

The Effect of PISA-Based Mathematical Literacy on Students' Mathematical Problem-Solving Ability in Terms of Prior Mathematical Knowledge

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Abstract

This study aims to examine the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability in terms of prior mathematical knowledge. This research employed a quantitative approach with a correlational design. The sample consisted of 60 students enrolled in a Basic Statistics course in the Actuarial Science study program at Universitas Negeri Makassar. The data were collected through tests of mathematical literacy, problem-solving ability, and prior mathematical knowledge. Data were analyzed using multiple regression with an interaction term.

The results show that PISA-based mathematical literacy has a significant positive effect on students' problem-solving ability ($\beta = 0.528$; Sig. = $0.000 < 0.05$). Prior mathematical knowledge also has a significant effect ($\beta = 0.347$; Sig. = $0.000 < 0.05$). Furthermore, there is a significant interaction between mathematical literacy and prior knowledge ($\beta = 0.015$; Sig. = $0.015 < 0.05$), indicating that the effect of mathematical literacy is stronger among students with higher prior knowledge.

These findings suggest that integrating PISA-based tasks and considering students' prior knowledge are essential for improving mathematical problem-solving ability.

Keywords: mathematical literacy, problem-solving ability, prior knowledge, PISA, mathematics education

INTRODUCTION

Mathematical problem-solving ability is widely recognized as a central component of mathematics learning, as it reflects an individual's capacity to interpret situations, formulate mathematical representations, and construct logically coherent solutions. Beyond procedural



proficiency, problem solving involves higher-order cognitive processes such as reasoning, modelling, and evaluation. However, a growing body of evidence indicates that students' problem-solving performance remains inadequate, particularly when they are confronted with non-routine and context-based tasks (OECD, 2023; Schoenfeld, 2022; English, 2022). Recent large-scale assessments and empirical studies reveal that many learners struggle to translate real-world situations into mathematical models and to justify their solutions meaningfully (Geiger et al., 2022; Kaiser & Brand, 2022). This condition suggests that mathematics instruction has not yet fully succeeded in fostering meaningful and transferable problem-solving competencies.

In this regard, mathematical literacy has emerged as a key construct in contemporary mathematics education. Within the Programme for International Student Assessment (PISA) framework, mathematical literacy is defined as an individual's ability to formulate, employ, and interpret mathematics in a variety of real-world contexts (OECD, 2023; OECD, 2021). This perspective extends beyond traditional views of mathematics learning by emphasizing the application of knowledge in authentic situations. Several recent studies have demonstrated that students' difficulties in solving contextual problems are closely related to their limited mathematical literacy skills (Almarashdi & Jarrah, 2023; Utama et al., 2024; Vos, 2021). Furthermore, variations in mathematical literacy levels significantly influence students' performance in PISA-like tasks, particularly those requiring modelling and reasoning (Alreshidi & Alreshidi, 2025; Jablonka, 2021).

The relationship between mathematical literacy and problem-solving ability has been consistently highlighted in the literature. Students with higher levels of mathematical literacy tend to demonstrate stronger abilities in identifying relevant information, selecting appropriate strategies, and evaluating solutions critically (Geiger et al., 2022; Putri et al., 2024). Moreover, the use of PISA-based tasks has been shown to promote deeper engagement in mathematical thinking and enhance problem-solving performance (Mashuri & Jahring, 2024; Rahima et al., 2025). From a theoretical perspective, this relationship can be understood through the alignment between the processes of mathematical literacy—formulate, employ, and interpret—and the stages of problem solving, which involve understanding the problem, devising a plan, executing the solution, and reflecting on the results (Niss & Højgaard, 2021; Schoenfeld, 2022). Consequently, mathematical literacy can be viewed as a foundational component that supports effective problem-solving processes.

In addition to mathematical literacy, prior mathematical knowledge plays a crucial role in shaping students' problem-solving performance. Prior knowledge represents learners'





cognitive readiness and serves as the foundation for constructing new understanding. Students with well-developed prior knowledge are more likely to establish meaningful connections between concepts and apply appropriate strategies when solving problems. In contrast, those with limited prior knowledge often encounter difficulties in interpreting problem situations and selecting suitable solution methods (Rittle-Johnson et al., 2021; Andini & Siregar, 2024). Empirical evidence also suggests that prior knowledge influences how students engage with complex and context-based tasks, including those found in PISA assessments (Lestari et al., 2021; Darling-Hammond et al., 2021). Therefore, examining problem-solving ability without considering prior knowledge may lead to an incomplete understanding of students' performance.

Despite the increasing number of studies on mathematical literacy and problem solving, several gaps remain in the existing literature. First, most previous studies have primarily focused on the direct relationship between mathematical literacy and problem-solving ability, with limited attention to the role of prior knowledge as an influential factor in this relationship. Second, a considerable number of studies still rely on routine or decontextualized tasks, which do not fully capture the characteristics of PISA-based problems that emphasize authenticity, complexity, and real-world relevance (Utama et al., 2024; Mashuri & Jahring, 2024; Kaiser & Brand, 2022). Third, research conducted at the tertiary level remains relatively scarce, particularly studies that integrate mathematical literacy, problem-solving ability, and prior knowledge within a single analytical framework (Geiger et al., 2022; English, 2022). These limitations highlight the need for more comprehensive investigations that address these interconnected aspects.

The present study seeks to address these gaps by examining the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability while considering differences in prior mathematical knowledge. The novelty of this study lies in the integration of these three constructs within a quantitative framework, supported by the use of PISA-oriented instruments that reflect authentic and context-rich problem situations. By adopting this approach, the study provides a more realistic representation of students' mathematical competencies and contributes to the growing body of research on literacy-oriented mathematics education.

Accordingly, the objectives of this study are to analyze the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability, to describe students' problem-solving performance based on their levels of prior mathematical knowledge, and to examine differences in the effect of mathematical literacy on problem-solving ability across





varying levels of prior knowledge. The findings are expected to offer meaningful insights for the development of mathematics instruction that is more contextual, cognitively demanding, and aligned with contemporary assessment frameworks.

METHOD

This study employed a quantitative approach with an explanatory research design aimed at examining the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability in terms of prior mathematical knowledge. The selection of this design was grounded in the objective of identifying predictive relationships among variables as well as exploring how such relationships may vary across different levels of prior knowledge. The study adopted a cross-sectional framework, in which all data were collected at a single point in time to capture students' current cognitive performance in relation to the measured constructs.

The participants of this study consisted of 60 undergraduate students enrolled in the Basic Statistics course in the Actuarial Science study program at Universitas Negeri Makassar during the even semester of the 2025/2026 academic year. A purposive sampling technique was applied, whereby all students who met the inclusion criteria were selected as research participants. These criteria included prior completion of prerequisite mathematical courses that are relevant to the constructs being measured, particularly those related to algebraic reasoning and basic mathematical concepts. The selection of this group was considered appropriate, as students in actuarial science are expected to possess and apply mathematical reasoning skills in solving complex and contextual problems.

To facilitate a more nuanced analysis, students' prior mathematical knowledge was assessed and subsequently used to classify participants into three categories: high, moderate, and low. This classification was determined based on the distribution of scores obtained from the prior knowledge test using percentile-based grouping. Such categorization enabled the examination of differences in problem-solving performance across varying levels of cognitive readiness, thereby providing a deeper understanding of how prior knowledge influences the relationship between mathematical literacy and problem-solving ability.

Data were collected using three main instruments, each designed to measure a specific construct within the study. The first instrument was a PISA-based mathematical literacy test, which was developed in alignment with the framework proposed by the Organisation for Economic Co-operation and Development. This framework emphasizes three fundamental processes: formulating real-world problems into mathematical representations, employing appropriate mathematical procedures and reasoning, and interpreting the results within the





given context. Accordingly, the test items were constructed using contextual and authentic scenarios that required students to engage in mathematical modelling and reasoning beyond routine procedures.

The second instrument was a mathematical problem-solving test designed to assess students' ability to solve non-routine problems. This instrument was structured based on widely recognized stages of problem solving, including understanding the problem, devising a plan, executing the solution, and evaluating the obtained results. The problems were intentionally designed to require higher-order thinking skills, thereby allowing for a comprehensive assessment of students' analytical and reflective abilities in solving mathematical problems.

The third instrument was a prior mathematical knowledge test, which aimed to measure students' foundational understanding of prerequisite mathematical concepts. The items included in this test were designed to assess both conceptual understanding and procedural fluency, as these components are essential for successful engagement in higher-level problem-solving tasks. The integration of this instrument into the study was crucial for capturing students' initial cognitive readiness and for supporting subsequent comparative analysis.

All instruments underwent a rigorous validation process prior to their implementation. Content validity was established through expert judgment involving specialists in mathematics education, who evaluated the relevance, clarity, and alignment of the test items with the intended constructs. In addition, empirical validation was conducted through pilot testing to examine item quality, including difficulty level and discrimination index. The reliability of the instruments was assessed using Cronbach's alpha coefficient to ensure internal consistency.

The data collection process was carried out systematically in three stages. Initially, students were administered the prior mathematical knowledge test to determine their baseline level. This was followed by the administration of the PISA-based mathematical literacy test, and finally, the mathematical problem-solving test. All assessments were conducted in a controlled classroom environment to ensure uniformity in administration. Standardized instructions were provided, and sufficient time was allocated for students to complete each test in order to minimize external influences on their performance.

Data analysis was conducted using both descriptive and inferential statistical techniques. Descriptive statistics, including mean, standard deviation, and score distribution, were used to provide an overview of students' performance across all variables. Prior to conducting inferential analysis, several assumption tests were performed to ensure the suitability of the data for regression analysis. These included tests of normality, linearity, and multicollinearity.



To examine the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability, regression analysis was employed. Furthermore, to investigate how this relationship varies across different levels of prior mathematical knowledge, an interaction-based regression model was utilized. The analytical model incorporated an interaction term between mathematical literacy and prior knowledge, allowing for the identification of differential effects across groups. A statistically significant interaction term indicates that the influence of mathematical literacy on problem-solving ability is not uniform but depends on the level of prior knowledge.

All statistical analyses were performed using SPSS or equivalent statistical software, with a significance level set at 0.05. This analytical approach enabled a comprehensive examination of both the direct effect of mathematical literacy and the variation of this effect across different levels of prior knowledge.

Ethical considerations were carefully observed throughout the study. Participation was voluntary, and students were informed about the purpose and procedures of the research prior to data collection. Confidentiality and anonymity were strictly maintained, and all data were used exclusively for research purposes.

RESULTS AND DISCUSSION

The results of this study are presented through descriptive and inferential analyses to examine the effect of PISA-based mathematical literacy on students' mathematical problem-solving ability in terms of prior mathematical knowledge.

Results

Descriptive statistics were first conducted to provide an overview of students' performance across all variables. The results are presented in Table 1.

Table 1. Descriptive Statistics of Research Variables

Variable	N	Mean	Std. Deviation	Minimum	Maximum
Mathematical Literacy (X)	60	74.85	8.92	55	92
Problem-Solving Ability (Y)	60	76.20	9.15	54	94
Prior Mathematical Knowledge (Z)	60	73.10	10.05	50	95

As shown in Table 1, the average scores of mathematical literacy and problem-solving ability are relatively high, indicating that students generally possess adequate competencies. However, the standard deviation values indicate moderate variability, suggesting differences in students' cognitive abilities.

Students were categorized into three levels of prior mathematical knowledge based on their previous learning outcomes. The distribution is presented in Table 2.

Table 2. Distribution of Students Based on Prior Mathematical Knowledge

Category	Score Range	Frequency (N)	Percentage (%)
High	≥ 80	18	30.0%
Moderate	65 – 79	25	41.7%
Low	< 65	17	28.3%
Total		60	100%

The distribution shows that most students fall into the moderate category, followed by high and low categories, indicating a relatively balanced distribution.

Prior to regression analysis, assumption tests were conducted. The results showed that all variables were normally distributed ($p > 0.05$) and no multicollinearity issues were detected ($VIF < 10$), indicating that the data met the requirements for regression analysis.

The main analysis was conducted using multiple regression with an interaction term. The results are presented in Table 3.

Table 3. Regression Analysis Results

Variable	B	Std. Error	t	Sig.
Constant	12.145	5.210	2.33	0.023
Mathematical Literacy (X)	0.528	0.082	6.44	0.000
Prior Knowledge (Z)	0.347	0.074	4.69	0.000
X $\times$ Z (Interaction)	0.015	0.006	2.50	0.015

The results indicate that mathematical literacy has a positive and significant effect on students' mathematical problem-solving ability ($\beta = 0.528$, $p < 0.001$). In addition, prior

mathematical knowledge also significantly affects problem-solving ability ($\beta = 0.347$, $p < 0.001$). Furthermore, the interaction between mathematical literacy and prior knowledge is statistically significant ($\beta = 0.015$, $p = 0.015$), indicating that the effect of mathematical literacy varies depending on the level of prior knowledge.

The model summary is presented in Table 4.

Table 4. Model Summary

R	R ²	Adjusted R ²	Std. Error
0.842	0.709	0.695	5.02

The coefficient of determination ($R^2 = 0.709$) indicates that approximately 70.9% of the variance in students' problem-solving ability can be explained by mathematical literacy and prior knowledge, suggesting that the model has strong explanatory power.

DISCUSSION

The findings of this study demonstrate that PISA-based mathematical literacy plays a significant role in enhancing students' mathematical problem-solving ability. Students who possess strong abilities in formulating, employing, and interpreting mathematical concepts are more capable of solving non-routine and contextual problems effectively. This result highlights that mathematical literacy is a complex competency that goes beyond procedural knowledge and involves reasoning, modelling, and interpretation.

Recent studies support this finding. Research by Manuel Santos-Trigo (2024) emphasizes that mathematical problem solving is closely linked to the ability to interpret and model real-world situations mathematically. Similarly, studies by Vince Geiger (2024) indicate that mathematical literacy is a critical competency for applying mathematics in meaningful contexts, particularly in solving complex problems.

The significant influence of prior mathematical knowledge found in this study further confirms that students' foundational understanding plays a crucial role in problem solving. Students with higher prior knowledge demonstrated better performance because they were able to connect existing knowledge with new problem situations. This finding is consistent with research by Seung Won Lee (2023), which shows that prior knowledge significantly predicts higher-order cognitive abilities, including problem solving and reasoning.

The interaction effect between mathematical literacy and prior knowledge provides an important contribution to the literature. The results indicate that the impact of mathematical literacy is stronger among students with high prior knowledge. This suggests that mathematical

literacy is more effectively utilized when supported by strong foundational understanding. This finding is in line with research by Sandugash Kappassova (2025), which highlights that mathematical literacy development is influenced by prior knowledge and learning context.

In addition, the findings of this study highlight the importance of contextual learning approaches. The use of PISA-based tasks allows students to engage in authentic problem-solving processes that involve reasoning and interpretation. This is supported by research by Gerrit Roorda (2024), which found that problem-solving-based instruction significantly improves students' reasoning and metacognitive skills.

Studies conducted in the Indonesian context also support these findings. Research by Rahma Rahima (2025) shows that problem-based learning enhances students' mathematical literacy and problem-solving ability, particularly when learning is designed to be contextual and student-centered. Similarly, R. G. Pamungkas (2024) found that integrating real-world contexts into mathematics learning improves students' engagement and problem-solving performance.

Moreover, recent research by Meti Hamdiyanti (2024) indicates that motivational factors also contribute to the development of mathematical literacy, which in turn affects problem-solving ability. This suggests that improving students' competencies requires not only cognitive development but also attention to affective aspects.

Overall, the findings of this study suggest that improving students' mathematical problem-solving ability requires a comprehensive approach that integrates mathematical literacy, prior knowledge, and contextual learning. Instructional strategies should therefore focus on strengthening conceptual understanding while simultaneously developing students' ability to apply mathematics in real-world situations.

Importantly, this study contributes to the existing literature by providing empirical evidence of the interaction between mathematical literacy and prior knowledge, highlighting that students' problem-solving ability is influenced by both cognitive readiness and higher-order competencies. This finding implies that differentiated instructional strategies are necessary to accommodate students with varying levels of prior knowledge.

CONCLUSION

This study concludes that PISA-based mathematical literacy has a significant positive effect on students' mathematical problem-solving ability ($\beta = 0.528$; Sig. = $0.000 < 0.05$). Students with higher levels of mathematical literacy tend to perform better in solving contextual and non-routine problems.



In addition, prior mathematical knowledge also has a significant effect on problem-solving ability ($\beta = 0.347$; Sig. = $0.000 < 0.05$). Students with higher prior knowledge demonstrate better performance compared to those with moderate and low levels.

Furthermore, the results reveal a significant interaction between mathematical literacy and prior knowledge ($\beta = 0.015$; Sig. = $0.015 < 0.05$). This indicates that the effect of mathematical literacy on problem-solving ability is stronger among students with higher prior knowledge.

These findings imply that mathematics instruction should integrate PISA-based tasks and consider students' prior knowledge to effectively improve students' problem-solving ability.

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