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Research articles

A comprehensive analysis of mathematical resilience in elementary school students: A gender and learning style perspective

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Abstrak Penelitian ini bertujuan untuk menguji resiliensi matematis siswa dalam kaitannya dengan gaya belajar dan jenis kelamin mereka. Dengan menggunakan desain komparatif non-eksperimental dan metodologi survei, penelitian ini menggunakan kuesioner resiliensi matematis dan gaya belajar sebagai instrumen pengumpulan data. Subjek penelitian terdiri dari 62 siswa sekolah dasar kelas lima dari Kota Stabat, Provinsi Sumatera Utara. Pengambilan sampel dilakukan dengan menggunakan teknik probability proportional sampling, menghasilkan 32 siswa perempuan dan 30 siswa laki-laki. Analisis data menggunakan uji ANOVA dua arah untuk menguji dampak dari dua variabel independen (gaya belajar dan jenis kelamin) terhadap variabel dependen (resiliensi matematis). Temuan penelitian mengungkapkan bahwa gaya belajar visual adalah gaya belajar yang paling umum (dominan) di antara siswa. Lebih jauh lagi, gaya belajar menunjukkan dampak yang signifikan pada resiliensi matematis, yang menunjukkan bahwa variasi dalam gaya belajar memberikan kontribusi secara substansial pada tingkat resiliensi matematis. Sebaliknya, tidak ditemukan pengaruh jenis kelamin pada resiliensi matematis. Selain itu, analisis menunjukkan tidak adanya interaksi antara gaya belajar dan jenis kelamin dalam mempengaruhi resiliensi matematis. Temuan ini menunjukkan bahwa gaya belajar secara mandiri mempengaruhi resiliensi matematis, tanpa moderasi apa pun oleh jenis kelamin. Implikasi dari penelitian ini menunjukkan bahwa ketika mempertimbangkan strategi pengajaran untuk meningkatkan resiliensi matematis, penekanan dapat diberikan pada gaya belajar individu tanpa perlu membedakan berdasarkan jenis kelamin.

Kata kunci *Resiliensi matematis, Gaya belajar, Gender*

Abstract This study investigates the relationship between students' mathematical resilience and their learning styles and gender. Employing a non-experimental comparative design and survey methodology, the study utilized mathematical resilience and learning style questionnaires as data collection instruments. The study's sample consisted of 62 fifth-grade elementary school students from Stabat City, North Sumatra Province. Sampling was conducted using the probability proportional sampling technique, resulting in 32 female and 30 male students. Data analysis employed a two-way ANOVA test to examine the impact of two independent variables (learning style and gender) on the dependent variable (mathematical resilience). The findings revealed that the visual learning style was the predominant learning style among students. Furthermore, the study demonstrated a significant correlation between learning styles and mathematical resilience, suggesting that variations in learning styles significantly influence mathematical resilience. In contrast, gender was found to have no discernible impact on mathematical resilience. Additionally, the analysis indicated no interaction between learning style and gender in influencing mathematical resilience. These findings imply that learning styles independently influence mathematical resilience, without any moderating effect of gender. The implications of this study suggest that when developing teaching strategies to enhance mathematical resilience, it is advisable to prioritize individual learning styles rather than differentiating based on gender.

Keywords *Mathematical resilience, Learning style, Gender*

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Introduction

As a fundamental subject throughout elementary and high school education, mathematics holds immense importance. Its significance extends beyond its content delivery, encompassing the outcomes achieved by students. Ideally, these outcomes align with the core objectives of mathematics education, which include fostering students' cognitive abilities, sharpening problem-solving skills, enabling them to attain high learning objectives, refining their communication abilities, and developing essential character traits. At the elementary level, mathematics instruction primarily focuses on introducing students to fundamental concepts such as geometry, measurement, and basic arithmetic operations (Cotič et al. 2024; Mainali, 2021).

Certainly, the intended learning objectives can be effectively achieved when students possess mathematical resilience. Ishak et al. (2020) elucidate that mathematical resilience is a fundamental prerequisite for successful mathematical learning. A key internal component that supports students' mathematical success is mathematical resilience. Students with robust resilience not only acquire the requisite mathematical skills but also develop the motivation to apply them in practical contexts. Furthermore, resilient students demonstrate effective communication abilities while maintaining their self-identity and adapting to various challenges they encounter. Consequently, efforts to cultivate mathematical resilience constitute a set of attitudes that foster a positive and conducive learning environment for mathematics (Komala, 2017; Agustin et al., 2019).

Given the paramount role of mathematical resilience in facilitating students' achievement of mathematical learning objectives, it is imperative that mathematical resilience be prioritized by educators, policymakers, and practitioners alike. Mathematical resilience is conceptualized as a positive, adaptive attitude toward mathematics, enabling students to persevere in their learning journey despite encountering difficulties (Johnston-Wilder & Lee, 2010; Rivera & Waxman, 2011). Over time, Lee and Johnston-Wilder (2017) have elucidated that mathematical resilience exhibits numerous characteristics with other psychological constructs, such as self-efficacy, optimism, motivation, and self-confidence. Yeager and Dweck (2012) conducted a comprehensive study across various contexts and defined resilience as a behavioral, attributional, or emotional response to academic or social challenges that is positive or beneficial for knowledge development. Furthermore, Hernandez-Martinez and Williams (2013) interpreted resilience in mathematics as students' reflective decision-making processes when confronted with novel situations. Lee and Ward-Penny (2022) provide a comprehensive definition of mathematical resilience, characterizing it as an attribute that enables students to attain successful outcomes even when undertaking challenging mathematical tasks, connoting a disposition of confidence, persistence, and inquiry toward the subject.

Based on the provided explanation, mathematical resilience can be conceptualized as a positive disposition towards successful outcomes, a willingness to exert effort, persistence in overcoming challenges, and a readiness for self-reflection and discussion. This resilience empowers learners to navigate obstacles that may arise during their mathematical learning journey, influenced by diverse factors such as the teaching methods employed, the inherent nature of mathematics, and prevalent beliefs about mathematical ability. This conceptualization further suggests that resilience emerges in response to some degree of difficulty. In the context of mathematics, challenges can manifest in various forms, including failing to meet learning objectives, exceeding students' tolerance, boredom, embarrassment stemming from poor

performance, inadequate curriculum or teaching quality, and unsupportive teacher-student or peer relationships.

As is widely acknowledged, mathematics learning has become increasingly challenging for many individuals, often resulting in anxiety or avoidance of activities that necessitate mathematical reasoning. Students encounter mathematics anxiety, which hinders their motivation to learn (Wang et al., 2014), negatively impacts their academic performance (Casinillo et al., 2022), and frequently evokes feelings of discomfort when engaged in mathematical tasks or attending mathematics classes (Ishak et al., 2020). Notably, some individuals express a persistent desire to avoid mathematics altogether (Lee & Morgan, 2024). Furthermore, mathematics anxiety transcends educational levels and has been identified even in elementary school children (Balt et al., 2022).

Overall negative emotional responses to mathematics may have a detrimental impact on students' learning performance in this subject (Skaalvik, 2018; Sorvo et al., 2019). Richardson and Suinn (1972) widely acknowledged that these negative emotional responses are often rooted in mathematics anxiety. If this anxiety is not promptly addressed, its impact can accumulate exponentially, akin to a snowball effect, which eventually becomes increasingly challenging to manage (Akkan & Horzum, 2024). Research conducted by Choi et al. (2020) demonstrated that mathematics anxiety is a significant predictor of students' numerical ability. In essence, this anxiety not only affects the emotional dimension but also influences students' cognitive behavior, leading to tension and stress during the learning process (Passolunghi et al., 2020).

In-depth observations conducted in several elementary schools and interviews with teachers revealed that numerous students exhibit low mathematical resilience, specifically their ability to persevere through difficulties when learning mathematics. This low resilience is evident in various learning situations, where students tend to abandon their efforts prematurely when confronted with challenging mathematical problems. Frequently, they seek immediate assistance from teachers or peers rather than attempting to find solutions independently. When faced with more intricate challenges, many students display excessive frustration and anxiety. Notably, some of them choose to refrain from attempting again after experiencing previous failures.

This phenomenon underscores the fact that students currently lack the resilience to confront academic challenges, particularly in mathematics. Furthermore, interviews with teachers who have dedicated their careers to elementary school mathematics education confirmed that low mathematical resilience is one of the primary impediments to enhancing the quality of learning. Teachers observed that students often lack confidence in solving mathematical problems. When they encounter errors, most of them perceive themselves as failures and lose their motivation to attempt again. This implies that students' relationship with mathematics may have been strained by systemic demands in the assessment and teaching of mathematics. However, this relationship can be restored. One approach to improving this relationship is by fostering students' mathematical resilience.

As outlined by Johnston-Wilder and Lee (2010), mathematical resilience emerges as a potential solution to address these challenges, characterized as the capacity to respond positively in the face of difficulties. The structure of mathematical resilience empowers students to effectively manage and shield themselves from detrimental emotions that may arise when encountering mathematical difficulties. Furthermore, research findings consistently demonstrate the positive correlation between mathematical resilience and students' achievement of mathematics learning objectives. Notably, Fatimah and Fitriani's (2021) study underscores the

influence of mathematical resilience on critical thinking skills. Additionally, Fitriani et al.'s (2023) research reveals the impact of mathematical resilience on students' problem-solving abilities within the mathematical domain. Moreover, Zandy and Negara's (2024) research suggests that students exhibiting high mathematical resilience demonstrate robust mathematical abilities. These students possess a comprehensive understanding of concepts, effectively applying conceptual fluency in problem-solving, strategy selection, and adaptive reasoning.

Cultivating mathematical resilience is a crucial strategy for maintaining motivation to learn mathematics. To support these efforts, it is essential to identify various aspects that distinguish the level of mathematical resilience among students. This identification is vital to provide a more comprehensive understanding that mathematical resilience is not solely influenced by challenges related to the learning model or the mathematics subject matter itself. Furthermore, mathematical resilience can also be influenced by internal factors of students that are individual characteristics. These internal factors encompass aspects of gender and learning style, which have the potential to manifest differences in confronting the challenges of learning mathematics. Several educators noted that there are patterns indicating differences in the manner in which male and female students respond to mathematical challenges. Male students tend to be more daring in attempting novel strategies, even if they are not necessarily correct, while female students exhibit greater caution and often hesitate when confronted with new mathematical challenges (Gajda et al., 2022). However, this distinction remains subjective and necessitates further research.

Furthermore, an intriguing aspect to consider is learning style. Learning style is a tool that enables students to utilize strategies and approaches that align with their needs for comprehension. In practical learning scenarios, educators observe that the disparity between learning methods and students' learning styles can significantly hinder their persistence in overcoming mathematical challenges. Certain students with specific learning styles appear to abandon their efforts more readily when the teaching approach deviates from their understanding of the material. Consequently, educators must comprehend the learning style of each student to ensure an effective teaching process. Otherwise, the educational efforts made may be less than optimal or even futile, as they do not correspond with the manner in which students absorb and comprehend information.

In this study, the types of learning styles analyzed encompass visual, auditory, and kinesthetic learning styles. Individuals with visual learning styles tend to acquire knowledge primarily through visual stimuli. They comprehend concepts more effectively when presented with illustrations, diagrams, or other visual aids. Conversely, if the learning method employed in class heavily relies on verbal explanations without visual support, students with this learning style may encounter difficulties and experience a decline in motivation. Auditory learners, on the other hand, acquire knowledge through auditory stimuli. They are more comfortable with oral explanations and discussions and require sufficient verbal interaction to grasp mathematical concepts. When faced with learning through reading or written exercises without verbal guidance, they may encounter challenges in tackling more complex problems. Kinesthetic learners, in contrast, learn significantly through movement, touch, and action. They prefer practice-based learning and engage in direct activities. If learning solely focuses on theoretical concepts without direct exploration, individuals with this learning style may easily become bored and lose motivation to persevere when encountering difficulties.

Several studies have examined resilience as a crucial aspect in the formation of students' mathematical identities, particularly in overcoming academic and social challenges. For

instance, research by Boutin-Martinez et al. (2019) and Sparks et al. (2021) underscores the resilience of high school students from the Latina/o community in maintaining their interest in STEM fields and avoiding school dropout. These students demonstrate the capacity to persevere in environments that may not always be supportive, fostering a stronger attachment to STEM education and motivating them to continue their studies up to the university level. In a similar context, but from the students' perspective, Leyva (2021) and Joseph et al. (2020) observed how Black women pursuing degrees in STEM-related disciplines rely on their mathematical identity as a source of strength. They not only demonstrate personal resilience in confronting gender and racial challenges in a predominantly white male environment but also develop strategies to overcome these obstacles. These studies demonstrate that resilience is not only a supportive factor but also an integral component of mathematical identity that contributes to students' motivation and success. Furthermore, Xenofontos and Andrews (2020) provide an educator's perspective. They examined the resilience expressed by active elementary school teachers, particularly how teachers shape their mathematical identity and develop self-efficacy in teaching mathematics. This research revealed that teachers' experiences in facing and overcoming the challenges of teaching mathematics also play a crucial role in building resilience, which in turn impacts the quality of student learning. Sucipto et al. (2024) conducted a study investigating the influence of Kolb's learning styles (divergent, convergent, assimilator, and accommodator) on functional thinking. The analysis revealed that students' learning styles exhibited a substantial impact on their functional thinking abilities.

Based on findings from several studies, there is evidence suggesting a positive correlation between mathematical resilience and students' achievement in mathematics learning. However, from the studies mentioned, we have not identified research specifically highlighting mathematical resilience at the elementary school level. To address this gap, we extend the review of elementary school students' mathematical resilience by examining their learning styles and gender. To elucidate the reasons behind the association between mathematics learning outcomes and learning styles, it is crucial to understand that learning is a multifaceted process designed to achieve academic success as a consequence of student performance (Ocampo et al., 2023; Cavite & Gonzaga, 2023). The learning process entails efforts to analyze, comprehend, and internalize presented information, which frequently presents challenges for individuals. This is where the pivotal role of learning styles becomes evident.

Learning styles serve as a crucial tool that empowers students to adopt strategies and approaches tailored to their unique needs in comprehending learning materials. As elucidated by Mohsenipouya et al. (2024), learning styles can be conceptualized as a personal approach to receiving and processing information, shaped by the interplay of genetic predispositions, life experiences, and individual aspirations. Furthermore, Cimermanová (2018) underscores the significance of considering learning styles in selecting the most suitable learning methods, techniques, and strategies. Ha (2021) also contends that learning styles reflect relatively stable psychological states and exert influence on students' academic performance. Nugroho et al. (2020) demonstrated that learning styles significantly influence independent learning patterns.

Conversely, numerous studies have demonstrated the role of gender in achieving academic success. Alan et al. (2018) conducted a study that revealed that female students guided by teachers with traditional gender roles exhibited lower scores on standardized mathematics achievement tests compared to male students under similar circumstances. In contrast, boys did not demonstrate a significant decline in their academic performance. Similar findings were

presented by Vera Gil (2024), who explored gender disparities in the relationship between psychological resilience and academic performance. The study unveiled that in females, several psychological resilience factors correlated with their academic achievement, whereas in males, there was no discernible correlation between psychological resilience and academic performance.

However, the findings of a study conducted by Amoado et al. (2024) revealed that high school students generally exhibited moderate levels of academic resilience and high levels of academic well-being. Notably, the study did not identify statistically significant differences in academic resilience or academic well-being based on gender. These findings provide valuable insights into the contextual nature of the influence of gender on academic resilience and well-being, acknowledging the impact of various internal and external factors that influence the individual.

Therefore, educators must possess a comprehensive understanding of the diverse learning styles of each student to facilitate effective teaching. Without this knowledge, educational efforts may be diminished or even ineffective, as they may not align with the manner in which students absorb and process information. This study delves into three distinct types of learning styles—visual, auditory, and kinesthetic—based on Neil Fleming's theory. Visual learners primarily learn through visual stimuli, auditory learners through auditory cues, and kinesthetic learners predominantly through movement, touch, and actions (Fleming, 2001; Rasheed & Wahid, 2021).

These factors suggest that elementary school students' low mathematical resilience is a multifaceted issue, influenced not only by internal factors such as motivation and self-confidence, but also by external factors such as classroom teaching methods. Consequently, more in-depth and comprehensive research is necessary to elucidate the correlation between learning styles and mathematical resilience among elementary school students. The primary objective of this study was to address the research gap pertaining to the relationship between learning styles and mathematical resilience among elementary school students. Based on these objectives, the following research questions were formulated: (1) What are the most prevalent learning styles among elementary school students in terms of their mathematical resilience? (2) Is there a correlation between learning styles and gender in terms of mathematical resilience? (3) Is there an interaction between the variables of mathematical resilience, learning styles, and gender? By comprehending the patterns of mathematical resilience based on gender and learning styles, this study aims to provide valuable insights for educators in developing instructional strategies that align with student characteristics. Thus, it is anticipated that students will not only grasp mathematical concepts more effectively, but also develop a stronger determination and resilience in overcoming various mathematical challenges.

Methods

This study employs a non-experimental comparative design. The selection of a non-experimental comparative research design in this study is grounded in the study's objective, which is to compare two or more groups without manipulating the independent variable. This design is suitable when the variables being investigated cannot or are unethical to manipulate, enabling researchers to discern differences between groups based on specific variables in natural settings (Gay et al., 2012). Furthermore, this design is frequently utilized in social and educational research to assess relationships and distinctions between groups based on certain characteristics, without direct intervention from the researcher (Creswell & Creswell, 2018).

Consequently, this approach facilitates a more comprehensive comprehension of the phenomenon under investigation in its authentic context. The research was comparative and explanatory in nature, aiming to examine differences between groups based on two factors (learning styles and gender) as well as their interaction.

The participants of this study were 62 fifth-grade elementary school students from Stabat City, North Sumatra Province. The participants consisted of 32 female and 30 male students. The selection of participants was conducted using the probability proportional sampling technique. This sampling method is particularly suitable for survey research in cases where sampling units vary in size or possess other significant characteristics that researchers aim to account for in the sample design (Cheung, 2021). By employing this technique, the study ensured that the selected sample accurately represented the target population, thereby enhancing the validity and generalizability of the findings.

Data were collected through a survey method employing two instruments: a mathematical resilience questionnaire and a learning style questionnaire. The Mathematical Resilience Questionnaire comprises 28 items, structured into four subscales as outlined by Johnston-Wilder et al. (2014). Table 1 provides an illustrative example of the mathematical resilience questionnaire utilized.

Table 1. Illustration of a mathematical resilience questionnaire instrument

No	Indicator	Sample of statement items
1	Understanding the Value of Mathematics (engagement in mathematical thinking and developing a personal appreciation for mathematics)	Studying mathematics does not significantly alter my learning patterns.
2	Growth Mindset, or the belief that intellectual abilities can be developed (strategy adaptation, learning skills, and building resilience in problem-solving)	I am confident in presenting my mathematical solutions to the class.
3	Understanding Mathematical Processes (developing options and opportunities for experimentation)	I consistently view failures in mathematics examinations as valuable learning opportunities that facilitate my improvement.
4	Awareness of Available Support from Peers, Teachers, ICT, the Internet, and so on. (Access to assistance and support, and access to media and learning resource support).	I have unrestricted access to a wide range of media and comprehensive mathematics learning resources.

The learning style questionnaire is based on Fleming's theory (2001) and comprises three subscales: visual, auditory, and kinesthetic. Each subscale consists of 18 items. Table 2 provides examples of the questionnaire items. Prior to their utilization in the study, the research instruments underwent a rigorous validation and testing process. The validation process was designed to ascertain the appropriateness and capability of the instruments to measure the intended constructs. The validation results demonstrated the instruments' suitability for use. Furthermore, reliability estimates were computed using Cronbach's Alpha to assess the instruments' internal consistency. The results revealed a reliability coefficient of 0.715 for the mathematical resilience questionnaire and 0.80 for the learning style questionnaire. Both reliability coefficients fall within the high category, indicating substantial consistency of the

instruments. Consequently, the instruments were deemed valid and reliable for their use in this study.

Table 2. Illustration of the learning style questionnaire instrument

No	Sample of questionnaire items	Description
1	I prefer reading: A. Quickly B. Aloud C. Using my finger as a guide	Option A, identifies a visual learning style. Option B, identifies an auditory learning style. Option C, identifies a kinesthetic learning style.
2	I easily remember things that: A. I see B. I hear C. I write	Option A, identifies a visual learning style. Option B, identifies an auditory learning style. Option C, identifies a kinesthetic learning style.

A two-way ANOVA was employed in this study to investigate the impact of two independent variables: learning style and gender, on the dependent variable: students' mathematical resilience. Two-Way Analysis of Variance (ANOVA) is a statistical analysis technique employed when the research objective entails a continuous dependent variable, such as test scores, time, or other measurements with an interval or ratio scale. In this context, continuous data possess values that can be quantified on a sequential scale, and the discrepancies between these values can be computationally meaningful. In Two-Way ANOVA, each independent variable is categorized into two or more groups. Consequently, the primary independent variable, such as gender, will partition the data into two categories (male and female), while the secondary independent variable, such as education level, can categorize the data into more than two categories (visual, auditory, and kinesthetic). This methodology facilitates the analysis of mean comparisons between groups formed by these two factors (Field, 2013; Pallant, 2020).

The two-way ANOVA not only assesses the primary effects of each independent variable on mathematical resilience but also enables the researcher to explore the interaction between learning style and gender. In essence, this analysis extends beyond evaluating the individual effects of learning style or gender to reveal how specific combinations of these variables uniquely influence students' mathematical resilience. In this study, the statistical significance level was established at $p < 0.05$, employing a two-tailed test. This threshold stipulates that results are deemed statistically significant only if the probability of their occurrence by chance is less than 5% (Andrade, 2019; Concato & Hartigan, 2016). In essence, if the *p*-value falls below 0.05, the null hypothesis, which posits the absence of an effect or interaction, is rejected. Consequently, it can be concluded that there exists a substantial relationship or interaction between learning style, gender, and students' mathematical resilience.

Findings and Discussion

This section presents the two primary components that constitute the research objectives. The first component entails identifying the most prevalent learning style among elementary school students and evaluating their level of mathematical resilience. Through this analysis, the study aims to provide a comprehensive overview of students' preferred learning styles and their resilience in overcoming mathematical challenges. The second component focuses on investigating the impact of learning style and gender on mathematical resilience, as well as examining their interplay. The outcomes of this analysis are anticipated to provide insights into

the role of learning style and gender in fostering mathematical resilience, thereby facilitating the identification of more effective learning strategies to support students' academic success.

A comprehensive analysis of students' learning styles and mathematical resilience

The learning style profiles of the 62 students participating in this study were categorized into three primary types: visual, auditory, and kinesthetic. This categorization was determined based on students' propensity for effectively receiving and processing information. Each group corresponds to a distinct learning preference. Table 3 provides a comprehensive description of the students' overall learning style profiles, offering an overview of the distribution and quantity of students within each learning category.

Table 3. Description of student learning styles

Gender	Learning styles		
	Visual	Auditory	Kinesthetic
Male (*N* = 30)	21(70%)	5(16.67%)	4(13.33%)
Female (*N* = 32)	24(75%)	6(18.75%)	2(6.25%)

Based on the data presented in Table 3, students' learning style preferences are predominantly visual. Specifically, as many as 70% of male students (21 individuals) exhibited a preference for visual learning styles. Similarly, 75% of female students (24 individuals) preferred visual learning styles. This finding suggests that the majority of students in this study favor processing information through visual representations. This suggests that students derive greater comprehension from visual representations, such as images, diagrams, and other forms of visualization, during the acquisition of knowledge. Additionally, Table 4 presents data on students' mathematical resilience, including the number of items per scale or factor, the mean (M), and the standard deviation (SD) for mathematical resilience assessments.

Table 4. Description of students' mathematical resilience

Subscale	*M*	*SD*
Mathematical resilience	88.58	5.479
Visual	90.556	4.679
Auditory	83.909	4.158
Kinesthetic	82.333	3.011
Mathematical resilience	88.58	5.479
Male	88.2	5.933
Female	88.938	5.086

Table 4 presents a statistical summary of the variables studied in this research. Based on the data, it is evident that the mean (M) score is greater than the standard deviation (SD) score. This indicates that the data tends to cluster around the mean value, suggesting a relatively low variation between values. In essence, most individuals in the sample possess scores that are not significantly distant from the mean. This finding also implies homogeneity within the data set. Furthermore, the data suggests that students with a visual learning style exhibit superior mathematical resilience compared to those with an auditory or kinesthetic learning style. This can be ascertained from the mathematical resilience score of students with a visual learning style. reached M = 90.556, with SD = 4.679 on a four-point Likert scale, this score suggests that

students with a visual learning style exhibit a higher level of mathematical resilience in overcoming challenges and difficulties in learning mathematics.

Furthermore, when compared based on gender, the mathematical resilience of male students is evident (M = 88.2, SD = 5.993). Additionally, female students (M = 88.938, SD = 5.086), the mathematical resilience scores of male and female students are relatively similar. This minor difference implies that, in general, gender does not have a substantial impact on students' mathematical resilience. Furthermore, the average mathematical resilience score for all students is M = 88.58. SD = 5.479.

These findings suggest that while there are slight variations in mathematical resilience based on learning styles and gender, these differences are not statistically significant overall. Consequently, programs or interventions are necessary to enhance students' resilience in confronting mathematical challenges, as their overall mathematical resilience remains at a moderate level. Furthermore, a more in-depth exploration into the influence of students' learning styles on their mathematical resilience would be beneficial in developing more effective and adaptable instructional strategies.

A comprehensive analysis of the interplay between learning style and gender in fostering mathematical resilience among elementary school students

To ascertain whether there is a substantial impact of learning style and gender on mathematical resilience, a two-way ANOVA was conducted. Prior to executing the two-way ANOVA, assumption checks were performed. The assumption of homogeneity of variance, which is a prerequisite for a two-way ANOVA, was met. (F (2, 56) = The p-value (1.936) is greater than 0.05, indicating that the null hypothesis is not rejected. Furthermore, the assumption of data normality, another prerequisite for ANOVA, was assessed. The results of this assumption check are presented in Figure 1, which provides a visual representation of the data distribution.

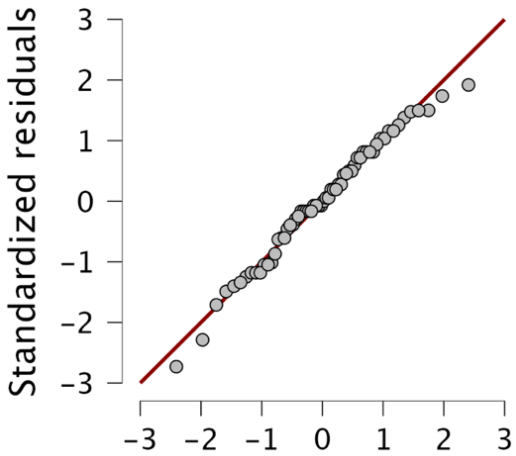

Figure 1. Visualization of data normality

Based on Figure 1, the data points are distributed relatively close to the diagonal line, indicating that the assumption of normality is satisfied. Overall, this examination confirms that the data meet the necessary criteria for two-way ANOVA, ensuring the reliability of subsequent analyses. With the assumptions fulfilled, the two-way ANOVA test was conducted. Table 5 presents the

results of the analysis, which examine the effects of learning style and gender on mathematical resilience.

Table 5. The influence of learning style and gender on mathematical resilience

ANOVA - MR

Cases	Sum of Squares	df	Mean Square	F	p	η^2_p
LS	604.722	2	302.361	14.382	< .001	0.339
Gender	0.647	1	0.647	0.031	0.861	5.493×10^{-4}
LS ✻ Gender	2.700	2	1.350	0.064	0.938	0.002
Residuals	1177.300	56	21.023			

Note. Type III Sum of Squares

Based on the analysis results presented in Table 5, it was determined that learning style (LS) has a substantial impact on mathematical resilience (MR). This finding is supported by the statistical analysis results, with $F(2, 56) = 14.382$ and a significance level of $p < 0.05$. These results indicate that variations in LS significantly influence MR. In essence, differences in learning styles can impact an individual's ability to persevere when confronted with mathematical challenges. Conversely, the analysis for the gender variable revealed no significant effect on MR. The results show $F(2, 56) = 0.031$ with a significance level of $p > 0.05$, indicating that gender differences do not have a meaningful impact on MR. To further elucidate which learning styles significantly influence mathematical resilience, additional analysis was conducted. A Post Hoc test was performed (as presented in Table 6) to specifically identify which learning styles contribute significantly to MR. This analysis provides a more comprehensive understanding of the relationship between specific LS and MR.

Table 6. Post Hoc results of the relationship between LS and MR

Post Hoc Comparisons - LS

		Mean Difference	SE	t	p_{tukey}
Visual	Auditory	6.608	1.548	4.269	< .001
	Kinesthetic	8.042	2.100	3.829	< .001
Auditory	Kinesthetic	1.433	2.423	0.592	0.825

Note. P-value adjusted for comparing a family of 3

Note. Results are averaged over the levels of: Gender

Based on the Post Hoc test results employing the Tukey method, several significant differences were identified among the LS groups in their impact on MR. A comparison between visual and auditory learning styles revealed a significant difference ($p < 0.05$). Furthermore, a comparison between visual and kinesthetic learning styles demonstrated a significant difference, with the visual learning style exerting a greater influence on mathematical resilience ($p < 0.05$). Notably, no significant difference was observed between auditory and kinesthetic learning styles in their impact on mathematical resilience ($p > 0.05$). These findings suggest that the visual learning style consistently exhibits a more pronounced positive impact on mathematical resilience compared to the other two learning styles, while there is no discernible difference between auditory and kinesthetic learning styles in their influence on mathematical resilience.

Furthermore, the analysis results presented in Table 5 demonstrate the absence of an interaction between learning style (LS) and gender in influencing mathematical resilience. This finding implies that the impact of learning style on mathematical resilience is not contingent upon an individual's gender, and conversely, the influence of gender on mathematical resilience is not contingent upon the type of learning style employed. This conclusion is supported by the statistical analysis, which yielded an $F(2, 56) = 0.064$ with a significance level of $p > 0.05$, indicating that the relationship is statistically insignificant. Consequently, it can be concluded that learning style and gender operate independently in influencing mathematical resilience. The implication of this finding is that when developing instructional strategies to enhance mathematical resilience, attention can be directed towards individual learning styles without the necessity of differentiation based on gender. This suggests that gender does not magnify or diminish the impact of specific learning styles on mathematical resilience.

This study presents several notable findings. Firstly, the visual learning style emerged as the most prevalent among the research sample. This dominance indicates that the majority of students in this study predominantly rely on visual abilities, such as interpreting diagrams, graphs, and illustrations, to comprehend learning materials. This finding aligns with Piaget's (1952) theory of cognitive development, which relates to the stages of human cognition. At elementary school age, children's cognitive development occurs in the concrete operational stage, during which they find it easier to comprehend concepts through visual representations and direct experiences. As they progress through higher levels of education, such as junior high school and high school, students may transition away from their visual learning style. This shift is accompanied by a change in their cognitive mindset, as described by Piaget in the formal operational stage. At this stage, students develop the ability to think logically and abstractly, without explicitly relying on visual representations (Piaget, 1972).

Not only was it dominant, but the visual learning style was also demonstrated to have a substantial impact on students' mathematical resilience. This suggests that students with a visual learning style are more likely to exhibit superior abilities in overcoming mathematical challenges, including solving intricate problems and demonstrating perseverance in situations that require logical reasoning skills. These findings align with the study conducted by Abdussakir et al. (2024), which demonstrated a propensity for students' creative thinking abilities to enhance as their academic performance improves, particularly in questions that incorporate visual elements. Additionally, the study identified a gender disparity, with male students exhibiting higher levels of creative thinking compared to their female peers. These findings suggest that visual representations, such as images, diagrams, and other forms of visualization, play a pivotal role in facilitating students' comprehension and processing of information more effectively during the knowledge acquisition process.

Conversely, the results indicate that gender does not have a significant impact on students' mathematical resilience. In other words, both male and female students have equal opportunities to develop their mathematical resilience, unaffected by gender differences. Furthermore, further analysis of the interaction between learning styles and gender in relation to mathematical resilience also yielded non-significant results. This implies that learning styles do not influence students' mathematical resilience differently based on their gender. These findings emphasize that learning style independently influences mathematical resilience, irrespective of gender.

First and foremost, learning styles significantly influence students' mathematical resilience. Research investigating the correlation between learning styles and academic performance has yielded pertinent findings and conclusions. The majority of empirical studies have demonstrated a clear and substantial relationship between learning styles and students' academic achievement, including their mathematical resilience. A substantial body of research conducted by scholars such as Autida (2024), Wan Hussin and Mohd Matore (2023), Almasri (2022), Cardino Jr & Ortega-Dela (2020), Yazıcı (2017), Khodabakhshzadeh et al. (2017), and Cuevas (2015) has investigated diverse experimental subjects, ranging from elementary school students to university students across various disciplines. All of these studies confirm that students' learning styles, which encompass visual, auditory, kinesthetic, and other learning preferences, directly impact how they approach academic challenges, particularly in the context of mathematics. Qualitatively, Syawahid and Putrawangsa (2017) conducted a study that revealed variations in students' mathematical literacy abilities based on their learning styles. Furthermore, their findings demonstrated a correlation between learning style and students' mathematical literacy levels.

Among the various learning styles analyzed in this study, the visual learning style significantly influences students' mathematical resilience. This finding suggests that students with a visual learning style perform better when confronted with mathematical challenges, such as solving complex problems or completing tasks that require high analytical skills. This aligns with the research findings of Sarican (2021), which demonstrate that students with a visual learning style exhibit greater success in mathematics compared to those who do not possess a visual learning style. This may be attributed to the visual learners' ability to rapidly comprehend information through visual representations, such as graphs, diagrams, or images, which are often pertinent in mathematics education. As elucidated by Machromah et al. (2021), students who adopt a visual learning style generally find it easier to organize and manipulate intricate information, which is paramount in subjects like mathematics, where abstract concepts frequently necessitate concrete visualization through visual representations. This also explains why students with a visual learning style tend to possess a greater aptitude for comprehending and solving mathematical problems effectively and efficiently. Based on findings reported by Apipah (2018), students who systematically, orderly, and clearly record the steps in solving mathematical problems demonstrate enhanced proficiency in this domain.

In contrast, a significant finding of this study aligns with the findings of Wan Hussin and Mohd Matore (2023), which suggest that the visual learning style is the most prevalent among students in mathematics subjects. Furthermore, the results of multiple regression analysis demonstrate that the visual learning style is a substantial contributor or predictor of academic procrastination variations in mathematics. This finding diverges from the findings of various global contexts, where the kinesthetic modality frequently emerges as the most preferred, with auditory preferences typically ranking second, as evidenced in studies by AlKhasawneh (2013), Stirling and Alquraini (2017), and Alrashdi et al. (2024).

Second, gender does not have a significant impact on students' mathematical resilience. In other words, both male and female students demonstrate comparable abilities in overcoming mathematical challenges, irrespective of gender disparities. This finding underscores that students' mathematical resilience is more influenced by internal factors, such as learning styles,

learning strategies, and personal motivation, rather than biological or gender-related factors. It implies that in the context of mathematics education, student success is more determined by the learning approaches and support they receive than by gender differences.

This study supports the principle of inclusive education, which aims to provide equal opportunities to all students, irrespective of gender. The findings of this study align with those of Nusaibah et al. (2024), which indicate no significant correlation between gender and mathematical resilience. Notably, their study also underscores that students naturally approach mathematical problems without being influenced by their gender. This suggests that the capacity to persist in challenging mathematical situations is a universal trait that is not associated with gender.

Despite the extensive research on the impact of gender on mathematical resilience, the literature presents conflicting conclusions. For instance, Mwangi and Ireri (2017), Anokye-Poku and Ampadu (2020), and Bashir et al. (2023) highlights varying results, indicating that gender may be relevant in specific contexts but insignificant in others. In contrast, Hyde et al. (1990) and Juwantara (2019) contend that the differences in mathematical resilience between male and female students are more frequently attributed to psychological and social factors, such as societal expectations, gender stereotypes, and cultural roles, rather than intrinsic or biological factors.

For instance, stereotypes associating mathematical ability with a specific gender can influence students' confidence, which, in turn, affects their approach to challenges in mathematics. Therefore, the finding that gender does not significantly influence mathematical resilience underscores the necessity for educational approaches that eliminate gender bias, promote equitable psychological development, and ensure that all students are provided with equal opportunities to realize their academic potential. In conclusion, these results provide a robust foundation for educators to prioritize student-centered learning strategies over considerations of gender differences. This is crucial in creating a fair learning environment where every student can thrive and demonstrate optimal mathematical resilience without being influenced by stereotypes or gender expectations.

Third, no interaction was discovered between learning styles and gender in influencing students' mathematical resilience. This finding suggests that learning styles exert a direct and independent impact on students' mathematical resilience, devoid of any influence from gender. In essence, male and female students possessing the same learning style, such as visual, auditory, or kinesthetic, have equal opportunities to develop mathematical resilience. This discovery underscores the prominence of learning styles as a more influential variable in shaping mathematical resilience compared to the interaction between learning styles and gender.

This outcome aligns with previous studies suggesting that learning styles are more closely associated with an individual's ability to absorb, comprehend, and apply information compared to demographic factors such as gender. For instance, Lu et al. (2003) emphasized that gender does not significantly influence students' learning outcomes, while Zhang et al. (2017) demonstrated that learning styles contribute to predicting academic achievement. Similarly, research by Bohrnstedt et al. (2024), Mozahem et al. (2020) and Rodríguez et al. (2020) supports the notion that gender does not play a primary role in academic ability differences, including in

mathematics. Consequently, the interaction between learning styles and gender becomes statistically insignificant.

In the context of mathematical resilience, students with specific learning styles, such as visual learners, may possess a greater aptitude for overcoming mathematical challenges by utilizing visual representations like graphs or diagrams to comprehend intricate concepts. This advantage extends to all students, irrespective of gender, further emphasizing the significance of considering learning styles when developing instructional strategies. For instance, Almoslamani (2022) demonstrated that aligning teaching methods with students' learning styles has a more pronounced impact on academic outcomes compared to demographic factors.

Furthermore, these findings are pertinent within the framework of inclusive education, where the primary objective is to establish a supportive learning environment for all students, free from bias. By excluding gender as a distinguishing factor, educators can more effectively design learning strategies that cater to students' needs and preferences. This approach not only enhances mathematical resilience but also fosters the development of critical thinking and problem-solving abilities.

The findings of this approach underscore the paramount importance of adopting a learning style-based approach in mathematics education, while gender should not be the primary focus. This approach not only promotes equity in education but also provides equal opportunities for all students to develop optimally in accordance with their unique learning preferences. Cheng et al. (2017) further emphasize that learning style-based instructional strategies can substantially enhance learning outcomes without being influenced by gender disparities, thereby reinforcing the significance of these findings in contemporary educational contexts.

Overall, this study revealed that visual learning is the predominant learning style among students, exerting a substantial influence on their mathematical resilience. Students with a visual learning style demonstrate enhanced capability in overcoming mathematical challenges, as they can effectively utilize visual representations such as diagrams and graphs to grasp intricate concepts. Notably, gender does not exhibit a significant impact on mathematical resilience, indicating that both male and female students possess equal opportunities for developing their mathematical resilience. Furthermore, no interaction was detected between learning style and gender in terms of mathematical resilience, suggesting that learning style operates as an independent factor in influencing students' mathematical resilience.

Given the substantial influence of the visual learning style on mathematical resilience, educators are strongly encouraged to incorporate a greater number of visual aids, such as diagrams, graphs, and interactive models, into mathematics instruction. By doing so, they can enhance students' comprehension and perseverance in solving intricate mathematical problems. Notably, no significant disparities in mathematical resilience were observed based on gender. Therefore, educators must ensure that mathematics education is devoid of gender stereotypes and provides equitable opportunities for all students to develop their full potential.

Conclusion

Overall, the findings of this study provide evidence of the influence of learning styles on mathematical resilience. The data support the primary objective of this research, which identifies the visual learning style as the dominant learning style. Additionally, the findings address the

second objective, demonstrating a significant influence of learning styles on mathematical resilience. Specifically, the visual learning style consistently exerts a greater impact on mathematical resilience compared to auditory and kinesthetic learning styles. In contrast, the analysis of gender reveals that gender does not have a significant effect on mathematical resilience. Furthermore, the data indicate no interaction between learning styles and gender in influencing mathematical resilience. These findings contribute to a deeper understanding of the relationship between learning styles and their impact on mathematical resilience.

The implications of this study suggest that when considering instructional strategies to enhance mathematical resilience, emphasis can be placed on individual learning styles without the need to differentiate based on gender. This finding indicates that gender does not amplify or diminish the effect of specific learning styles on mathematical resilience. Given the crucial role of mathematical resilience in students' academic success, educational institutions should design intervention programs specifically aimed at enhancing mathematical resilience. These programs should include training in critical thinking and visual-based problem-solving. Further research is necessary to explore other factors that may influence students' mathematical resilience, such as motivation, learning strategies, and social and psychological factors. By examining these factors, we can gain a more comprehensive understanding of effective strategies for developing mathematical resilience.

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