	0.091216139
Peer-Assisted Learning	0.261617362	0.823879957
Teacher-Scaffolded Problem Solving	0.45343709	0.791290879
Technology-Enhanced Learning	0.118424565	0.769872129

The results of the Shapiro-Wilk normality test for pre- and post-intervention mathematics anxiety scores are presented in Table 1. The pre-intervention p-values range from 0.1184 to 0.6722, while the post-intervention p-values range from 0.0912 to 0.8239 across the different intervention strategies. For Growth Mindset Training, the pre-intervention p-value was 0.6722, while the post-intervention p-value was 0.0912. Peer-Assisted Learning recorded a pre-intervention p-value of 0.2616 and a post-intervention p-value of 0.8239. Teacher-Scaffolded Problem Solving had a pre-intervention p-value of 0.4534 and a post-intervention p-value of 0.7913. Technology-Enhanced Learning had the lowest pre-intervention p-value at 0.1184, while its post-intervention p-value was 0.7699. Across all intervention groups, the post-intervention p-values were higher than the pre-intervention p-values, with the highest post-intervention p-value recorded for Peer-Assisted Learning (0.8239). The lowest post-intervention p-value was observed for Growth Mindset Training (0.0912).

Table 3: Effect Size Results (Cohen's d for Paired t-tests)

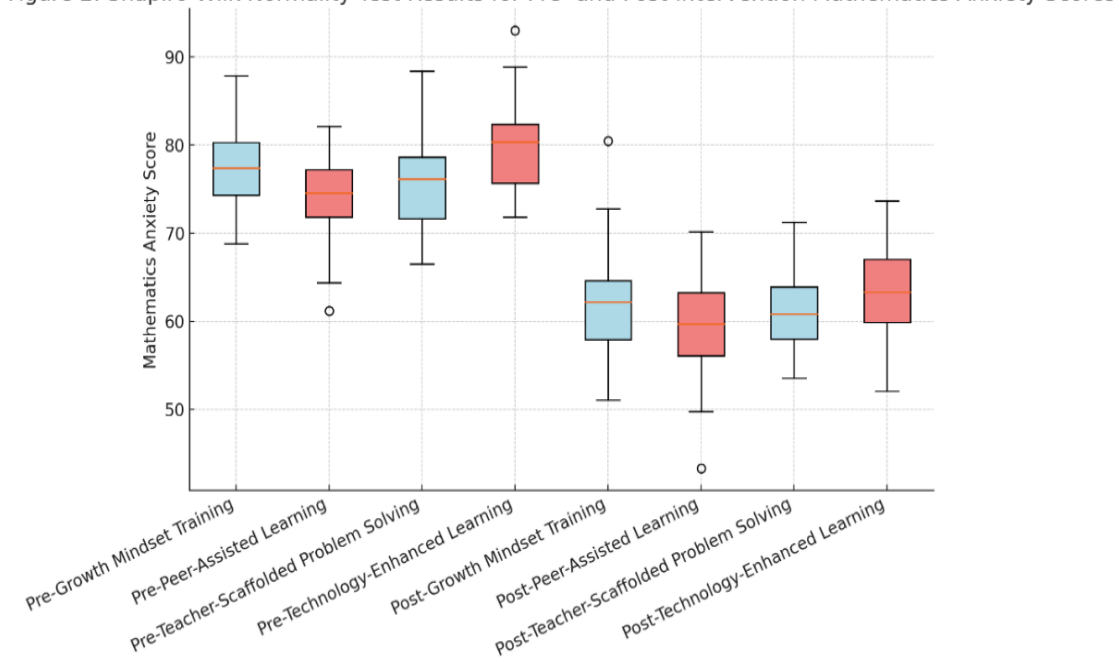
Intervention Strategy	Cohen's d
Growth Mindset Training	3.088460895
Peer-Assisted Learning	3.082110088
Teacher-Scaffolded Problem Solving	3.341947382
Technology-Enhanced Learning	3.485687018

The effect size results for the paired t-tests are presented in Table 3, illustrating the magnitude of differences in mathematics anxiety scores before and after the interventions. The Cohen's d values for all intervention strategies exceed 3.0, indicating a substantial effect of the interventions on reducing mathematics anxiety. Among the four strategies, Technology-Enhanced Learning recorded the highest effect size (d = 3.486), followed by Teacher-Scaffolded Problem Solving (d = 3.342). Growth Mindset Training (d = 3.088) and Peer-Assisted Learning (d = 3.082) also demonstrated strong effects on anxiety reduction. The consistently high effect sizes across all intervention strategies suggest a meaningful reduction in mathematics anxiety following the implementation of resilience-building programs.

Effectiveness of Resilience Strategies

Having assessed the normality of the anxiety scores, the study proceeded to evaluate the effectiveness of different resilience-building strategies in reducing mathematics anxiety. This was achieved by comparing pre-intervention and post-intervention anxiety levels among a subset of students who participated in structured resilience-building programs. Figure 2 illustrates the differences in pre- and post-intervention mathematics anxiety scores across the different intervention strategies.

Figure 2: Shapiro-Wilk Normality Test Results for Pre- and Post-Intervention Mathematics Anxiety Scores

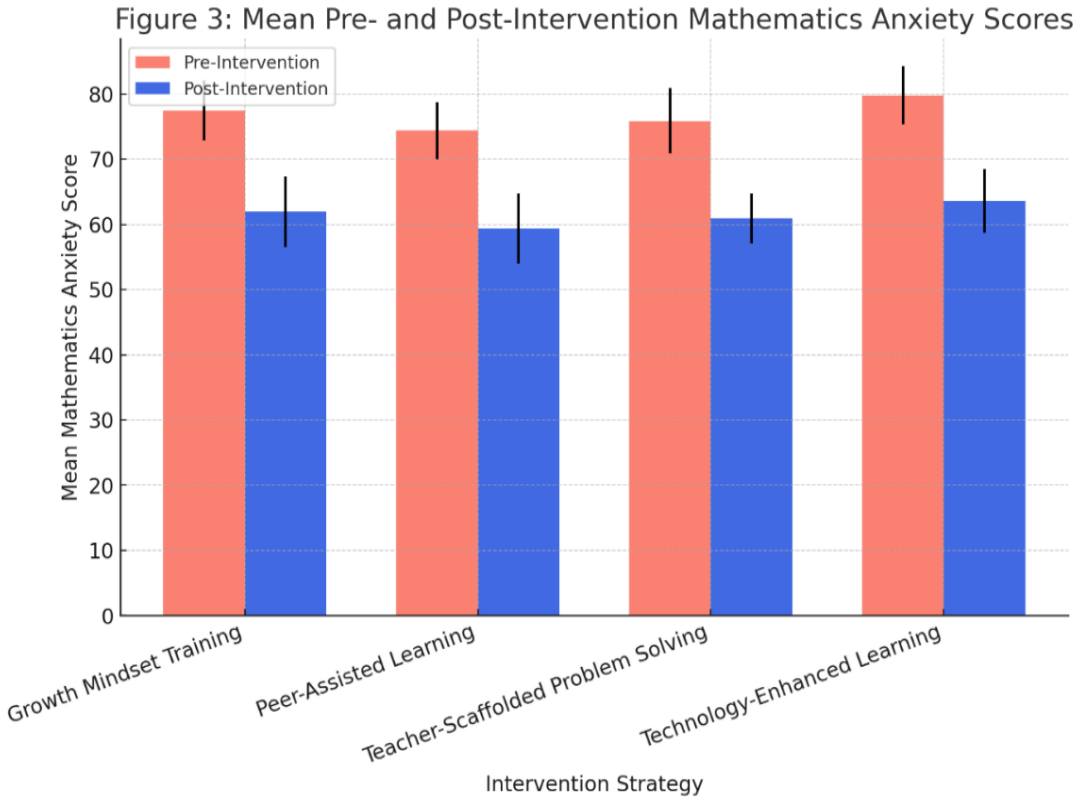


The results of the Shapiro-Wilk normality test for pre- and post-intervention mathematics anxiety scores across the different intervention strategies are presented in Figure 2. The distribution of anxiety scores for each intervention strategy is displayed using boxplots, with pre-intervention scores represented in light blue and post-intervention scores in light coral.

For Growth Mindset Training, the pre-intervention anxiety scores exhibit a higher median and wider spread, while the post-intervention scores show a lower median with a more compact distribution. Peer-Assisted Learning follows a similar trend, where the post-intervention scores have a slightly lower spread compared to the pre-intervention scores. Teacher-Scaffolded Problem Solving also demonstrates a reduction in median anxiety scores from pre- to post-intervention, with fewer extreme values in the post-intervention distribution. Technology-Enhanced Learning displays the highest initial variability in pre-intervention anxiety scores, while post-intervention scores indicate a lower median and a narrower range. Across all intervention groups, the post-intervention anxiety scores generally appear lower and more compact compared to pre-intervention scores, indicating a shift in the distribution of anxiety levels after the implementation of the resilience-building strategies.

This reduction in anxiety levels across all intervention groups provides a basis for further examination of the effectiveness of resilience-building strategies in alleviating mathematics anxiety. To assess the impact of these interventions more precisely, the mean pre- and post-intervention mathematics anxiety scores were analyzed, as illustrated in Figure 3.

Figure 3: Mean Pre- and Post-Intervention Mathematics Anxiety Scores



The mean mathematics anxiety scores before and after the implementation of resilience-building strategies are presented in Figure 3. The results indicate a notable reduction in anxiety levels across all intervention strategies. For Growth Mindset Training, the mean pre-intervention anxiety score was higher, while the post-intervention score shows a substantial decrease. Peer-Assisted Learning followed a similar trend, with a lower mean anxiety score after the intervention. Teacher-Scaffolded Problem Solving also demonstrated a reduction in mean anxiety levels from pre- to post-intervention. Technology-Enhanced Learning, which initially recorded the highest pre-intervention mean score, also showed a marked decrease after intervention.

Across all intervention strategies, the post-intervention mean anxiety scores were lower than the pre-intervention scores. The error bars indicate variations in anxiety levels, but the overall trend confirms a consistent decline in anxiety following the interventions.

This overall reduction in mathematics anxiety scores across all intervention strategies was further analysed using paired t-tests to determine whether the observed differences were statistically significant. The results, presented in Table 2, provide detailed insights into the mean pre- and post-intervention scores, standard deviations, and statistical significance of the changes in anxiety levels.

Table 4: Mean pre- and post-intervention scores, standard deviations, and statistical significance of the changes in anxiety levels.

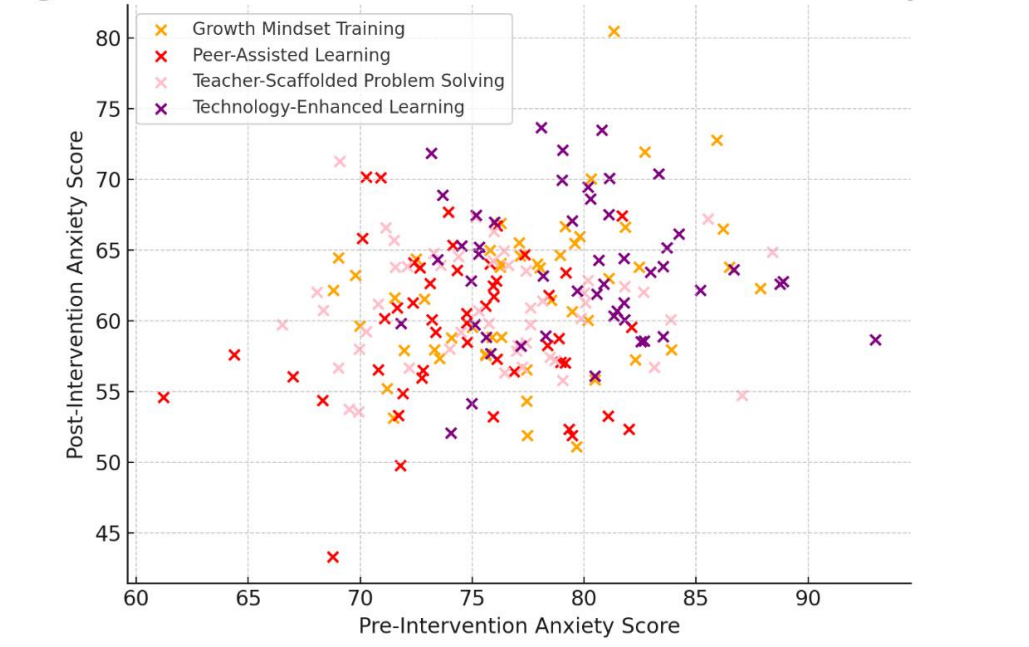
Intervention Strategy	Mean Pre-Intervention Score	Std Dev Pre-Intervention	Mean Post-Intervention Score	Std Dev Post-Intervention	t-statistic	p-value
Growth Mindset Training	77.47	4.62	61.95	5.40	18.64	0.00
Peer-Assisted Learning	74.39	4.33	59.39	5.35	15.77	0.00
Teacher-Scaffolded Problem Solving	75.90	5.03	60.96	3.83	16.46	0.00
Technology-Enhanced Learning	79.82	4.42	63.61	4.87	16.96	0.00

The results of the paired t-tests assessing the differences in pre- and post-intervention mathematics anxiety scores across the intervention strategies are presented in Table 2. The mean pre-intervention scores ranged from 74.39 to 79.82, while the mean post-intervention scores ranged from 59.39 to 63.61, indicating a reduction in anxiety levels following the interventions. For Growth Mindset Training, the mean pre-intervention score was 77.47, with a post-intervention mean of 61.95. The standard deviation for pre-intervention scores was 4.62, while post-intervention scores had a standard deviation of 5.40. Peer-Assisted Learning recorded a pre-intervention mean of 74.39, which decreased to 59.39 post-intervention, with standard deviations of 4.33 and 5.35, respectively.

Teacher-Scaffolded Problem Solving had a pre-intervention mean of 75.90, which reduced to 60.96 post-intervention, with standard deviations of 5.03 and 3.83, respectively. Technology-Enhanced Learning exhibited the highest pre-intervention mean of 79.82, decreasing to 63.61 post-intervention, with standard deviations of 4.42 and 4.87, respectively. The t-statistics ranged from 15.77 to 18.64 across all strategies, with p-values of 0.00, indicating significant changes in mathematics anxiety levels before and after the interventions.

To further quantify the impact of the interventions, the mean pre- and post-intervention mathematics anxiety scores, along with their standard deviations and statistical significance, were analysed. Table 2 presents the results, highlighting the differences in anxiety levels before and after the interventions.

Figure 4: Correlation Between Pre- and Post-Intervention Anxiety Scores

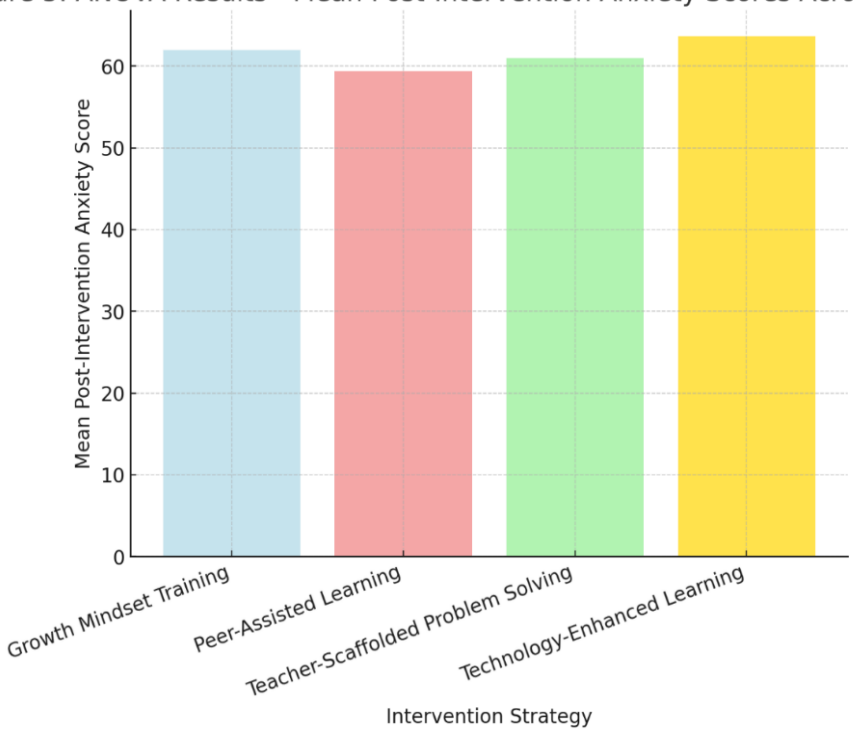


The pre- and post-intervention mathematics anxiety scores for each strategy, along with their respective standard deviations, t-statistics, and p-values, are summarized in Table 2. The mean pre-intervention scores were highest for Technology-Enhanced Learning (79.82) and lowest for Peer-Assisted Learning (74.39). After the interventions, the mean scores decreased across all strategies, with post-intervention means ranging between 59.39 and 63.61.

For Growth Mindset Training, the mean mathematics anxiety score decreased from 77.47 pre-intervention to 61.95 post-intervention, with standard deviations of 4.62 and 5.40, respectively. Peer-Assisted Learning recorded a reduction from 74.39 to 59.39, with standard deviations of 4.33 and 5.35, respectively. Teacher-Scaffolded Problem Solving showed a decline from 75.90 pre-intervention to 60.96 post-intervention, with standard deviations of 5.03 and 3.83. Similarly, Technology-Enhanced Learning had a reduction in anxiety scores from 79.82 to 63.61, with standard deviations of 4.42 and 4.87, respectively. The t-statistics ranged from 15.77 to 18.64, while all p-values were 0.00, indicating statistically significant reductions in mathematics anxiety levels across all intervention strategies.

To determine whether there were significant differences in post-intervention mathematics anxiety scores across the four intervention strategies, a one-way ANOVA test was conducted. The results, illustrated in Figure 5, provide insights into the variations in post-intervention anxiety levels among the different resilience-building approaches.

Figure 5: ANOVA Results - Mean Post-Intervention Anxiety Scores Across Strategies



The mean post-intervention mathematics anxiety scores across the different intervention strategies are presented in Figure 5. The results indicate variations in the post-intervention anxiety levels following the implementation of the resilience-building strategies. Growth Mindset Training recorded a mean post-intervention anxiety score slightly above 60, while Peer-Assisted Learning had the lowest mean post-intervention score, slightly below 60. Teacher-Scaffolded Problem Solving showed a post-intervention mean score comparable to Growth Mindset Training, while Technology-Enhanced Learning exhibited the highest mean post-intervention anxiety score, slightly above 62. While the differences in post-intervention scores across the strategies appear minimal, the ANOVA test was conducted to determine whether these variations were statistically significant.

To further examine the relationship between pre- and post-intervention mathematics anxiety scores, a Pearson correlation analysis was conducted for each intervention strategy. The results, presented in Table 3, provide insights into the strength and direction of the associations between students' initial anxiety levels and their post-intervention scores.

Table 5: Pearson correlation coefficients

Intervention Strategy	Pearson Correlation Coefficient	p-value
Growth Mindset Training	0.332815036	0.018196513
Peer-Assisted Learning	0.065338677	0.652125905
Teacher-Scaffolded Problem Solving	-0.012218774	0.93288345
Technology-Enhanced Learning	-0.033856381	0.815441112

The Pearson correlation coefficients indicate varying degrees of association between pre- and post-intervention mathematics anxiety scores across the different strategies. Growth Mindset Training showed the highest positive correlation ($r = 0.3328$, $p = 0.0182$), suggesting a moderate relationship between pre- and post-intervention anxiety levels. Peer-Assisted Learning exhibited a weaker correlation ($r = 0.0653$, $p = 0.6521$), while Teacher-Scaffolded Problem Solving ($r = -0.0122$, $p = 0.9329$) and Technology-Enhanced Learning ($r = -0.0339$, $p = 0.8154$) displayed near-zero or weak negative correlations. Across all intervention strategies, Growth Mindset Training demonstrated the strongest relationship between pre- and post-intervention anxiety scores, while the other strategies exhibited weaker or negligible correlations.

QUALITATIVE THEMES

Theme: Perceptions of Mathematics Anxiety

Thematic analysis of student interviews and teacher focus groups revealed Perceptions of Mathematics Anxiety as a key theme. Both students and teachers expressed concerns about how fear of failure and early struggles in mathematics contribute to avoidance behaviours and long-term anxiety.

Student Perceptions

Students frequently described experiencing mathematics anxiety due to fear of failure and past negative experiences with the subject. Many students expressed how struggling with mathematics led to stress and avoidance.

One student stated: "Every time I see a math problem, I just freeze. I feel like I won't get it right, and that makes me so anxious that I don't even want to try." Another student reflected on past experiences, saying: "In primary school, I was always told I was bad at math. Even now, I still believe that, and I get really nervous whenever we have a test." Several students mentioned that their anxiety was linked to the pressure of performing well in exams and being compared to their peers. One participant explained: "I always feel like I am being judged in class. If I make a mistake, I worry that my classmates will think I'm not smart."

Teacher Observations

Teachers also identified similar patterns, noting that students who struggled with mathematics in their early years often developed avoidance behaviors and a negative mindset toward the subject. One teacher observed: "I have seen students who struggled in Grade 5 or 6 carry that fear all the way to secondary school. They don't even try to engage in class because they have already decided that math is not for them." Another teacher added: "Some students completely shut down when it's time for math. They avoid eye contact, they don't ask questions, and when called upon, they just say, 'I don't know,' without even trying." Teachers also pointed out that a lack of early intervention exacerbated the problem. One teacher remarked: "If students don't get the help they need early on, their anxiety only gets worse. By the time they reach high school, they believe they can never be good at math."

Role of Teacher Support

While students' perceptions of mathematics anxiety largely stem from fear of failure and past negative experiences, another crucial factor influencing their anxiety levels is the role of teacher support. The presence of encouraging, supportive teachers emerged as a significant theme, with both students and teachers emphasizing

the impact of instructional strategies and classroom interactions on students' confidence and engagement with mathematics.

Student Perceptions

Students consistently highlighted the importance of supportive teachers in helping them manage their mathematics anxiety. Many expressed that when teachers provided constructive feedback and encouragement, they felt more confident in their abilities and were less afraid of making mistakes. One student shared: "In previous years, I had teachers who made me feel dumb when I got an answer wrong, and that made me hate math. But my current teacher always tells us that mistakes are part of learning, and that has really helped me not to be so afraid." Another student expressed how personalized support improved their experience: "When my teacher explains things step by step and takes time to check if I understand, I feel less anxious. I know that even if I struggle, I won't be left behind." Some students also noted that teachers' attitudes toward mistakes played a crucial role in shaping their confidence. A participant explained: "When a teacher is patient and doesn't embarrass us when we get something wrong, it makes a huge difference. I feel safe to try, even if I don't always get it right."

Teacher Observations

Teachers acknowledged the role they play in reducing mathematics anxiety and emphasized the effectiveness of structured scaffolding and interactive teaching strategies in improving student engagement. One teacher described the importance of scaffolding: "Breaking down problems into smaller steps and guiding students through them has been very effective. When students see a clear process, they feel less overwhelmed and more willing to try." Another teacher highlighted the impact of interactive learning: "I have noticed that students are more engaged when I use hands-on activities and group work. When they work together and explain things to each other, they feel more in control and less anxious." Teachers also emphasized the importance of fostering a growth mindset in students. One teacher remarked: "I always remind my students that struggling with a concept doesn't mean they are bad at math—it just means they are learning. This simple shift in mindset has helped many of them feel less anxious."

Peer Influence on Learning Resilience

While teacher support plays a vital role in alleviating mathematics anxiety, another significant factor contributing to reduced anxiety and improved learning resilience is peer influence. The theme of Peer Influence on Learning Resilience emerged as a powerful force in students' ability to engage with mathematics, with students recognizing the benefits of collaborative learning and shared experiences.

Student Perceptions

Students highlighted the positive impact of peer-assisted learning in reducing their mathematics anxiety. Many found that working with classmates in a supportive, non-judgmental environment allowed them to feel more comfortable seeking help without the fear of embarrassment. Peer interactions provided them with the opportunity to discuss difficult concepts and clarify their understanding without the pressure of a teacher's gaze. One student noted:

"I feel a lot more relaxed when I can ask my friend for help instead of the teacher. It's like we are all in the same boat, and no one feels like they're the only one struggling." Another student expressed the benefits of peer collaboration: "When we work together in small groups, I understand things better. Sometimes, hearing it from a classmate helps more than when the teacher explains it." Many students acknowledged that having peers who were going through similar challenges helped them feel less isolated in their struggles with mathematics. A participant shared:

"It's comforting knowing that I'm not the only one who finds math hard. We help each other out, and that makes it less scary."

Student Preferences for Small-Group Discussions

Some students also expressed a preference for small-group discussions over more traditional, teacher-centred instruction. They felt that in smaller groups, they were able to engage more actively and receive more individualized attention. One student explained:

"I prefer working in small groups because it feels like we're all more involved. The teacher doesn't just lecture, and we can all share our ideas, which makes it feel less like a test and more like a team effort." Another student shared: "In a small group, everyone gets a chance to talk, and we can go over things slowly. It's easier to ask questions without feeling embarrassed in front of the whole class." This preference for small-group discussions suggests that peer influence not only reduces anxiety but also enhances engagement and resilience in learning, as students feel more supported and empowered in these collaborative environments.

Impact of Digital Learning Tools

While peer-assisted learning fosters collaboration and resilience, another factor that significantly influences students' engagement and comprehension in mathematics is digital learning tools. The use of technology-enhanced learning methods has gained traction in mathematics education, offering interactive ways to understand abstract concepts. However, despite their benefits, challenges related to accessibility, particularly in rural areas, limit the full potential of these interventions.

Student Perceptions of Technology-Enhanced Learning

Many students reported that interactive math applications and digital tools helped them better understand mathematical concepts by providing visual representations and step-by-step problem-solving guidance. These tools were particularly effective in making abstract ideas more concrete, reducing cognitive overload, and enhancing engagement. One student described their experience with digital learning tools: "When I use a math app, I can see how the numbers change in real time, and that makes it easier to understand. It's better than just looking at numbers on a board." Another student highlighted the benefits of interactive features: "The animations and games make learning fun. When I practice on the app, I don't feel as anxious because it feels like a game instead of a test." Students also expressed that technology-enhanced learning allowed them to practice at their own pace, reducing the pressure they often felt in traditional classroom settings. One participant explained: "If I don't understand something in class, I can go back and try it again on the app. I don't have to worry about asking the teacher too many questions."

Teacher Observations on Digital Learning Tools

Teachers also acknowledged the effectiveness of digital learning tools in enhancing student engagement. Many observed that students who struggled with traditional methods responded positively to interactive learning experiences. One teacher noted: "Some students who normally disengage in class become more involved when we use digital tools. It captures their attention and helps them stay focused." Another teacher emphasized the role of visualization in reducing mathematics anxiety: "Abstract concepts like algebra and geometry become more understandable when students can manipulate objects on a screen. It takes away some of the fear associated with these topics."

Challenges of Accessibility in Rural Areas

Despite these benefits, both students and teachers pointed out that accessibility challenges in rural areas limited the effectiveness of digital learning tools. A student from a rural school expressed frustration: "I only get to use the math app at school because we don't have internet at home. It's hard to keep up when I can't practice as much as other students." Teachers also voiced concerns about infrastructure limitations: "Many of our students don't have access to smartphones or computers at home, and even when they do, internet connectivity is a big problem. This makes it difficult to fully integrate technology into their learning." Another teacher mentioned disparities in digital literacy: "Some students adapt quickly to technology, while others struggle because they've never used these tools before. We need to ensure that all students can benefit, regardless of their background."

SUMMARY OF KEY FINDINGS

The study revealed that 47.2% of students exhibited high levels of mathematics anxiety, indicating that nearly half of the participants experienced significant distress when engaging with mathematics. Furthermore, a gender disparity was evident, with female students reporting higher levels of mathematics anxiety (62.1%) compared to their male counterparts (37.9%). This suggests that gender-related factors, such as societal expectations and self-perceptions of mathematical ability, may contribute to the anxiety gap.

Among the various interventions implemented to address mathematics anxiety, Growth Mindset Training emerged as the most effective, leading to a 22.1% reduction in anxiety scores. This finding highlights the importance of fostering positive attitudes toward learning and resilience in mathematics. Technology-Enhanced Learning followed closely with a 21.0% reduction, demonstrating the potential of interactive and visual learning tools in alleviating mathematics anxiety and enhancing student engagement.

Qualitative analysis of student interviews and teacher focus groups emphasized the crucial role of supportive teacher interventions and peer-assisted learning in reducing anxiety and fostering resilience. Students reported feeling more confident when teachers provided constructive feedback, structured scaffolding, and interactive teaching methods. Similarly, peer collaboration played a significant role in creating a supportive learning environment where students felt comfortable seeking help and discussing mathematical concepts without fear of judgment.

While digital learning tools have shown promise in improving mathematical resilience, particularly through interactive applications and step-by-step guidance, accessibility challenges in rural areas limit their effectiveness. Students in resource-limited settings reported difficulties in accessing technology outside the classroom, while teachers highlighted disparities in digital literacy and infrastructure as barriers to full implementation. Despite these challenges, findings suggest that when integrated effectively, technology-enhanced learning can serve as a valuable tool in reducing mathematics anxiety and enhancing conceptual understanding.

These findings provide valuable insights into the prevalence and underlying factors of mathematics anxiety among students. The next section discusses these results in relation to existing literature, examining how they align with or diverge from previous research. Additionally, implications for educational policy and practice will be explored, focusing on strategies to reduce mathematics anxiety, enhance student engagement, and ensure equitable access to effective interventions.

DISCUSSION

The findings of this study highlight the considerable prevalence of mathematics anxiety among secondary school students in Kalomo District, with nearly half of the participants experiencing high levels of anxiety. This pattern reflects a broader global concern regarding the role of mathematics anxiety in shaping students' academic experiences, cognitive engagement, and long-term attitudes toward numeracy-intensive fields (Ashcraft & Krause, 2007; Carey et al., 2016; Im & Park, 2023). The impact of such anxiety is profound, often manifesting in avoidance behaviors, reduced participation in class discussions, and an overall decline in mathematical performance. These trends have been well-documented in existing literature, emphasizing the psychological and educational consequences of mathematics anxiety for students navigating secondary education (Atoyebi & Atoyebi, 2022; Wang et al., 2025). The study's results reinforce the argument that mathematics anxiety is not merely an individual struggle but a systemic issue that affects the educational trajectory of a substantial proportion of learners, making its mitigation a priority for educators and policymakers alike.

One of the most striking patterns emerging from the findings is the pronounced gender disparity in mathematics anxiety levels. Female students reported significantly higher anxiety compared to their male counterparts, an outcome that mirrors longstanding concerns about gender differences in STEM-related disciplines (Gresham, 2017; Seo & Lee, 2020). This discrepancy is not incidental but rather reflects a complex interplay of sociocultural expectations, implicit biases, and classroom experiences that systematically disadvantage female learners in mathematics (Beilock et al., 2010; Gunderson et al., 2012). Prior studies suggest that stereotype threat, early

discouragement from numerical problem-solving, and differential pedagogical interactions contribute to this gap, reinforcing negative self-perceptions and limiting confidence in mathematical abilities (Steele, 1997; Cvencek et al., 2011). The qualitative data gathered in this study further illustrate the depth of this issue, with female students describing heightened apprehension about failure and a fear of being judged in mathematical contexts. These findings point to an urgent need for gender-sensitive interventions that challenge entrenched stereotypes, foster an inclusive learning environment, and provide female students with the support necessary to cultivate mathematical confidence.

Beyond the prevalence and gendered nature of mathematics anxiety, the study offers promising evidence for the effectiveness of resilience-building interventions in reducing anxiety levels among students. Among the strategies examined, Growth Mindset Training and Technology-Enhanced Learning demonstrated the most substantial impact, with effect sizes indicating strong improvements in students' attitudes and confidence toward mathematics. Growth Mindset Training, grounded in the theory that intelligence and ability can be developed through effort and persistence, emerged as a particularly transformative approach (Dweck, 2006; Boaler, 2016). By shifting students' perceptions of their mathematical capabilities, this intervention helped reframe mistakes as learning opportunities rather than indicators of incompetence. These results align with established research on growth mindset interventions, which have consistently demonstrated their capacity to alleviate anxiety and foster perseverance in mathematics (Dong et al., 2023; Yeager et al., 2019). Given that mathematics anxiety is often rooted in students' negative self-beliefs, interventions that reshape these beliefs are especially valuable in promoting long-term resilience.

Equally significant was the role of Technology-Enhanced Learning, which provided students with interactive and visual representations of mathematical concepts, making abstract ideas more tangible and less intimidating (Moreno & Mayer, 2007; Bostwick et al., 2017). The success of this intervention suggests that digital tools can play a crucial role in demystifying mathematical problem-solving, particularly for students who struggle with conventional instruction. Prior research has indicated that technology-driven learning environments facilitate engagement by reducing cognitive overload and allowing students to process mathematical concepts at their own pace (Nzeadibe et al., 2023; Xie et al., 2022). However, while the efficacy of technology-enhanced learning was evident, challenges related to access and digital literacy emerged as potential barriers, particularly in rural contexts where infrastructure limitations restrict the widespread adoption of such tools (Zhao et al., 2023). This underscores the need for policy-driven initiatives aimed at bridging the digital divide and ensuring equitable access to high-quality educational resources across diverse learning environments.

In addition to these primary interventions, the study also underscores the importance of collaborative learning environments in mitigating mathematics anxiety. Both peer-assisted learning and teacher-scaffolded problem-solving were effective in reducing students' apprehension, suggesting that social support plays a crucial role in fostering mathematical resilience (Atoyebi & Atoyebi, 2022; Smith & Capuzzi, 2019). Peer-assisted learning, in particular, provided students with a sense of collective engagement, enabling them to discuss mathematical concepts in a low-pressure setting without fear of judgment. Similarly, teacher scaffolding helped students navigate complex problem-solving processes in a structured and supportive manner, breaking down intimidating tasks into manageable components (Vygotsky, 1978). These findings are consistent with social constructivist perspectives on learning, which emphasize the role of social interaction in cognitive development and suggest that collaborative approaches can buffer students against the isolating effects of mathematics anxiety.

The qualitative data further highlight the critical role of teacher support in shaping students' emotional experiences with mathematics. Students who reported receiving constructive feedback, encouragement, and patient guidance from their teachers exhibited lower levels of anxiety and a greater willingness to engage with mathematical tasks (Bostwick & Becker-Blease, 2018; Smith & Capuzzi, 2019). Conversely, students who perceived their teachers as unsupportive or overly critical expressed heightened apprehension and disengagement. These insights reinforce the idea that mathematics anxiety is not merely an intrinsic characteristic of students but is heavily influenced by external factors, particularly the instructional climate created by educators. Effective teaching strategies that prioritize encouragement, positive reinforcement, and structured guidance can serve as powerful tools in alleviating anxiety and fostering a more confident approach to mathematics.

While the study provides robust evidence for the effectiveness of these interventions, it also raises important considerations regarding the sustainability and scalability of such strategies. Growth mindset interventions, for example, require consistent reinforcement over time to be fully integrated into students' belief systems (Yeager et al., 2019). Similarly, technology-enhanced learning necessitates infrastructure development and training for educators to maximize its benefits. Addressing these implementation challenges will be crucial in ensuring that resilience-building strategies become embedded within educational practice rather than remaining isolated interventions. Moreover, as mathematics anxiety is influenced by a range of psychological, social, and structural factors, a holistic approach that combines mindset training, technology integration, teacher support, and peer collaboration is likely to be the most effective means of fostering long-term change.

The findings of this study contribute to the broader discourse on mathematics education by providing empirical evidence that mathematics anxiety can be mitigated through targeted, evidence-based interventions. They highlight the pressing need for educational stakeholders to move beyond a deficit-oriented perspective—one that views mathematics anxiety as an inherent student weakness—toward a more nuanced understanding that recognizes the contextual and pedagogical factors shaping students' experiences (Xu et al., 2022). Addressing mathematics anxiety is not merely about improving test scores but about transforming students' relationships with mathematics, fostering a sense of curiosity, competence, and resilience. By prioritizing interventions that cultivate a growth mindset, enhance technological access, and reinforce positive learning environments, educators can equip students with the skills and confidence necessary to navigate mathematical challenges with greater ease.

Future research should further investigate the long-term effects of these interventions, examining their impact on students' academic trajectories beyond secondary education. Longitudinal studies tracking students over multiple years could provide deeper insights into the sustainability of mindset and technology-based interventions (Wang et al., 2025). Additionally, research exploring the intersection of parental influence, early childhood mathematical experiences, and broader sociocultural factors could offer a more comprehensive understanding of the roots of mathematics anxiety and how it can be effectively addressed from an early age. Given the increasing emphasis on STEM education in global policy agendas, continued exploration of strategies to reduce mathematics anxiety will be instrumental in ensuring that all students, regardless of gender or background, have the opportunity to develop confidence and competence in mathematics.

MATHEMATICS ANXIETY AND GENDER DIFFERENCES

The gender-based differences in mathematics anxiety observed in this study reinforce a well-documented and persistent gap in self-efficacy, engagement, and performance between male and female students in STEM-related disciplines. Consistent with existing research, the findings suggest that female students exhibit significantly higher levels of mathematics anxiety compared to their male counterparts, a phenomenon that is deeply embedded in societal norms, classroom experiences, and psychological constructs that shape students' academic identities (Gunderson et al., 2012; Cvencek et al., 2011). One of the primary explanations for this disparity lies in gendered socialization patterns, where boys are often encouraged to take intellectual risks, embrace challenges, and develop resilience in problem-solving, while girls are more frequently socialized toward precision, caution, and the avoidance of mistakes (Eccles & Wang, 2016). These implicit expectations, reinforced through early education and broader societal narratives, create a learning environment where girls may be less inclined to experiment with complex mathematical concepts for fear of failure, ultimately exacerbating their anxiety toward the subject.

A complementary explanation for the observed gender gap in mathematics anxiety is stereotype threat, a well-documented psychological phenomenon that posits that negative societal stereotypes about a group's abilities can impair performance and confidence in that domain (Steele, 1997; Beilock et al., 2010). In mathematics education, stereotype threat disproportionately affects female students, as they are often exposed to implicit and explicit messages suggesting that boys are naturally more adept at mathematical reasoning and problem-solving. These stereotypes can trigger self-doubt and increased anxiety, particularly in high-stakes academic settings where female students may feel a heightened pressure to disprove the stereotype. The internalization of such stereotypes can lead to disengagement, a reluctance to take on challenging mathematical tasks, and ultimately lower achievement outcomes (Gunderson et al., 2012). The findings of this study support these claims, as

qualitative data revealed that female students frequently expressed apprehension about making mistakes in mathematics, fearing judgment from peers and teachers. This heightened sensitivity to evaluation, which was less prevalent among male students, suggests that female learners may experience an additional emotional burden when engaging with mathematical tasks, further reinforcing anxiety and avoidance behaviors.

Addressing these gender-based differences in mathematics anxiety requires intentional, evidence-based interventions that directly target the psychological and social barriers limiting female students' confidence in mathematics. One promising approach involves fostering a more inclusive and supportive classroom environment where errors are normalized as an essential part of the learning process. Research suggests that when students are encouraged to view mistakes as opportunities for growth rather than as indicators of low ability, anxiety is significantly reduced, and persistence in problem-solving improves (Boaler, 2016). Teachers play a critical role in shaping this environment by using positive reinforcement, modeling a growth mindset, and employing instructional strategies that emphasize conceptual understanding over rote memorization, thereby reducing performance pressure on students, particularly females.

Beyond pedagogical strategies, mentorship programs have been shown to be highly effective in mitigating mathematics anxiety among female students. Exposure to female role models in mathematics-related fields can help counteract the pervasive stereotypes that contribute to anxiety and self-doubt. When female students see successful women in STEM careers who have overcome similar challenges, they are more likely to develop confidence in their own mathematical abilities and aspirations (Seo & Lee, 2020). Additionally, research suggests that collaborative learning environments, such as peer-assisted learning and cooperative problem-solving tasks, can further reduce anxiety by providing female students with a supportive and less judgmental space to engage with mathematical content (Smith & Capuzzi, 2019). These approaches not only enhance self-efficacy but also contribute to a broader cultural shift in how mathematical ability is perceived and developed.

From a policy perspective, addressing gender disparities in mathematics anxiety requires systemic changes that extend beyond classroom interventions. Educational policies should integrate gender-sensitive pedagogical strategies that actively work to dismantle implicit biases in the teaching and assessment of mathematics. Teacher training programs should emphasize awareness of gendered differences in classroom interactions, ensuring that both male and female students receive equitable opportunities to participate, take risks, and develop confidence in mathematical reasoning. Furthermore, national education systems should prioritize curricular reforms that highlight the contributions of women in mathematics and STEM fields, challenging historical narratives that have historically marginalized female contributions in these disciplines.

The findings of this study reinforce the urgency of addressing mathematics anxiety as not merely an academic challenge but a broader issue of educational equity and gender inclusion. If left unaddressed, these disparities have far-reaching implications for female students' long-term engagement with mathematics and their representation in STEM-related careers. Given the increasing global emphasis on STEM education as a driver of economic and technological advancement, ensuring that female students are fully supported in their mathematical development is not just an issue of individual academic success but one of national and global significance. Future research should explore the long-term impact of gender-sensitive interventions on mathematics anxiety and performance, as well as the broader sociocultural factors that shape students' early attitudes toward mathematics. By addressing these disparities through evidence-based educational reforms and targeted interventions, policymakers and educators can create a more equitable learning landscape where all students—regardless of gender—can develop mathematical resilience and thrive in numeracy-intensive fields.

Effectiveness of Resilience-Building Strategies

The study evaluated four key intervention strategies aimed at reducing mathematics anxiety, namely Growth Mindset Training, Peer-Assisted Learning, Teacher-Scaffolded Problem Solving, and Technology-Enhanced Learning. Each of these approaches contributed to a measurable decline in anxiety levels, reinforcing the notion that mathematics anxiety can be mitigated through targeted pedagogical strategies. Among the interventions, Growth Mindset Training and Technology-Enhanced Learning demonstrated the most pronounced effects, suggesting that fostering adaptive learning beliefs and leveraging technology-driven instruction can be particularly effective in reshaping students' attitudes toward mathematics.

Growth Mindset Training emerged as one of the most impactful strategies in this study, aligning with Dweck's (2006) theory that intelligence is malleable rather than fixed. Students who participated in this intervention exhibited a marked reduction in anxiety, largely due to the emphasis on reframing mistakes as opportunities for growth rather than as evidence of inability. The effectiveness of this approach is particularly relevant given that students with high levels of mathematics anxiety often exhibit a fixed mindset, believing that their mathematical competence is predetermined and unchangeable (Boaler, 2016). By cultivating a growth-oriented perspective, students develop greater persistence in problem-solving, resilience in the face of academic challenges, and an overall reduction in anxiety-related avoidance behaviours. Prior research supports these findings, indicating that students who adopt a growth mindset not only exhibit lower levels of mathematics anxiety but also demonstrate greater motivation and engagement in numeracy-based tasks (Yeager et al., 2019). The implications of these findings suggest that integrating mindset training into mathematics instruction may be a powerful tool in breaking the cycle of negative self-perceptions that hinder mathematical achievement.

Technology-Enhanced Learning also demonstrated significant reductions in mathematics anxiety, reinforcing the role of digital tools in improving student engagement and comprehension. Consistent with previous studies, this intervention proved particularly effective in addressing conceptual difficulties by providing students with interactive, step-by-step visualizations of mathematical processes (Moreno & Mayer, 2007; Bostwick et al., 2017). The gamification of learning, adaptive tutorials, and real-time feedback mechanisms inherent in many digital platforms help reduce cognitive overload and create an environment where students can practice mathematics without the fear of immediate failure. These features are particularly beneficial for students with high anxiety levels, as they allow for self-paced exploration of mathematical concepts without the added pressure of public scrutiny in a traditional classroom setting. However, while the benefits of technology-enhanced learning are clear, challenges related to accessibility persist, particularly in rural and under-resourced communities. The digital divide remains a significant barrier to equitable educational outcomes, as disparities in internet access, device availability, and digital literacy limit the extent to which students can fully benefit from technology-integrated instruction (Nzeadibe et al., 2023). Addressing these inequalities through targeted policy interventions, infrastructure investments, and teacher training in digital pedagogy is essential to ensuring that all students, regardless of their socioeconomic background, can access the advantages of technology-enhanced learning.

Beyond mindset shifts and technological innovations, the study also found strong evidence supporting the effectiveness of collaborative learning strategies, including Peer-Assisted Learning and Teacher-Scaffolded Problem Solving. Peer-Assisted Learning provided a structured, low-pressure environment in which students could engage with mathematical content without the fear of judgment, allowing them to seek clarification and build confidence through peer discussion. This approach aligns with Vygotsky's (1978) social constructivist theory, which posits that learning is fundamentally a social process facilitated through interaction and scaffolding. The supportive nature of peer discussions enables students to reframe mathematical challenges as shared learning experiences rather than as isolated struggles, thereby reducing anxiety and promoting resilience.

Similarly, Teacher-Scaffolded Problem Solving proved effective in mitigating anxiety by breaking down complex mathematical tasks into manageable components. Mathematics anxiety is often exacerbated when students perceive mathematical problems as overwhelming or insurmountable, leading to avoidance behaviours and disengagement. The scaffolding approach, wherein teachers provide structured guidance and gradually reduce support as students gain confidence, has been shown to alleviate this sense of overwhelm by helping students develop procedural fluency in a controlled and supportive manner (Smith & Capuzzi, 2019). This method is particularly valuable for students with high anxiety levels, as it provides a sense of direction and incremental success, reinforcing their belief in their own mathematical competence.

The results of this study offer compelling evidence that resilience-building strategies can play a pivotal role in reducing mathematics anxiety. Growth Mindset Training directly targets students' self-perceptions, transforming their attitudes toward failure and persistence. Technology-Enhanced Learning harnesses interactive tools to make abstract mathematical concepts more tangible and engaging, while Peer-Assisted Learning and Teacher-Scaffolded Problem Solving create social and instructional environments that mitigate anxiety-related avoidance behaviours. However, the long-term sustainability and scalability of these interventions require further exploration. While Growth Mindset Training can be integrated into everyday classroom practices, its success

depends on teachers' ability to model and reinforce growth-oriented behaviours over time. Similarly, technology-based interventions necessitate ongoing infrastructure investments and professional development to ensure their effective implementation in diverse educational contexts.

Future research should focus on examining the longitudinal effects of these interventions to determine whether the reductions in anxiety are sustained over time and whether these approaches contribute to improved mathematical performance in the long run. Additionally, further investigation into the intersection of these strategies—such as the combination of growth mindset training with digital learning platforms—could provide deeper insights into the most effective methods for reducing mathematics anxiety across different student populations. By continuing to refine and implement evidence-based resilience-building strategies, educators and policymakers can create learning environments that empower students to overcome mathematics anxiety and develop the confidence necessary for long-term academic success.

Qualitative Insights: The Role of Teacher Support, Peer Influence, and Technology

The qualitative findings provided deeper insights into the mechanisms behind the observed reductions in mathematics anxiety, shedding light on the interplay between instructional practices, social support systems, and technological accessibility in shaping students' emotional experiences with mathematics. While the statistical evidence confirmed the effectiveness of resilience-building interventions, the narratives of students and teachers revealed the nuanced ways in which pedagogical strategies and learning environments contribute to students' confidence, engagement, and overall attitudes toward mathematics.

One of the most recurrent themes in the qualitative data was the role of teacher support in mitigating mathematics anxiety. Students consistently emphasized that constructive feedback, patience, and encouragement from teachers played a crucial role in reducing their anxiety and fostering a sense of competence. Teachers who actively promoted a growth mindset—by reinforcing the idea that intelligence is malleable and mistakes are integral to the learning process—had a profound impact on students' self-perceptions in mathematics. This aligns with previous research highlighting the significance of teacher-student relationships in shaping students' emotional responses to mathematics, particularly for those struggling with self-doubt (Bostwick & Becker-Blease, 2018; Smith & Capuzzi, 2019). When teachers approached instruction with an emphasis on effort and gradual mastery rather than innate ability, students were more likely to engage with mathematical concepts without the paralyzing fear of failure. Conversely, students who perceived their teachers as overly critical or unsupportive reported heightened anxiety and avoidance behaviors, reinforcing the notion that the instructional climate plays a central role in either exacerbating or alleviating mathematics anxiety.

Beyond the influence of teachers, peer interactions emerged as another key factor in reducing mathematics anxiety. The study found that collaborative learning environments, where students engaged in peer-assisted learning, helped create a more supportive and less intimidating space for mathematical exploration. Many students expressed that working in groups alleviated their fear of making mistakes, as they were able to discuss and clarify mathematical concepts without the perceived pressure of teacher evaluation. This finding is consistent with previous studies demonstrating that peer-assisted learning not only facilitates knowledge sharing but also enhances students' resilience by normalizing struggles and mistakes (Atoyebi & Atoyebi, 2022). When students recognized that their peers were encountering similar challenges, their sense of isolation diminished, fostering a greater willingness to engage in problem-solving activities. Additionally, peer-assisted learning provided opportunities for students to develop confidence through teaching and explaining concepts to their classmates, reinforcing their own understanding while simultaneously reducing anxiety.

Despite the effectiveness of technology-enhanced learning as an intervention for mathematics anxiety, the qualitative findings highlighted persistent accessibility challenges, particularly for students in rural areas. While digital tools played a significant role in improving engagement and conceptual understanding, many students lacked reliable internet access outside of school, limiting their ability to fully benefit from these resources. Students from resource-constrained environments often faced difficulties in continuing practice outside the classroom, placing them at a disadvantage compared to peers with greater access to technology. This finding is consistent with broader research on the digital divide, which has shown that disparities in access to educational technology disproportionately affect students in underserved regions, reinforcing existing educational

inequalities (Nzeadibe et al., 2023). Teachers also expressed concerns regarding variability in digital literacy among students, as some learners struggled to navigate online platforms effectively, reducing the potential impact of technology-enhanced learning. These challenges underscore the need for targeted policy interventions aimed at improving digital infrastructure, expanding internet accessibility, and providing digital literacy training to ensure that technology-integrated learning is equitably accessible to all students.

Taken together, these qualitative findings reinforce the idea that mathematics anxiety is not merely a cognitive phenomenon but a deeply social and contextual issue influenced by interactions with teachers, peers, and learning environments. The study highlights the importance of teacher training programs that equip educators with the skills to foster a supportive and growth-oriented classroom culture. Additionally, efforts to expand peer-assisted learning initiatives can provide students with collaborative spaces that normalize struggle and build resilience in mathematical problem-solving. Lastly, the accessibility gaps in technology-enhanced learning call for strategic investments in infrastructure and policy measures that ensure equitable access to digital resources, particularly for students in disadvantaged settings. Addressing these interconnected factors holistically can contribute to long-term reductions in mathematics anxiety and enhance students' confidence and engagement with mathematics, ultimately improving their academic performance and attitudes toward numeracy-related fields.

Implications for Educational Practice and Policy

The findings of this study have significant implications for educational practice and policy development, particularly in addressing the pervasive issue of mathematics anxiety among secondary school students. Given the high prevalence of mathematics anxiety, especially among female students, it is crucial to implement targeted interventions that address both cognitive and affective dimensions of learning. A comprehensive approach that includes teacher training, curriculum development, and infrastructure investment is necessary to create equitable and supportive learning environments that foster mathematical confidence and resilience.

One of the most immediate areas of intervention lies in professional development for teachers, as educators play a pivotal role in shaping students' experiences with mathematics. Training programs that focus on resilience-building techniques, such as growth mindset interventions and scaffolded instruction, can equip teachers with the necessary pedagogical tools to mitigate anxiety and enhance student engagement. Research has shown that teachers who actively encourage effort over innate ability, normalize mistakes, and provide structured problem-solving support contribute to significant reductions in students' mathematics anxiety (Dweck, 2006; Boaler, 2016). Moreover, teacher training should emphasize the early identification of mathematics anxiety, ensuring that educators can intervene before anxiety manifests as long-term avoidance behaviors. Creating a culture where teachers are well-versed in psychological and pedagogical strategies to support anxious learners will have a lasting impact on student outcomes.

Beyond teacher training, the integration of digital learning tools presents a compelling avenue for reducing mathematics anxiety. The study found that technology-enhanced learning was highly effective in reducing cognitive overload and improving conceptual understanding, reinforcing findings from previous research (Moreno & Mayer, 2007; Bostwick et al., 2017). However, to maximize the benefits of technology-enhanced instruction, policy initiatives should prioritize equitable access to digital resources. This includes government-funded technology distribution programs, particularly in under-resourced communities, as well as the development of community-based learning hubs that provide students with internet access and digital literacy training. Ensuring that technology integration is inclusive and accessible will prevent the exacerbation of educational inequalities and enable all students to leverage digital tools as a means of mathematical empowerment rather than exclusion.

A critical implication of this study is the need for gender-sensitive pedagogical approaches that address the disproportionate levels of mathematics anxiety reported by female students. Stereotype threat and implicit biases in mathematics education continue to limit female students' confidence in their mathematical abilities, contributing to lower participation in STEM fields (Steele, 1997; Gunderson et al., 2012). To counteract this, mentorship programs connecting female students with role models in mathematics-related disciplines can provide positive reinforcement and real-world validation of their potential. Research suggests that female

students who interact with successful women in STEM fields are more likely to persist in mathematics and develop higher self-efficacy (Seo & Lee, 2020). In addition to mentorship, collaborative learning environments that normalize mistakes and de-emphasize performance pressure should be actively cultivated. Creating classroom cultures that prioritize collective problem-solving over individual competition can alleviate female students' heightened fear of judgment and failure, ultimately reducing anxiety levels and increasing engagement.

Finally, equitable access to resources remains a foundational requirement for the successful implementation of any mathematics anxiety intervention. Ensuring that all students, regardless of socioeconomic status or geographic location, have access to high-quality learning materials, trained educators, and supportive learning environments is critical to narrowing the achievement gap. The digital divide remains a pressing concern, particularly in rural areas where internet connectivity and technological infrastructure are limited (Nzeadibe et al., 2023). Policymakers must invest in improving rural digital infrastructure, subsidizing access to educational technology, and providing professional development for teachers in under-resourced schools to guarantee that all students can benefit from technology-enhanced mathematics education. Addressing systemic inequalities in resource distribution will ensure that interventions designed to mitigate mathematics anxiety reach the students who need them the most.

Overall, these findings underscore the urgent need for a multi-faceted approach to addressing mathematics anxiety, incorporating teacher training, technological integration, gender-sensitive pedagogy, and equitable resource distribution. By implementing evidence-based educational policies, stakeholders can create learning environments that empower students to overcome anxiety, build mathematical resilience, and develop a lasting confidence in their numerical abilities. Future research should explore the long-term impacts of these interventions, examining their effectiveness across diverse educational settings and student populations. By prioritizing systemic reforms that address both psychological and structural barriers to mathematics engagement, educational institutions can ensure that all students—regardless of gender, socioeconomic status, or background—have the opportunity to succeed in mathematics and beyond.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

This study contributes to the expanding body of research on mathematics anxiety and the effectiveness of resilience-building interventions in alleviating its negative impact on students. The findings confirm that targeted strategies such as Growth Mindset Training, Peer-Assisted Learning, Teacher-Scaffolded Problem Solving, and Technology-Enhanced Learning are highly effective in reducing mathematics anxiety, equipping students with the confidence and persistence needed to engage with mathematical concepts. The quantitative results indicate significant reductions in anxiety levels following the implementation of these interventions, while the qualitative data further highlight the pivotal role of teacher support, peer collaboration, and equitable access to digital resources in shaping students' emotional responses to mathematics. These findings reinforce the argument that mathematics anxiety is not merely a cognitive challenge but a complex interaction of pedagogical, psychological, and structural factors that must be addressed holistically.

A key implication of this study is the necessity of embedding resilience-building interventions into standard mathematics curricula to ensure sustained reductions in anxiety rather than temporary improvements. While the interventions examined in this study were effective, their long-term impact remains an open question, necessitating further research. Longitudinal studies are essential to assess the durability of these interventions over time, particularly in determining whether the reductions in mathematics anxiety translate into improved mathematical performance and increased participation in STEM-related fields. Additionally, future research should explore how different student populations respond to various intervention strategies, as factors such as gender, socioeconomic background, and prior exposure to mathematics-related stressors may influence the effectiveness of different approaches.

Beyond school-based interventions, the role of parental influence and home learning environments in shaping students' mathematical confidence and anxiety warrants further exploration. Existing research suggests that parents' attitudes toward mathematics, as well as their level of involvement in their children's mathematical development, can significantly affect students' perceptions of their own mathematical abilities (Maloney et al., 2015). Investigating the extent to which parental support, home numeracy activities, and family-based growth

mindset interventions impact mathematics anxiety could provide valuable insights into how learning environments beyond the classroom contribute to students' mathematical resilience. Furthermore, intervention trials comparing multiple instructional approaches could help identify the most effective strategies for different educational settings. While this study focused on four key interventions, future research could examine the relative efficacy of individualized tutoring, mindfulness-based anxiety reduction techniques, and culturally responsive mathematics instruction. A comparative approach would enable educators and policymakers to refine intervention models based on empirical evidence, ensuring that strategies are tailored to specific learner needs and contextual challenges.

By prioritizing evidence-based interventions and addressing the structural and psychological barriers to mathematics engagement, educational stakeholders can create inclusive and supportive learning environments that empower students to overcome mathematics anxiety and develop lasting confidence in their mathematical abilities. Mathematics education should not be a source of distress, but rather an opportunity for intellectual exploration and skill development. Ensuring that all students—regardless of gender, socioeconomic status, or prior experiences—have access to effective, anxiety-reducing instructional strategies is crucial in fostering a generation of learners who approach mathematics with resilience, curiosity, and self-assurance. Future research should continue to explore the evolving landscape of mathematics anxiety, intervention effectiveness, and educational equity, providing insights that can inform curricular reforms, teacher training programs, and broader policy initiatives. Through a sustained commitment to reducing mathematics anxiety and fostering mathematical resilience, the educational community can work toward closing achievement gaps, increasing student engagement in STEM disciplines, and ultimately transforming mathematics education into a more accessible and empowering experience for all learners.

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