Journal of Advanced Sciences and Mathematics Education
Volume 6, Issue 1, 252 - 263
e_ISSN: 2798-2351
DOI: 10.58524/jasme.v6i1.1120

Exploring the mediating roles of self-confidence and mathematical resilience in the relationship between problem-based learning and students' mathematical literacy

Muhamad Sukri Situmeang*
UIN Syarif Hidayatullah, INDONESIA

Ahmad Dimyati
UIN Syarif Hidayatullah, INDONESIA

Chasan Ma'ruf
STAI Publisistik Thawalib Jakarta, INDONESIA

Article Info

Article history:

Received: Jan 02, 2026
Revised: Feb 27, 2026
Accepted: March 15, 2026

Keywords:

Mathematical Literacy;
Mathematical Resilience;
Mediation Analysis;
Problem-Based Learning;
Self-Confidence.

Abstract

Background: Mathematical literacy is widely recognized as a key competence that enables students to interpret, analyze, and apply mathematical ideas in everyday contexts. Despite its importance, many students still experience difficulties developing this competence due to limited opportunities for meaningful problem solving and insufficient support for affective factors such as confidence and resilience.
Aims: This study aimed to investigate the mediating roles of self-confidence and mathematical resilience in the relationship between Problem-Based Learning (PBL) and students' mathematical literacy.
Method: A true experimental design with a posttest-only control group was employed. The participants consisted of students from four State Islamic Junior High Schools in Bogor Regency selected through multistage random sampling. The experimental group was taught using the PBL approach, while the control group received conventional instruction. Data were collected using a mathematical literacy test and questionnaires measuring students' self-confidence and mathematical resilience. The data were analyzed using independent samples t-tests, path analysis, and Sobel tests to examine both direct and indirect relationships among variables.
Results: The findings revealed that students exposed to PBL achieved significantly higher scores in mathematical literacy, self-confidence, and mathematical resilience than those in conventional classes ($p < 0.05$). Path analysis indicated that PBL had a direct positive effect on mathematical literacy, while both self-confidence and mathematical resilience acted as significant mediators.
Conclusion: These findings suggest that PBL can enhance students' mathematical literacy not only through instructional processes but also by strengthening important affective attributes in mathematics learning.

To cite this article: Situmeang, M, S., Dimyati, A., & Ma'ruf, C. (2026). Exploring the Mediating Roles of Self-Confidence and Mathematical Resilience in the Relationship Between Problem-Based Learning and Students' Mathematical Literacy. *Journal of Advanced Sciences and Mathematics Education, 6*(1), 252-263.

INTRODUCTION

Mathematical literacy has become an increasingly important competence in contemporary education (Bolstad, 2023; Manfreda Kolar & Hodnik, 2021). It does not merely refer to the ability to perform mathematical calculations but also encompasses the capacity to interpret, analyze, and apply mathematical ideas when dealing with real-life situations. Students who develop strong mathematical literacy are able to reason quantitatively, evaluate information critically, and use mathematical concepts to solve problems encountered in everyday life. The significance of mathematical literacy has been widely emphasized in international educational frameworks, particularly through large-scale assessments such as the Programme for International Student

*** Corresponding author:**
Situmeang, UIN Syarif Hidayatullah, Indonesia
msukri.situmeang@uinjkt.ac.id

Assessment (PISA) (Liu et al., 2024). These assessments highlight that students are expected to formulate, employ, and interpret mathematics when confronted with contextual problems. Consequently, strengthening students' mathematical literacy has become a central objective in mathematics education across many countries (Almarashdi & Jarrah, 2022).

Despite this growing emphasis, the development of mathematical literacy among students remains a challenge in many classrooms (Hwang & Ham, 2021). Mathematics instruction is frequently dominated by procedural teaching that focuses on memorizing formulas and solving routine exercises. Such instructional practices often provide limited opportunities for students to explore ideas, construct meaning, and engage in reasoning processes that are essential for developing mathematical literacy (Mukuka et al., 2023). In response to these challenges, educational researchers and practitioners have explored learning approaches that encourage active participation and meaningful problem solving (Marougkas et al., 2023; Mertler, 2021). One instructional approach that has gained considerable attention is Problem-Based Learning (PBL). This approach emphasizes the use of authentic problems as the starting point for learning activities, allowing students to investigate ideas collaboratively and construct knowledge through inquiry and discussion (Anchunda & Kaewurai, 2025).

However, learning outcomes in mathematics are not determined solely by instructional strategies. Students' affective characteristics also influence how they approach mathematical tasks and respond to challenges (Olivares et al., 2021). Among these characteristics, self-confidence and mathematical resilience are particularly relevant. Self-confidence reflects students' belief in their own abilities to understand and solve mathematical problems, while mathematical resilience refers to their capacity to persist and remain engaged when facing difficulties (Panaoura, 2025).

Problem-Based Learning has been widely recognized as a student-centered instructional approach that promotes active learning and higher-order thinking skills (Yu & Zin, 2023). In PBL environments, learning begins with complex and meaningful problems that require students to investigate, discuss, and develop possible solutions collaboratively. Through this process, students are encouraged to construct knowledge independently and apply mathematical concepts in meaningful contexts (Polman et al., 2021). Previous studies have reported that PBL can enhance students' engagement, conceptual understanding, and problem-solving ability in mathematics learning (Rehman et al., 2024). By engaging with authentic problems, students are given opportunities to explore different solution strategies and develop deeper reasoning skills. These learning experiences are considered essential for strengthening students' ability to interpret and apply mathematical knowledge in real-world situations. In addition to cognitive development, research in mathematics education has increasingly highlighted the role of affective factors (Koskinen & Pitkäniemi, 2022). Self-confidence, for instance, influences students' willingness to participate in learning activities and attempt challenging problems. Students who believe in their mathematical abilities are more likely to express ideas, engage in discussions, and persist in completing tasks. Another important affective attribute is mathematical resilience. Mathematical resilience refers to students' persistence and adaptability when encountering difficulties in mathematics learning (Aydın & Erdem, 2023). Students who demonstrate higher levels of resilience tend to perceive challenges as opportunities for learning rather than as obstacles. As a result, they are more likely to sustain effort and maintain engagement when solving complex mathematical problems. Taken together, these studies suggest that both cognitive and affective factors contribute to students' mathematical learning outcomes. Therefore, examining how instructional approaches interact with students' affective characteristics may provide a deeper understanding of the development of mathematical literacy.

Although numerous studies have examined the effectiveness of Problem-Based Learning in mathematics education, many of these studies primarily focus on its direct impact on cognitive outcomes, such as academic achievement or problem-solving ability (Aslan & Duruhan, 2021a). Research that specifically investigates how PBL contributes to the development of mathematical literacy remains relatively limited. Similarly, studies exploring affective factors in mathematics learning often examine variables such as self-confidence or resilience independently (Panaoura, 2025). While these investigations provide valuable insights into each variable, they rarely analyze how multiple affective attributes interact simultaneously within a single explanatory framework. Furthermore, empirical studies that explore the mediating roles of both self-confidence and mathematical resilience in the relationship between instructional approaches and mathematical literacy are still scarce (Akkan & Horzum, 2024). Without examining these mediating mechanisms, the processes through which instructional strategies influence students' literacy development may not be fully understood.

Considering the interconnected roles of cognitive and affective factors in mathematics learning, it is important to examine how instructional approaches influence students' mathematical literacy through multiple pathways. Problem-Based Learning offers a learning environment in which students actively engage with authentic problems, collaborate with peers, and construct mathematical understanding through inquiry and reflection. Within such learning contexts, students may gradually develop stronger confidence in their mathematical abilities and greater resilience when facing challenging problems (Qi, 2025). These affective developments may serve as important mechanisms that support students' ability to interpret, analyze, and apply mathematical concepts effectively (Guo et al., 2025; Schukajlow et al., 2023).

Based on the issues and research gaps described above, this study aims to explore the mediating roles of self-confidence and mathematical resilience in the relationship between Problem-Based Learning and students' mathematical literacy. The study examines whether the implementation of Problem-Based Learning contributes to the improvement of students' mathematical literacy and analyzes how this relationship is influenced by the development of students' affective characteristics. In particular, the research investigates the extent to which Problem-Based Learning influences students' self-confidence and mathematical resilience and further examines whether these two affective factors function as mediating mechanisms that help explain how instructional strategies affect students' mathematical literacy.

METHOD

Research Design

This study employed a true experimental design using a posttest-only control group design. The design involved two groups of students: an experimental group that received instruction using the Problem-Based Learning (PBL) model and a control group that received conventional mathematics instruction. The purpose of using this design was to examine the effect of the learning model on students' mathematical literacy after the instructional treatment. In this design, the experimental group was taught using the Problem-Based Learning approach, while the control group followed conventional learning practices commonly implemented in mathematics classrooms. After the instructional treatment was completed, both groups were given a posttest to measure their mathematical literacy.

Participants

The participants of this study were students from four State Islamic Junior High Schools (MTsN) in Bogor Regency. The sample was selected using a multistage random sampling technique to ensure that the selected classes represented the accessible population. From each school, two classes were selected to represent the experimental and control groups. Each class consisted of 32 students, resulting in a total of 128 students in the experimental group and 128 students in the

control group. All participants were Grade IX students who had previously studied the mathematics topics related to the learning materials used in this study.
The distribution of participants across the schools is presented in Table 1.

Table 1. Research Sample Data of MTs Students in Bogor Regency

No	School Name	Experimental Class	Total	Control Class	Total	Region
1	MTsN 1 Bogor	IX/2	32	IX/4	32	East Bogor
2	MTsN 2 Bogor	IX/3	32	IX/1	32	West Bogor
3	MTsN 3 Bogor	IX/5	32	IX/2	32	Middle Bogor
4	MTsN 4 Bogor	IX/1	32	IX/6	32	North Bogor

Research Procedure

The study began with the selection of participating schools and classes using multistage random sampling. The selected classes were then assigned as experimental and control groups. The experimental classes received mathematics instruction using the Problem-Based Learning model, while the control classes followed conventional teaching approaches. During the learning process, students in the experimental group were encouraged to work collaboratively in solving contextual mathematical problems. The learning activities emphasized discussion, exploration of ideas, and the development of problem-solving strategies. In contrast, the control group received teacher-centered instruction focusing on explanations and routine exercises.

After the completion of the learning treatment, students in both groups were administered a posttest to measure their mathematical literacy ability. In addition, questionnaires were distributed to assess students' self-confidence and mathematical resilience during mathematics learning. The conceptual relationships among the research variables are illustrated in Figure 2.

Problem-Based Learning (X1) → Self-Confidence (X2)
Problem-Based Learning (X1) → Mathematical Resilience (X3)
Problem-Based Learning (X1) → Mathematical Literacy (Y)
Self-Confidence (X2) → Mathematical Literacy (Y)
Mathematical Resilience (X3) → Mathematical Literacy (Y)

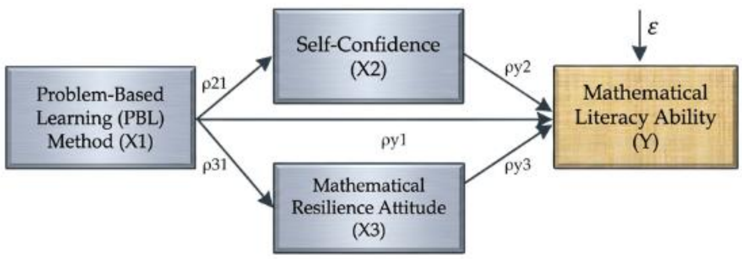

Figure 2. Research Model

Instruments

Several instruments were used to collect the data in this study. Mathematical literacy was measured using a written test developed based on indicators derived from the PISA mathematical literacy framework. The test assessed students' ability to interpret problems, apply mathematical concepts, and reason in contextual situations. Students' self-confidence was measured using a Likert-scale questionnaire that examined students' beliefs regarding their ability to understand and solve mathematical problems. Similarly, mathematical resilience was measured using a questionnaire designed to capture students' persistence and attitudes when encountering mathematical challenges. An observation sheet was also used to document the implementation of the Problem-Based Learning model during classroom instruction. A summary of the instruments used in this study is presented in Table 2.

Table 2. Data Summary (Narrative Table)

Variable	Data Type	Instrument
PBL Learning Method	Perception / Treatment Score	Questionnaire / Observation
Self-Confidence	Likert Score	Questionnaire
Mathematical Resilience Attitude	Likert Score	Questionnaire
Mathematical Literacy Ability	Test Score	Written Test

Data Analysis

The collected data were analyzed using several statistical techniques. Prior to hypothesis testing, prerequisite analyses were conducted to ensure that the data met the assumptions required for parametric statistical tests. These analyses included normality tests and homogeneity tests. After the assumptions were satisfied, an independent samples t-test was conducted to examine whether there were significant differences between the experimental and control groups in terms of mathematical literacy, self-confidence, and mathematical resilience. To further investigate the relationships among the research variables, path analysis was employed to analyze the direct and indirect effects of Problem-Based Learning on students' mathematical literacy. In addition, the Sobel test was used to examine whether self-confidence and mathematical resilience functioned as mediating variables in the relationship between Problem-Based Learning and mathematical literacy.

RESULTS AND DISCUSSION

Results

Assumption Testing

Before examining the relationships among the variables, several preliminary statistical tests were conducted to ensure that the data met the assumptions required for parametric analysis. These tests included the normality test and the homogeneity of variance test. Verifying these assumptions is important because the validity of subsequent statistical procedures depends on whether the data distribution meets the required criteria.

The distribution of the data was first evaluated using the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. The results of these analyses are presented in Table 3.

Table 3. Tests of Normality (Kolmogorov–Smirnov and Shapiro–Wilk)

	Factor	Kolmogorov-Smirnova	Shapiro-Wil				
		Statistic	df	Sig.	Statistic	df	Sig.
Mathematical Literacy	Experimental	.068	128	.200*	.990	128	.485
	Control	.047	128	.200*	.994	128	.859
Self-Confidence	Experimental	.063	128	.200*	.988	128	.325
	Control	.052	128	.200*	.995	128	.911
Mathematical Resilience Attitude	Experimental	.047	128	.200*	.988	128	.319
	Control	.060	128	.200*	.987	128	.284

As shown in Table 3, all variables demonstrate significance values greater than the commonly used threshold of 0.05. The Kolmogorov–Smirnov test produced significance values of 0.200, while the Shapiro–Wilk test also indicated significance values above 0.05 for all measured variables. These findings indicate that the distributions of mathematical literacy ability, self-confidence, and mathematical resilience can be considered normal in both the experimental and control groups.

Following the normality test, a homogeneity of variance test was conducted using Levene's Test. The analysis yielded significance values of 0.632 for mathematical literacy, 0.733 for self-confidence, and 0.170 for mathematical resilience. Since all values exceed 0.05, the assumption of equal variance between groups is satisfied. With both normality and homogeneity assumptions fulfilled, the data were considered appropriate for further parametric analysis.

Differences Between Experimental and Control Groups

After confirming that the data satisfied the required assumptions, an independent samples t-test was conducted to examine whether differences existed between the experimental and control groups. The results of this analysis are summarized in Table 4.

Table 4. Independent Samples t-Test Results

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
Mathematical Literacy	Equal variances assumed	.229	.632	3.772	254	<.001	<.001	3.703	.982	1.770	5.636
	Equal variances not assumed			3.772	253.992	<.001	<.001	3.703	.982	1.770	5.636
Self-Confidence	Equal variances assumed	.117	.733	2.796	254	.003	.006	3.680	1.316	1.088	6.272
	Equal variances not assumed			2.796	253.755	.003	.006	3.680	1.316	1.088	6.272
Mathematical Resilience Attitude	Equal variances assumed	1.894	.170	8.588	254	<.001	<.001	14.602	1.700	11.253	17.950
	Equal variances not assumed			8.588	249.789	<.001	<.001	14.602	1.700	11.253	17.950

The results reveal statistically significant differences between the two groups for all variables examined in this study. In terms of mathematical literacy ability, the significance value obtained was $p < 0.001$, indicating that the difference between groups was statistically meaningful. The calculated t-value ($t = 3.772$) exceeded the critical value ($t = 1.969$), suggesting that students who participated in the Problem-Based Learning environment achieved higher mathematical literacy scores than those who experienced conventional instruction.

A similar pattern was observed for self-confidence. The analysis yielded a significance value of $p = 0.006$, which is below the 0.05 significance level. The calculated t-value ($t = 2.796$) also exceeded the critical value, indicating that students in the experimental group demonstrated higher confidence in their mathematical abilities compared with students in the control group.

For mathematical resilience, the difference between the two groups was even more pronounced. The analysis produced a significance value of $p < 0.001$, with a calculated t-value of 8.588, which is substantially greater than the critical value. This finding indicates that students exposed to Problem-Based Learning exhibited stronger persistence and adaptability when facing mathematical challenges.

Taken together, these results suggest that the implementation of the Problem-Based Learning model contributes positively to students' cognitive and affective development, particularly in relation to mathematical literacy, confidence, and resilience.

Correlation Analysis

To explore how the variables in this study relate to one another, a correlation analysis was performed. The correlation coefficients are presented in Table 5.

Table 5. Correlation Matrix of Research Variables

		Mathematical Literacy	PBL Method	Self-Confidence	Mathematical Resilience Attitude
Mathematical Literacy	Pearson Correlation	1	.423**	.388**	.372**
	Sig. (2-tailed)		<.001	<.001	<.001
	N	128	128	128	128
PBL Method	Pearson Correlation	.423**	1	.196*	.449**
	Sig. (2-tailed)	<.001		.026	<.001
	N	128	129	129	128
Self-Confidence	Pearson Correlation	.388**	.196*	1	.150
	Sig. (2-tailed)	<.001	.026		.090
	N	128	129	129	128
Mathematical Resilience Attitude	Pearson Correlation	.372**	.449**	.150	1
	Sig. (2-tailed)	<.001	<.001	.090	
	N	128	128	128	128

The results indicate that mathematical literacy ability is positively associated with several variables examined in this study. Specifically, mathematical literacy shows a moderate correlation with the Problem-Based Learning method ($r = 0.423$, $p < 0.001$), as well as with self-confidence ($r = 0.388$, $p < 0.001$) and mathematical resilience ($r = 0.372$, $p < 0.001$). These findings suggest that students who demonstrate stronger affective characteristics tend to perform better in mathematical literacy tasks.

The analysis also indicates that the implementation of Problem-Based Learning is positively related to both self-confidence ($r = 0.196$, $p = 0.026$) and mathematical resilience ($r = 0.449$, $p < 0.001$). This relationship suggests that learning environments that emphasize problem-solving and collaborative exploration may help foster positive attitudes and persistence in mathematics learning.

However, the relationship between self-confidence and mathematical resilience was not found to be statistically significant ($r = 0.150$, $p = 0.090$). This result indicates that although both variables contribute to students' mathematical literacy, they may represent different psychological dimensions within the learning process.

Path Analysis

To examine the direct and indirect relationships among the variables, a path analysis was conducted. The structural relationships investigated in this study are illustrated in Figure 2.

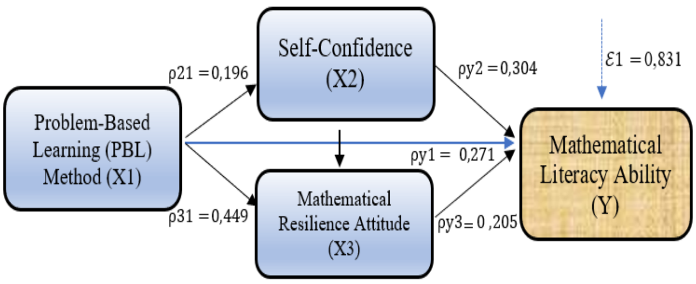

Figure 2. Research Model (Path Diagram)

The results of the path analysis are presented in Table 6.

Table 6. Path Model of Sub-Structure 1

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	21.348	7.266		2.938	.004
	PBL Method	.144	.045	.271	3.211	.002
	Self-Confidence	.179	.045	.304	3.983	<.001
	Mathematical Resilience Attitude	.127	.052	.205	2.448	.016

a. Dependent Variable: Mathematical Literacy Ability

The analysis indicates that the Problem-Based Learning method has a positive and statistically significant effect on students' mathematical literacy ability (β = 0.271, p = 0.002). This result suggests that students who participate in learning environments centered on problem solving and exploration tend to demonstrate stronger mathematical literacy skills.

Among the predictor variables included in the model, self-confidence shows the strongest contribution to mathematical literacy (β = 0.304, $p < 0.001$). This finding highlights the importance of students' belief in their mathematical capabilities when engaging with complex problem-solving tasks.

Mathematical resilience also demonstrates a significant influence on mathematical literacy (β = 0.205, p = 0.016), indicating that students who are able to persist and remain engaged when encountering difficulties tend to achieve better literacy outcomes.

The coefficient of determination obtained from the model (R^2 = 0.309) indicates that approximately 30.9% of the variance in students' mathematical literacy ability can be explained by the combined influence of Problem-Based Learning, self-confidence, and mathematical resilience.

Mediation Analysis

To further investigate whether self-confidence and mathematical resilience function as mediating variables, a Sobel test was conducted. The results of this analysis are presented in Table 7.

Table 7. Sobel Test Results

No.	Indirect Effect	Z_{hitung}	Z_{tabel}	Decision	Conclusion
1.	PBL Learning (X1) on Mathematical Literacy Ability (Y) via Self-Confidence (X2)	2,048	1,966	H_0 rejected H_1 accepted	Proven to mediate
2.	PBL Learning (X1) on Mathematical Literacy Ability (Y) via Mathematical Resilience (X3)	3,530	1,966	H_0 rejected H_1 accepted	Proven to mediate

The Sobel test results indicate that both indirect pathways are statistically significant. The calculated Z-values (2.048 and 3.530) exceed the critical value of 1.966, confirming the presence of significant mediation effects.

These findings indicate that the influence of Problem-Based Learning on mathematical literacy is not limited to a direct instructional effect. Instead, part of this influence occurs through the development of students' self-confidence and mathematical resilience. In other words, learning environments that encourage problem exploration and collaborative discussion may strengthen students' affective characteristics, which in turn support the development of their mathematical literacy.

Discussion

The present study was conducted to explore the relationship between Problem-Based Learning, self-confidence, mathematical resilience, and students' mathematical literacy. The findings indicate that the implementation of Problem-Based Learning contributes positively to students' mathematical literacy ability. Students who participated in learning environments structured around contextual problems and collaborative exploration demonstrated significantly higher literacy scores than those who experienced conventional instruction. This result suggests that instructional approaches emphasizing active engagement and problem-solving processes can support students in developing a deeper understanding of mathematical concepts Bahar et al. (2021) and may contribute to the improvement of mathematical literacy in classroom learning.

One possible explanation for this finding lies in the nature of Problem-Based Learning itself (Ssemugenyi, 2023). In PBL environments, students are encouraged to explore problems, formulate ideas, and construct solutions through discussion and reflection. These learning processes allow students to engage with mathematical concepts in meaningful contexts rather than simply memorizing procedures. As a result, students are more likely to develop the ability to interpret mathematical information, apply reasoning, and make connections between mathematical ideas and real-life situations (Mahmud & Mohd Drus, 2023). Such experiences are closely aligned with the core components of mathematical literacy.

The findings of this study also reveal that Problem-Based Learning has a positive influence on students' self-confidence. Students who participated in problem-based activities demonstrated higher levels of confidence in their ability to understand and solve mathematical problems. This result may be attributed to the learning environment created by PBL, where students are encouraged to express ideas, discuss different solution strategies, and actively participate in the learning process (Aslan & Duruhan, 2021). When students are given opportunities to contribute and see that their ideas are valued, their belief in their mathematical capabilities tends to grow (Hiğde & Aktamış, 2022). In addition to self-confidence, the results indicate that Problem-Based Learning also contributes to the development of students' mathematical resilience. Students exposed to PBL demonstrated stronger persistence when dealing with challenging mathematical tasks. This finding is consistent with the idea that learning environments emphasizing inquiry and collaboration can help students develop adaptive attitudes toward difficulties (Niemi, 2021). Rather than avoiding challenging problems, students in such environments may learn to view difficulties as part of the learning process.

Another important finding of this study concerns the mediating roles of self-confidence and mathematical resilience in the relationship between Problem-Based Learning and mathematical literacy. The mediation analysis indicates that the influence of PBL on mathematical literacy is not limited to direct instructional effects. Instead, part of this influence operates indirectly through students' affective characteristics (Butakor et al., 2021). In other words, when students develop stronger confidence in their mathematical abilities and greater resilience in facing difficulties, they become better equipped to engage with mathematical tasks that require interpretation, reasoning, and problem solving.

These findings highlight the importance of considering both cognitive and affective dimensions in mathematics learning. While instructional strategies such as Problem-Based Learning can provide meaningful learning experiences, the development of positive affective attributes plays an equally important role in supporting students' mathematical performance. Students who believe in their abilities and remain persistent when encountering challenges are more likely to actively engage in mathematical reasoning processes (Barnes, 2021).

From a pedagogical perspective, the results of this study suggest that mathematics instruction should not focus solely on procedural knowledge (Kacmaz & Dubé, 2022). Instead, learning environments should be designed to encourage exploration, discussion, and reflection. Problem-Based Learning offers one possible approach for achieving this goal because it provides opportunities for students to interact with mathematical ideas in authentic and meaningful ways. At the same time, such environments may help foster students' confidence and resilience, which ultimately support the development of mathematical literacy.

Overall, the findings of this study reinforce the view that effective mathematics learning involves the interaction between instructional practices and students' affective characteristics (Zhu & Kaiser, 2022). By integrating problem-based instructional strategies with efforts to cultivate students' confidence and resilience, educators may be able to create learning experiences that better support the development of mathematical literacy.

Implications

The findings of this study provide several important implications for mathematics learning. The positive influence of Problem-Based Learning on students' mathematical literacy indicates that learning environments which emphasize problem exploration, discussion, and collaborative reasoning can support deeper mathematical understanding. Through engagement with contextual problems, students are not only encouraged to apply mathematical concepts but also to interpret information and develop reasoning skills. At the same time, the results of this study show that affective factors such as self-confidence and mathematical resilience play a meaningful role in supporting students' learning processes. When students feel confident in their abilities and are able to persist when encountering difficulties, they are more likely to engage actively with mathematical tasks. Therefore, mathematics instruction should not only focus on conceptual understanding but should also create learning environments that support the development of positive learning attitudes and persistence in solving problems.

Limitations

Despite the contributions of this study, several limitations should be acknowledged. First, the study was conducted within a limited educational context involving students from several State Islamic Junior High Schools in one region. As a result, the findings may not fully represent students from different educational settings or grade levels. Second, the research relied primarily on quantitative data obtained through tests and questionnaires. Although these instruments provide useful information about students' performance and perceptions, they may not fully capture the complexity of students' learning experiences during the implementation of Problem-Based Learning. Future studies may benefit from incorporating qualitative data, such as classroom observations or interviews, to gain a deeper understanding of how students develop confidence and resilience during mathematics learning.

Suggestions

Based on the findings and limitations of this study, several suggestions can be proposed for future research. Further studies may consider examining the implementation of Problem-Based Learning in different educational contexts and with larger or more diverse samples to obtain a broader understanding of its impact on students' mathematical literacy. In addition, future research may explore other affective variables that could influence students' engagement in mathematics learning, such as motivation, self-efficacy, or learning anxiety. Investigating these variables may provide a more comprehensive picture of how instructional strategies interact with students' psychological characteristics in supporting the development of mathematical literacy.

CONCLUSION

This study examined the relationship between Problem-Based Learning, self-confidence, mathematical resilience, and students' mathematical literacy. The findings indicate that students who participated in learning activities based on Problem-Based Learning demonstrated higher levels of mathematical literacy compared with those who experienced conventional instruction. Learning environments that encourage students to engage with contextual problems, discuss ideas collaboratively, and explore different solution strategies appear to support a deeper understanding of mathematical concepts. In addition to its direct influence on mathematical literacy, the implementation of Problem-Based Learning was also associated with the development of students' self-confidence and mathematical resilience. Students who develop stronger confidence in their mathematical abilities and show persistence when facing challenging tasks tend to engage more actively in reasoning and problem-solving processes. Furthermore, the mediation analysis suggests that the relationship between Problem-Based Learning and mathematical literacy is partly explained by these affective characteristics, indicating that improvements in mathematical literacy are not solely the result of instructional activities but are also related to students' confidence and resilience in learning mathematics. Overall, these findings highlight the importance of creating learning environments that integrate meaningful problem exploration with the development of positive learning attitudes, as such conditions may provide more effective support for the growth of students' mathematical literacy.

AKNOWLEDGMENT

The authors would like to express their sincere appreciation to the schools and students who participated in this study for their cooperation and willingness to be involved in the research process. The authors also extend their gratitude to the teachers and school administrators who supported the implementation of the learning activities during the data collection stage. Their assistance and openness made it possible to conduct this research in a constructive learning environment. Finally, the authors acknowledge all individuals who contributed valuable support and feedback throughout the completion of this study.

AUTHOR CONTRIBUTIONS STATEMENT

The author was responsible for the entire research process, including the conceptualization of the study, research design, data collection, data analysis, interpretation of the findings, and manuscript preparation. The author also conducted the literature review, developed the research instruments, and revised the manuscript prior to submission.

REFERENCES

Akkan, S. N., & Horzum, T. (2024). Illuminating the Landscape of Mathematical Resilience: A Systematic Review. *Journal of Pedagogical Research*, *8*(1), 312–338.

Almarashdi, H. S., & Jarrah, A. M. (2022). The Impact of a Proposed Mathematics Enrichment Program on UAE Students' Mathematical Literacy Based on the PISA Framework. *Sustainability*, *14*(18). https://doi.org/10.3390/su141811259

Anchunda, H. Y., & Kaewurai, W. (2025). An instructional model development based on inquiry-based and problem-based approaches to enhance prospective teachers' teamwork and collaborative problem-solving competence. *Social Sciences & Humanities Open*, *11*, 101480. https://doi.org/10.1016/j.ssaho.2025.101480

Aslan, S. A., & Duruhan, K. (2021a). The effect of virtual learning environments designed according to problem-based learning approach to students' success, problem-solving skills, and motivations. *Education and Information Technologies*, *26*(2), 2253–2283. https://doi.org/10.1007/s10639-020-10354-6

Aslan, S. A., & Duruhan, K. (2021b). The effect of virtual learning environments designed according to problem-based learning approach to students' success, problem-solving skills, and motivations. *Education and Information Technologies*, *26*(2), 2253–2283. https://doi.org/10.1007/s10639-020-10354-6

Aydın, M., & Erdem, C. (2023). Profiles of academically resilient students: An examination on TIMSS mathematics data. *Current Psychology*, *42*(22), 18916–18927. https://doi.org/10.1007/s12144-022-03055-5

Bahar, A. K., Maker, C. J., & Scherbakova, A. (2021). The role of teachers' implementation of the Real Engagement in Active Problem Solving (REAPS) model in developing creative problem solving in mathematics. *Australasian Journal of Gifted Education*, *30*(2), 26–39. https://doi.org/10.3316/informit.134990209201977

Barnes, A. (2021). Enjoyment in learning mathematics: Its role as a potential barrier to children's perseverance in mathematical reasoning. *Educational Studies in Mathematics*, *106*(1), 45–63. https://doi.org/10.1007/s10649-020-09992-x

Bolstad, O. H. (2023). Lower secondary students' encounters with mathematical literacy. *Mathematics Education Research Journal*, *35*(1), 237–253. https://doi.org/10.1007/s13394-021-00386-7

Butakor, P. K., Guo, Q., & Adebanji, A. O. (2021). Using structural equation modeling to examine the relationship between Ghanaian teachers' emotional intelligence, job satisfaction, professional identity, and work engagement. *Psychology in the Schools*, *58*(3), 534–552. https://doi.org/10.1002/pits.22462

Guo, W., Wang, J., Li, N., & Wang, L. (2025). The impact of teacher emotional support on learning engagement among college students mediated by academic self-efficacy and academic resilience. *Scientific Reports*, *15*(1), 3670. https://doi.org/10.1038/s41598-025-88187-x

Hiğde, E., & Aktamış, H. (2022). The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views. *Thinking Skills and Creativity*, *43*, 101000. https://doi.org/10.1016/j.tsc.2022.101000

Hwang, J., & Ham, Y. (2021). Relationship between Mathematical Literacy and Opportunity to Learn with Different Types of Mathematical Tasks. *Journal on Mathematics Education*, *12*(2), 199–222.

Kacmaz, G., & Dubé, A. K. (2022). Examining pedagogical approaches and types of mathematics knowledge in educational games: A meta-analysis and critical review. *Educational Research Review*, *35*, 100428. https://doi.org/10.1016/j.edurev.2021.100428

Koskinen, R., & Pitkäniemi, H. (2022). Meaningful Learning in Mathematics: A Research Synthesis of Teaching Approaches. *International Electronic Journal of Mathematics Education*, *17*(2). https://doi.org/10.29333/iejme/11715

Liu, X., Hansen, K. Y., Valcke, M., & De Neve, J. (2024). A decade of PISA: Student perceived instructional quality and mathematics achievement across European countries. *ZDM – Mathematics Education*, *56*(5), 859–891. https://doi.org/10.1007/s11858-024-01630-7

Mahmud, M. S., & Mohd Drus, N. F. (2023). The use of oral questioning to improve students' reasoning skills in primary school mathematics learning. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1126816

Manfreda Kolar, V., & Hodnik, T. (2021). Mathematical Literacy from the Perspective of Solving Contextual Problems. *European Journal of Educational Research*, *10*(1), 467–483.

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13). https://doi.org/10.3390/electronics12132832

Mertler, C. A. (2021). Action Research as Teacher Inquiry: A Viable Strategy for Resolving Problems of Practice. *Practical Assessment, Research & Evaluation*, *26*. https://eric.ed.gov/?id=EJ1314304

Mukuka, A., Balimuttajjo, S., & Mutarutinya, V. (2023). Teacher efforts towards the development of students' mathematical reasoning skills. *Heliyon*, *9*(4). https://doi.org/10.1016/j.heliyon.2023.e14789

Niemi, K. (2021). 'The best guess for the future?' Teachers' adaptation to open and flexible learning environments in Finland. *Education Inquiry*, *12*(3), 282–300. https://doi.org/10.1080/20004508.2020.1816371

Olivares, D., Lupiáñez, J. L., & Segovia, I. (2021). Roles and characteristics of problem solving in the mathematics curriculum: A review. *International Journal of Mathematical Education in Science and Technology*, *52*(7), 1079–1096. https://doi.org/10.1080/0020739X.2020.1738579

Panaoura, R. (2025a). Sustainable Learning Practices in Engineering Mathematics: Building Self-Regulation and Resilience. *Sustainability*, *17*(22). https://doi.org/10.3390/su172210137

Panaoura, R. (2025b). Sustainable Learning Practices in Engineering Mathematics: Building Self-Regulation and Resilience. *Sustainability*, *17*(22). https://doi.org/10.3390/su172210137

Polman, J., Hornstra, L., & Volman, M. (2021). The meaning of meaningful learning in mathematics in upper-primary education. *Learning Environments Research*, *24*(3), 469–486. https://doi.org/10.1007/s10984-020-09337-8

Qi, C. (2025). The impact of adolescent innovation on academic resilience, distance learning self-efficacy, and academic performance. *Scientific Reports*, *15*(1), 12396. https://doi.org/10.1038/s41598-025-91542-7

Rehman, N., Huang, X., Mahmood, A., AlGerafi, M. A. M., & Javed, S. (2024). Project-based learning as a catalyst for 21st-Century skills and student engagement in the math classroom. *Heliyon*, *10*(23). https://doi.org/10.1016/j.heliyon.2024.e39988

Schukajlow, S., Rakoczy, K., & Pekrun, R. (2023). Emotions and motivation in mathematics education: Where we are today and where we need to go. *ZDM – Mathematics Education*, *55*(2), 249–267. https://doi.org/10.1007/s11858-022-01463-2

Ssemugenyi, F. (2023). Teaching and learning methods compared: A pedagogical evaluation of problem-based learning (PBL) and lecture methods in developing learners' cognitive abilities. *Cogent Education*, *10*(1), 2187943. https://doi.org/10.1080/2331186X.2023.2187943

Yu, L., & Zin, Z. M. (2023). The critical thinking-oriented adaptations of problem-based learning models: A systematic review. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1139987

Zhu, Y., & Kaiser, G. (2022). Impacts of classroom teaching practices on students' mathematics learning interest, mathematics self-efficacy and mathematics test achievements: A secondary analysis of Shanghai data from the international video study Global Teaching InSights. *ZDM – Mathematics Education*, *54*(3), 581–593. https://doi.org/10.1007/s11858-022-01343-9