Kalamatika: Jurnal Pendidikan Matematika

P-ISSN 2527-5615
E-ISSN 2527-5607

Journal homepage: https://kalamatika.matematika-uhamka.com/

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To cite this entry:

Sazali, M., Priatna, N., Herman., T, (2025). Students' mathematical procedural fluency in solving mathematical problems in terms of mathematical resilience and gender. *Kalamatika: Jurnal Pendidikan Matematika*, *11*(1), 1-19. https://doi.org/10.22236/KALAMATIKA.vol11no1.2026pp1-19

Link to the article online:
https://kalamatika.matematika-uhamka.com/index.php/kmk/article/view/746

Submitted: *Jun 29, 2025* | Revised: *Oct 27, 2025* | Accepted: *Oct 28, 2025*
Published online: *April 30, 2026*

Kalamatika: Jurnal Pendidikan Matematika
Volume 11, No. 1, April 2026, pages 1-19
DOI: 10.22236/KALAMATIKA.vol11no1.2026pp1-19

Students' mathematical procedural fluency in solving mathematical problems in terms of mathematical resilience and gender

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ABSTRACT

Mathematical resilience and gender are often associated with differences in students' skills and ways of thinking while learning mathematics. This study aims to simultaneously describe students' mathematical procedural abilities in terms of mathematical resilience and gender. Data were collected from 19 participants selected through purposive sampling based on criteria relevant to the research variables. A procedural fluency test and a student mathematical resilience questionnaire were used; both instruments had been previously validated by experts, who concluded that they were suitable for use. The data analysis technique employed was ANCOVA (Analysis of Covariance). The results indicated that both resilience and gender appeared to influence students' mathematical procedural fluency; however, resilience was the factor that made a meaningful difference, not gender. Qualitative analysis, including resilience questionnaires, interviews, and test result descriptions, revealed that both male and female students can demonstrate strong mathematical procedural fluency when they possess high mathematical resilience. As a result, gender differences did not emerge as a significant influence, as both groups had equal opportunities when their mathematical resilience was high. The absence of a significant gender effect is suspected to be due to the relatively small sample size used in this study, which may not have provided sufficient statistical power to detect the actual effect. Due to the limitations of this study, these findings should be considered preliminary. Further research is needed using a larger sample size and more representative sampling to better examine the combined influence of gender and resilience on mathematical procedural fluency.

KEYWORDS

Gender; mathematical resilience; procedural fluency

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INTRODUCTION

Mathematics at every school level, from elementary to secondary school, is taught with varying materials and levels of difficulty. As mathematics develops, the material becomes increasingly complex. Students' fluency in selecting and applying strategies determines their success in solving mathematical problems whose solutions can be demonstrated systematically (Rambe & Afri, 2020). Procedural fluency is an ability related to students' understanding of mathematical concepts and their knowledge of selecting, applying, and modifying appropriate procedures in solving mathematical problems (Nur et al., 2022; Safitri & Lestari, 2022). Students' mathematical procedural fluency can be observed through indicators such as the ability to select procedures, use procedures, and apply procedures effectively (Firdaus, 2019).

In practice, various student characteristics in responding to mathematics learning can be observed. Some students perceive mathematics as a subject full of numbers, formulas, and abstract theories (Ratna & Yahya, 2022). while others are motivated and feel challenged to understand and solve mathematical problems. There are also students who view mathematics as too difficult to engage with seriously (Dahlan, 2019; Sari et al., 2023). Previous experiences usually influence these perceptions. Students who are successful in learning mathematics tend to have the desire to continue learning and achieve satisfactory results, whereas students who have previously experienced failure may become reluctant to learn and tend to avoid mathematics (Haerunnisa & Imami, 2022; Nurhayati & Nimah, 2023).

A negative attitude toward mathematics can affect the learning process. Students who lack motivation to learn may easily give up, experience anxiety, and encounter difficulties when learning mathematics (Wicaksono & Saufi, 2013; Hutauruk, 2020). If students are unable to overcome such emotional learning difficulties, this will affect their mathematics learning outcomes (Pantoja et al., 2020; Altakhyneh, 2020). Some students also fail to reflect on their learning outcomes because they have already given up and perceive mathematics as inherently difficult. Thus, issues of students easily giving up, feeling anxious, and experiencing difficulty in learning should be a concern in the learning process. These difficulties can be addressed through attitudes such as perseverance, confidence, resilience, and hard work (Margolis & McCabe, 2003; Nurhayati & Nimah, 2023; Hutauruk, 2019). Mathematical resilience is one of the affective factors needed to address such challenges in mathematics learning (Johnston-Wilder et al., 2018).

According to Citra, (2021), students are said to have mathematical resilience if they are able to learn and master mathematics, including understanding mathematical concepts, creating and implementing strategies, and demonstrating perseverance, persistence, and a positive response when facing mathematical challenges. Mathematical resilience is reflected in attitudes such as diligence, self-confidence, hard work in facing problems, generating new ideas, finding creative solutions, and using experiences of failure to build motivation (Kurniawan & Agoestanto, 2023; Ulhasna et al., 2024). Students with strong resilience tend to believe that mathematics is a valuable discipline worth learning, which in turn can improve their mathematical abilities (Hutauruk, 2020; Safitri et al., 2021; Setiawan et al., (2022). This belief supports students' willingness and persistence to learn mathematics despite difficulties.

In addition to mathematical resilience, gender factors are also often associated with differences in students' mathematical learning abilities. Some previous studies have shown differences in learning styles between male and female students, including in determining strategies in procedural aspects. Research conducted by Ardani & Nurkhafidhoh (2021) showed that in solving mathematical word problems, male and female students tend to demonstrate different abilities. In addition, research conducted by Firdaus & Shodikin (2022) revealed that female students are superior in creative thinking skills compared to male students in the context of solving word problems.

Many previous studies have examined mathematical procedural fluency; however, most have focused only on the relationship between two variables, such as self-regulated learning, learning style, or conceptual understanding. Meanwhile, the relationship between mathematical resilience and procedural fluency, as well as differences in procedural fluency based on gender, remains underexplored. This study extends the analysis by integrating three variables—procedural fluency, resilience, and gender differences—into a single analytical framework using ANCOVA. This represents a novelty of the present study compared to previous research (e.g., Ardani & Nurkhafidhoh, 2021; Nurfadilah & Siswanto, 2020). This study was conducted to analyze students' procedural fluency in solving mathematical problems based on mathematical resilience and gender simultaneously.

ANCOVA in educational research is widely recognized as a statistical test used to examine differences in group means while controlling for the influence of covariates. (Wulandari, 2011). Previous studies have shown that ANCOVA provides deeper insights by controlling covariates while revealing relationships between variables (Ariyani & Prasetyo, 2021). Thus, in this study, ANCOVA enables a comprehensive analysis of the influence of mathematical resilience and gender on procedural fluency, as well as the identification of which factors have the most significant impact on students' mathematical procedural fluency.

METHODS

This study employed a quantitative approach with an ex post facto design, a non-experimental research design that allows the determination of cause-and-effect relationships by analyzing data without the researcher directly manipulating the independent variables (Permadi et al., 2020). Both gender and mathematical resilience are inherent characteristics of students. Data were collected from participants selected through purposive sampling based on criteria relevant to the research variables. Data collection techniques included a mathematical procedural fluency test and a mathematical resilience questionnaire, both of which were independently developed by the researchers. These instruments were designed based on indicators of procedural fluency and mathematical resilience. The test instrument consisted of three essay questions focused on statistics topic.

Students' mathematical procedural fluency was measured based on indicators, namely the ability to select procedures, use procedures, and apply procedures effectively (National Research Council, 2001; Downton et al., 2019). The mathematical resilience questionnaire consisted of 30 statements, both positive and negative. Before use, the instruments underwent expert validation to ensure that each item represented the indicators of the variables under study, so that the data collected aligned with the research objectives. The procedural fluency test and mathematical resilience questionnaire in this study were validated by experts, namely mathematics education lecturers and teachers. The instruments were declared valid if the experts provided no revisions or suggestions and accepted both the content and format (Yusup, 2018).

After data collection, mathematical resilience was categorized into three levels: low, medium, and high. The grouping was based on norm-referenced assessment (PAN), which aims to compare relative differences between students within a group (Asrul et al., 2014). Student classification was conducted based on categorization guidelines adapted from (Putri & Warmi, 2022) as shown in Table 1.

Table 1. Categories of students' mathematical resilience ability

Interval	Criteria
$X > \bar{x} + SD$	High
$\bar{x} - SD \leq X \leq \bar{x} + SD$	Medium
$X < \bar{x} - SD$	Low

The primary focus of this study was to examine students' mathematical procedural fluency in relation to mathematical resilience and gender differences. The data analysis technique used was ANCOVA (Analysis of Covariance). The analysis was conducted using the SPSS software to facilitate quantitative interpretation of the results.

In addition to quantitative analysis, this study also analyzed qualitative data obtained from resilience questionnaires, interviews, and descriptions of students' test results. The resilience questionnaire was scored for each item, and the mean and percentage were calculated to determine students' resilience levels. The questionnaire results were analyzed descriptively to provide an overview of students' resilience profiles. To gain a deeper understanding of students' resilience and mathematical procedural fluency, content analysis was also conducted on students' responses, based on Miles and Huberman (1994) and Sitasari (2022). Through this analysis, the researchers identified students' problem-solving strategies, reasoning processes, and the types of errors that occurred during problem solving. In addition to questionnaire data and analysis of students' answers, thematic analysis was conducted on interview data to further explore students' mathematical resilience and to triangulate their responses. Haryoko, et al.

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(2020) stated that thematic analysis can be used to identify and analyze meaningful qualitative data obtained from interviews and surveys. By combining these data sources, the study provides a more comprehensive understanding of how resilience and gender influence mathematical procedural fluency.

RESULT AND DISCUSSION

This section presents the research results systematically, describing the main findings in relation to the research focus and questions. The research participants consisted of 19 grade XI junior high school students, comprising 7 male students and 12 female students. The validity of the instruments was assessed by experts, namely mathematics education lecturers and mathematics teachers, who concluded that both the mathematical resilience questionnaire and the mathematical procedural fluency test were suitable for use. The data analyzed in this study consisted of students' scores on mathematical procedural fluency in solving statistics problems.

Table 2. Students' mathematical resilience ability

Mathematical Resilience	Mean	Std. Deviation	N	Percentage
Low	23.00	15.100	3	15.78%
Medium	59.43	26.343	14	73.68%
High	79.50	2.121	2	10.53%
Total	55.79	27.906	19	100%

Students' mathematical resilience was measured using a questionnaire with the following indicators: (1) students have the willingness to learn and master mathematics; (2) students recognize the importance of learning and mastering mathematics; (3) students have confidence in learning and mastering mathematics; (4) students are aware of their limitations and learning needs in mathematics; and (5) students can overcome difficulties that arise in efforts to learn and master mathematics. After the data on students' mathematical resilience were obtained from the questionnaire, they were converted into an ordinal scale and categorized into three levels (see Table 2): low, medium, and high.

The ANCOVA test was conducted using SPSS. The results indicate that mathematical resilience and gender differences collectively have a significant effect on students' mathematical procedural fluency. The complete ANCOVA results are presented in Table 3.

Table 3. Test of Between-Subjects Effects

Dependent Variable: Procedural Fluency

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5906.658[a]	3	1968.886	3.614	.037	.421
Intercept	256.092	1	256.092	.474	.502	.031
JK	1371.429	1	1371.429	2.536	.132	.145
RM	5374.577	2	2687.288	4.970	.022	.399
Error	8110.500	15	540.700			
Toral	73154.000	19				
Corrected Total	14017.158	18				

R Squared = .421 (Adjusted R Squared = .306)

Based on Table 4, the value of Levene's test of equality of variances is 0.257. Since the significance value ($p = 0.257$) is greater than $\alpha = 0.05$, the null hypothesis is not rejected at the 0.05 significance level. This indicates that there is no significant difference in the error variances of students' mathematical procedural fluency scores.

The researchers then grouped the students based on mathematical resilience categories. From Table 2, 15% of students were categorized as having low mathematical resilience, 75% as having moderate resilience, and 10% as having high resilience. After all data were obtained, an analysis was conducted to examine students' mathematical procedural fluency in relation to both mathematical resilience and gender using the ANCOVA test.

Table 4. Levene's Test of Equality of Error Variances

Dependent Variable:	Procedural Fluency		
F	df1	df2	Sig.
1.479	2	16	.257

Test the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + JK + RM

Based on Table 3, the significance value (Sig. = 0.037) is less than $\alpha = 0.05$; therefore, H_0 is rejected at the 0.05 significance level. This indicates that, simultaneously, mathematical resilience and gender have a significant effect on students' mathematical procedural fluency. The effect size, measured using Partial Eta Squared, is 0.421, which corresponds to approximately 42%.

The analysis also examined whether gender, treated as a covariate in this study, has an influence on students' mathematical procedural fluency. If the Sig. value is less than $\alpha = 0.05$, then gender has a significant effect on procedural fluency. However, the results show Sig. = $0.132 > 0.05$; thus, the null hypothesis (H_0) is not rejected at the 0.05 significance level. This means that gender does not have a significant effect on students' mathematical procedural fluency.

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Mathematical resilience, treated as an independent variable in this study, shows a significance value of 0.022 < 0.05. Since the Sig. value is less than $\alpha = 0.05$, H_0 is rejected at the 0.05 significance level. This indicates that students' mathematical resilience has a significant effect on their mathematical procedural fluency.

1. Students with low procedural fluency and low mathematical resilience

After administering the mathematical resilience instrument, it was found that 15.78% of students had low mathematical resilience. Students with low mathematical resilience in solving problem-solving tasks were found to have weaker procedural fluency. These students tended to select less appropriate and less relevant procedures, and some did not use procedures at all. Their ability to apply procedures was also limited, as reflected in frequent errors when solving problems. The results of students' answers with low procedural fluency and low mathematical resilience are presented in Figure 1.

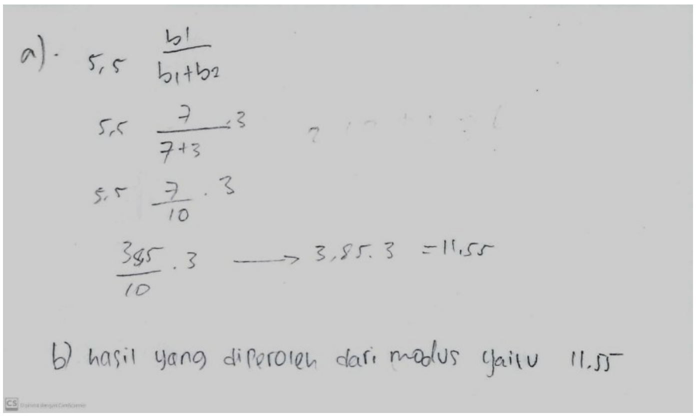

Figure 1. Answers of students with low procedural fluency and low mathematical resilience

2. Students with moderate mathematical resilience and sufficient mathematical procedural fluency

A total of 73.68% of students were categorized as having moderate mathematical resilience. Mathematical resilience helps students select solution procedures that are generally appropriate and relevant. Students with moderate mathematical resilience are able to apply procedures; however, some errors may still occur. Their final answers are often close to the correct solution, although procedural inaccuracies and computational mistakes are still evident in some cases. The results of students' responses with moderate mathematical resilience and sufficient mathematical procedural fluency are presented in Figure 2.

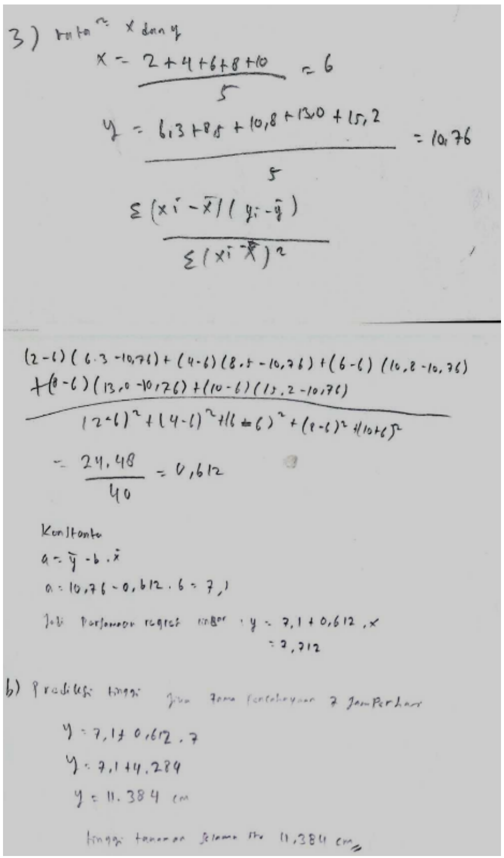

Figure 2. Students' answers with moderate mathematical resilience and sufficient mathematical procedural fluency

3. Students with high mathematical resilience and good mathematical procedural fluency ability

Students with high mathematical resilience (10.53%) demonstrate strong mathematical procedural fluency skills. These students are able to select appropriate and relevant procedures for solving mathematical problems. They also apply procedures correctly and consistently, resulting in accurate solutions. High mathematical resilience helps students complete problem-solving tasks more effectively compared to students with low mathematical resilience (Rahmatiya & Miatun, 2020; Ghifari & Usdiyana, 2023). The responses of students with high mathematical resilience and strong mathematical procedural fluency are shown in Figure 3.

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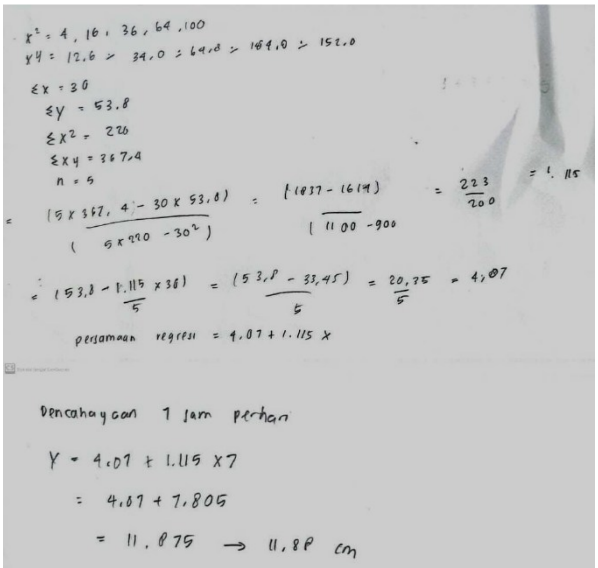

Figure 3. Results of students' answers with high mathematical resilience and good mathematical procedural fluency ability

Procedural fluency is an important component of mathematical ability (Nur et al., 2022; Safitri & Lestari, 2022). Students are not only required to understand procedures but also to carry out and apply them efficiently and accurately. The research findings indicate that mathematical resilience influences mathematical procedural fluency, suggesting that perseverance, the ability to overcome difficulties, and mental resilience are important aspects of students' procedural fluency in solving mathematical problems.

The current paradigm of mathematics learning in schools emphasizes the development of positive attitudes and emotional support to foster students' motivation to learn mathematics. Engaging learning strategies can increase students' enthusiasm, helping them persist rather than give up when solving mathematical problems (Irawan & Febriyanti, 2016; Kurniawan et al., 2019). In addition, teachers need to create learning environments that support the development of mathematical resilience. Students with high mathematical resilience believe that consistent effort can lead to success. This is typically shown through persistence, efficient use of procedures, and attempts to use alternative strategies when initial approaches fail (Zanthy, 2018; Hutauruk, 2019; Himawan & Noer, 2021). Teachers can implement learning strategies using non-routine problems and problem-based approaches to engage students' thinking and problem-solving skills (Indriani et al., 2024; Astuti et al., 2023; Rachman et al., 2023).

Students with moderate mathematical resilience demonstrate sufficient perseverance but still require guidance, as they may give up when unable to plan or apply appropriate procedures without trying alternative strategies. A gradual learning strategy can be applied, in which teachers begin with simple problems and gradually progress to more complex ones. Teachers model problem-solving steps using appropriate procedures, after which students observe and then work independently. In addition, students should be encouraged to engage in self-reflection to develop awareness of their thinking processes and strengthen motivation to learn.

Students with low mathematical resilience are typically characterized by a tendency to give up easily and experience frustration in learning mathematics. They also tend to lack motivation, perceiving mathematics as too difficult to engage with (Dahlan, 2019; Sari et al., 2023). In problem-solving situations, these students often give up early, especially when procedures do not immediately lead to correct results. Therefore, students with low mathematical resilience need support in both cognitive and affective aspects of learning mathematics. A positive attitude toward mathematics fosters optimism in problem solving, helping students persist even after initial failure (Rahmawati & Zhanty, 2019; Nuraeni et al., 2022).

In addition, it is necessary to identify and strengthen students' understanding of basic concepts, starting from simple material and gradually increasing in difficulty so that students experience small successes in learning mathematics. When students experience success, they gain positive learning experiences that increase motivation. This is consistent with Thorndike's Law of Effect, which states that behaviors followed by satisfaction are more likely to be repeated (Oktaria et al., 2023).

In addition to mathematical resilience, gender was also examined as a factor influencing procedural fluency. The results of this study indicate that gender does not significantly influence students' mathematical procedural fluency. Based on statistical analysis, the difference was not significant. This suggests that both male and female students can achieve high procedural fluency when they have high mathematical resilience. These results contrast with previous studies that reported gender-based differences in mathematical problem-solving ability.

Quantitative analysis shows that procedural fluency is more closely related to resilience, while gender does not have a significant effect. However, quantitative results alone cannot explain why this pattern occurs; therefore, qualitative analysis was conducted. Qualitative data from questionnaires, interviews, and test descriptions indicate consistent patterns. Students with high mathematical resilience, regardless of gender, were better able to overcome procedural difficulties. Questionnaire data showed that high resilience supported persistence in solving complex problems.

This was also confirmed by interview data, where students with high mathematical resilience stated, "*I will try other methods if I encounter difficulties in using a procedure*."

These students demonstrated confidence and persistence in applying procedures, as reflected in test results (Figure 3). although minor calculation errors occasionally occurred. In contrast, students with low mathematical resilience, regardless of gender, tend to give up easily when facing procedural difficulties. They reported that mathematics is difficult to understand and preferred to stop rather than try alternative strategies.

Analysis of students' test responses showed similar patterns. Students with high mathematical resilience tended to be more careful and systematic in applying problem-solving procedures. These findings were consistent across both male and female students. In addition, analysis of the resilience questionnaire showed that it measured students' willingness to learn mathematics, confidence in solving problems, and ability to recover after failure.

Interview results further revealed that mathematical resilience does not differ substantially based on gender. Both male and female students agreed that persistence and practice are important in overcoming mathematical difficulties. For example, M1 (a male student with high mathematical resilience) disagreed with the statement, "*When given difficult math problems, I immediately give up and feel unable to solve them.*" Similarly, F1 (a female student) agreed with the statement, "*When I use the wrong method in learning mathematics, I know how to adjust and relearn the correct method*."

In other cases, M2 and F2, students with low and moderate mathematical resilience, tended to give up easily and did not review their work when facing difficulties. M2 stated, "*I often make the same mistakes when experiencing difficulties in solving math problems*."

The questionnaire results suggest slight tendencies in behavior: male students appeared more enthusiastic in trying various strategies, while female students appeared more consistent and persistent. However, these differences were not significant. Both groups also reported experiencing frustration and a tendency to give up when facing difficult problems under certain conditions. This may explain why ANCOVA results showed no significant effect of gender on procedural fluency.

Although these findings differ from some previous studies, this does not imply the absence of gender differences in general, but rather highlights methodological considerations, particularly sample size. The lack of a significant gender effect is likely due to the relatively small sample, which may not have provided sufficient statistical power to detect differences. Therefore, generalizations should be made with caution (Alzoubi, 2024).

Overall, the findings suggest two interpretations: (1) based on ANCOVA and qualitative analysis, gender does not significantly influence students' mathematical procedural fluency;

and (2) the effect of gender may not have been fully detected due to sample limitations. Thus, these findings should be considered preliminary, and further research is needed.

Future studies are recommended to use larger and more representative samples to obtain more robust results and a clearer understanding of the relationship between gender, resilience, and procedural fluency.

CONCLUSION

Based on the ANCOVA results, mathematical resilience and gender together explain 42% of the variation in students' mathematical procedural fluency. However, this effect is primarily driven by mathematical resilience rather than gender. Qualitative findings, including questionnaires, interviews, and test analyses, show that both male and female students can demonstrate strong procedural fluency when they have high mathematical resilience. Although gender was not found to have a significant effect, this finding may be influenced by the relatively small sample size, which limited the ability to detect differences. Therefore, further research with larger samples is needed to obtain more accurate and generalizable results.

ACKNOWLEDGMENTS

The author would like to thank all participants for their support and contribution to this research.

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