Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram
https://e-journal.undikma.ac.id/index.php/prismasains/index
e-mail: prismasains.pkpsm@gmail.com

July 2026. Vol. 14, No. 3
p-ISSN: 2338-4530
e-ISSN: 2540-7899
pp. 1432-1455

Analysis of Students' Mathematical Literacy Skills on Space and Shape Content

[1*]Karina Nurwijayanti, [2]Tri Kurniah Lestari

[1*]Department of Information Management, Faculty of Vocational Studies, Universitas Teknologi Mataram, Mataram, Indonesia

[2]Department of Elementary School Teacher Education, Faculty of Teacher Training and Education, Universitas Yapis Papua, Jayapura, Indonesia

*Corresponding Author e-mail: karinanurwijayanti.math@gmail.com

Received: December 2025; Revised: June 2026; Published: July 2026

Abstract

This study employs a qualitative descriptive design with a case study approach. This study aims to describe students' mathematical literacy abilities in the Space and Shape content of PISA. The Programme for International Student Assessment (PISA) analytical framework posits that the evaluation of mathematical literacy necessitates an integrated approach involving four primary dimensions: mathematical content, processes, contexts, and competencies. With respect to mathematical content, the framework delineates four distinct categories: Change and Relationships, Space and Shape, Quantity, and Uncertainty and Data. Space and Shape literacy is essential, as it encompasses the ability to understand and interpret forms, space, and real-world situations through geometric representations. This literacy demands the application of geometric concepts, spatial visualization, and the capacities for reasoning, modeling, and reflection in problem-solving. The findings indicate that students' mathematical literacy skills vary across distinct ability levels. High-ability students successfully fulfill the formulate and employ aspects. Conversely, moderate-ability students encounter difficulties with geometric representation and complex problem-solving, while low-ability students struggle across all stages of the mathematical literacy process. Notably, the interpret aspect is the most frequently unfulfilled component across all student categories. These outcomes demonstrate that the formulate, employ, and interpret processes are interrelated, suggesting that deficiencies in the initial stages impede success in subsequent phases. The implications of this research suggest the necessity of problem-based and contextual learning supported by visual representations, mathematical discussions, reflection, and scaffolding strategies to develop students' formulate, employ, and interpret competencies in solving real-world problems.

Keywords: Mathematical literacy skills; PISA; Space and shape; Qualitative descriptive; Secondary students

How to Cite: Nurwijayanti, K., & Lestari, T. K. (2026). Analysis of Students' Mathematical Literacy Skills on Space and Shape Content. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(3), 1432–1455. https://doi.org/10.33394/j-ps.v14i3.18850

https://doi.org/10.33394/j-ps.v14i3.18850

INTRODUCTION

In the contemporary era, mathematical literacy is fundamental to education, as it is intrinsically linked to an individual's capacity for problem-solving and adaptation within an evolving global landscape. It serves as a critical metric for evaluating cognitive abilities, specifically critical thinking and the functional application of mathematics in daily life. Furthermore, mathematical literacy encompasses not only computational proficiency but also the formulation, application, and interpretation of mathematical concepts across diverse contexts (OECD, 2018). Mathematical literacy pertains to an individual's capacity to comprehend and apply mathematical principles across diverse contexts (Dagdelen & Yildiz, 2022; Kabael & Baran, 2023). Spanning from foundational numeracy to sophisticated mathematical reasoning and critical thinking, it is conceptualized as a multifaceted construct encompassing a broad spectrum of cognitive abilities (Borgonovi et al., 2021; Gal et al., 2020).

Song (2024) delineates three primary dimensions of mathematical literacy: (a) competency and skills, involving problem-solving and computational proficiency; (b) real-world application, referring to the functional utility of mathematics in empirical situations; and (c) communicative and reasoning dimensions, which facilitate engagement in mathematical discourse. These components align closely with the focal points of the PISA framework. Furthermore, this perspective is consistent with the findings of Suprapto & Suryani (2023) and (Dewi & Maulida, 2023), who identify key indicators of mathematical literacy as the ability to represent problems, translate them into mathematical models, formulate strategic designs, utilize symbols and operations, and employ rigorous mathematical reasoning. As a primary domain of PISA, mathematical literacy is assessed biennially alongside reading and scientific literacy (Clarke & Bazaldua, 2021; Morgan & Volante, 2016).

The Programme for International Student Assessment (PISA) serves as a critical international benchmark for evaluating the competencies of 15-year-old students globally. Its primary focus lies in the application of mathematics to authentic, real-world contexts, moving beyond the mere assessment of curricular content (Clarke & Bazaldua, 2021; Tekin & Pinar, 2023). Specifically, PISA measures mathematical literacy by assessing students' capacity to utilize school-acquired knowledge in functional settings. Furthermore, this assessment transcends basic academic evaluation; it serves as a reflection of an education system's efficacy in fostering student readiness for contemporary societal challenges (Schmidt et al., 2015).

The recent OECD (2024) evaluation indicates that Indonesia continues to rank among the lower-performing participants in the PISA 2022 assessment. Out of 62 participating nations, Indonesia placed 56th, with an overall mathematical literacy score below 380 points—a significant discrepancy when compared to the OECD average of 468 points OECD (2024). Furthermore, the results highlight a substantial deficit in creative thinking, where Indonesia scored below 20 points, notably lower than the international mean of 33 points. According to the report, Indonesia is categorized among the 14 lowest-performing countries in creative thinking; more than 50% of Indonesian students failed to reach the basic proficiency threshold (Level 2) across the domains of mathematics, reading, and science, as well as in the specialized 2022 creative thinking assessment OECD (2024).

The PISA framework encompasses four primary mathematical content domains: (a) Space and Shape, (b) Change and Relationships, (c) Quantity, and (d) Uncertainty and Data (OECD, 2022; Qadry, 2022). Among these domains, the present study focuses specifically on Space and Shape. This content area constitutes a fundamental pillar of mathematical literacy; it extends beyond pure Euclidean geometry to incorporate spatial visualization, spatial reasoning, and the utilization of various instruments to interpret and manipulate spatial representations (Börner et al., 2019; Lane et al., 2018). Furthermore, this domain pertains to the systematic analysis of geometric concepts and the representation of empirical forms within mathematical problem-solving contexts. Extant literature on Space and Shape emphasizes that contextualized problems, visual configurations, and open-ended reasoning significantly influence student performance on geometry-related tasks (Lane & Sorby, 2021; Wang & Yang, 2016). The emphasis on the Space and Shape domain is intrinsically linked to geometry and, by extension, profoundly connected to the spatial surroundings and environmental objects encountered by students (Maharani & Aini, 2021; Qadry, 2022).

The PISA 'Space and Shape' component encompasses elements central to spatial reasoning, specifically emphasizing geometry, spatial visualization, measurement, and algebra (Lane & Sorby, 2021). This content area is of significant pedagogical value, as it integrates a diverse array of mathematical activities. These include 'understanding perspective in images, creating and reading maps, transforming shapes with and without technology, interpreting three-dimensional views from various perspectives, and constructing representations of shapes' (Lane et al., 2018). Furthermore, the Space and Shape domain is essential due to its relevance to physical phenomena encountered in daily life, as it pertains to patterns, properties, spatial orientations, and the encoding or decoding of visual information (Ozgen, 2019). This domain is particularly salient because it necessitates that students interpret geometric models of empirical situations and apply spatial reasoning within novel contexts (Nasution et al., 2019). Ultimately, analyzing student performance in Space and Shape literacy reveals their capacity to translate between abstract mathematical representations and concrete real-world contexts—a skill fundamental to mathematical literacy as conceptualized by PISA (Machromah et al., 2020; Nasution et al., 2019). The Space and Shape content assesses students' understanding of geometric forms and spatial concepts in relevant contexts (Aini, 2022) and evaluates visual representation skills, namely the ability to interpret visual representations in geometry problems (Faizatunnisa et al., 2023). This domain encompasses the analysis of geometric concepts and the representation of real-world forms in mathematical problem solving. Items in this domain assess students' ability to identify various shapes, determine similarities and differences across dimensions and representations, and understand the characteristics of an object in relation to its position (Munfarikhatin & Natsir, 2020)

Extant research emphasizes that the visualization of space and shape serves as both a core competency and a potential barrier to academic achievement across various educational levels (Adams et al., 2023; Ozdemir & Polat, 2024; Silitonga et al., 2023). As a critical component of geometric comprehension, spatial visualization necessitates the coordination of multiple representations and high-dimensional processing. This complexity often induces a significant cognitive load, which frequently becomes a primary source of student difficulty when performing Space and Shape tasks (Adams et al., 2023; Ng et al., 2022; Silitonga et al., 2023). Furthermore, the requirement to consistently integrate diverse representational forms—specifically images, symbols, and procedures—is identified as a major factor contributing to challenges in geometry-related tasks. Consequently, the Space and Shape domain requires a robust link between geometric concepts and real-world contexts; in the absence of such connections, students often struggle to construct meaningful conceptual frameworks and accurate spatial mental models (Japa et al., 2017; Liu et al., 2025).

Several factors potentially contribute to the difficulties Indonesian students encounter when resolving Space and Shape items in the PISA assessment, including challenges in spatial visualization, deficient geometric reasoning, and the suboptimal use of representations. Masfufah & Afriansyah (2021) identified that students struggle with these problems primarily due to impairments in visualizing complex inquiries. Furthermore, underdeveloped geometric reasoning often prevents students from comprehending the intricate relationships among geometric elements, thereby hindering their capacity to address items requiring higher-order thinking and the functional application of geometric knowledge (Sinclair et al., 2016). An additional contributing factor is the inability to utilize multiple representations, such as diagrams, illustrations, or manipulatives. This is corroborated by Sugiarti et al., (2022), who reported that students with moderate-to-low mathematical ability often fail to meet the symbolic (e.g., equations or mathematical expressions) and verbal (e.g., written discourse) representational demands inherent in PISA Space and Shape tasks.

Based on the above discussion, it is important to analyze students' mathematical literacy skills on PISA items, particularly within the Space and Shape content. Therefore, the purpose of this study is to describe students' mathematical literacy skills in the Space and Shape domain. In this study, the framework of mathematical literacy consists of three core domains: (a) formulate, (b) employ, and (c) interpret.

While previous research on mathematical literacy has been extensively conducted, most studies predominantly focus on measuring students' literacy levels through test scores or analyses based on PISA competency frameworks. In contrast, this study distinguishes itself by providing an in-depth analysis of the performance and characteristics of each student group across three specific domains: formulate, employ, and interpret. Furthermore, it delineates the distinct difficulties and obstacles that differentiate each proficiency group within these three aspects, and outlines pedagogical implications to effectively enhance students' formulate, employ, and interpret competencies.

In light of these problems, this study addresses the following research questions: (1) How do the characteristics of students' mathematical literacy in Space and Shape content vary across the *formulate*, *employ*, and *interpret* stages based on their ability levels? (2) What are the specific difficulties and obstacles encountered by students in the *formulate*, *employ*, and *interpret* processes during Space and Shape problem-solving? and (3) What instructional strategies can be recommended to foster students' mathematical literacy competencies within these three processes?.

METHOD

Research Design

This study employs a qualitative descriptive design with a case study approach. The qualitative descriptive approach was utilized to provide an in-depth description and understanding of students' mathematical literacy skills within the space and shape content domain. This assessment is based on the students' ability to formulate information and problems, transform information into mathematical models, design problem-solving strategies, apply mathematical formulas or concepts, and interpret the obtained results. The research focuses on uncovering the meanings, characteristics, and phenomena of students' mathematical literacy in detail, utilizing data derived from test results, interviews, and documentation.

The case study approach was selected to concentrate on a specific phenomenon: students' mathematical literacy skills in solving problems related to space and shape. The unit of analysis for this study consists of the mathematical literacy abilities of three students, representing high, moderate, and low achievement levels, respectively. Through this approach, the researcher can conduct a profound exploration of how students formulate problems, employ mathematical concepts and procedures, and interpret outcomes within the context of geometry and space. Furthermore, the case study allows for a comprehensive overview of students' cognitive patterns, emergent errors, utilized strategies, and the factors influencing their mathematical literacy skills within this specific content area.

Research Participants

The research was conducted in Class IX B at SMP Negeri 1 Kediri. The participants in Class IX B consisted of 31 students with a mean age of approximately 15 years. Sampling was performed using a stratified purposive sampling technique. Based on the results of an initial ability test administered to all 31 students, the participants were categorized into three groups: high (H), moderate (M), and low (L) ability levels. Table 1 presents the results of the initial geometry proficiency test, which comprised 10 multiple-choice items focused on geometry content.

Table 1. Distribution of Students' Initial Geometry Proficiency Levels in Class IX B

Initial	Correct Answer	Baseline Score	Initial	Correct Answer	Baseline Score	Initial	Correct Answer	Baseline Score
S1	8	80	S11	6	60	S21	7	70
S2	9	90	S12	9	90	S22	10	100
S3	8	80	S13	9	90	S23	9	90
S4	6	60	S14	7	70	S24	7	70
S5	7	70	S15	7	70	S25	7	70
S6	6	60	S16	6	60	S26	5	50
S7	9	90	S17	9	90	S27	7	70
S8	10	100	S18	7	70	S28	6	60
S9	8	80	S19	5	50	S29	7	70
S10	5	50	S20	8	80	S30	7	70
						S31	5	50

Participants were stratified into high, moderate, and low ability groups based on their initial assessment scores. The score intervals utilized for this classification are detailed in the table 2.

Table 2. Classification Levels for Initial Geometry Proficiency

No	Category	Description
1	High	$x \geq 87$
2	Medium	$58 \leq x < 87$
3	Low	$x < 58$

This study employs an exploratory case study design. Consequently, a stratified purposive sampling technique was utilized to select one representative participant from each proficiency level: one student from the high-ability group, one from the moderate-ability group, and one from the low-ability group. Table 3 summarizes the study participants according to their initial ability levels.

Table 3. Research Participant

No	Ability Category	Initials	Informant Code
1	High	S8	H
2	Moderate	S24	M
3	Low	S19	L

Research Instruments

The research instrumentation included an initial geometry proficiency test, a mathematical literacy assessment in the domain of space and shape, and interview protocols. Initial geometry proficiency was assessed through 10 multiple-choice items at the lower secondary level. Each correct answer was valued at 10 points, while incorrect answers were scored as zero. Table 4 delineates the assessment indicators for initial geometry proficiency.

Table 4. Assessment Indicators for the Initial Geometry Proficiency Test

Variable	Topic	Indicators	Item Number
Lower Secondary Geometry	Lines and Angles	– Solving contextual problems involving the relationship between angles on two intersecting lines.	1
		– Solving mathematical problems involving the relationship between angles on parallel and transversal lines	2
	Congruence and Similarity	– Calculating side lengths or angle measures in congruent figures within real-world contexts.	3
		– Solving contextual problems involving geometric similarity.	4
	Pythagorean Theorem	– Applying the Pythagorean theorem to determine the distance between two points.	5
		– Solving contextual problems using the Pythagorean theorem.	6
	Circles	– Determining the area of a circle.	7
		– Solving mathematical problems involving the area of a circle.	8
	Geometric Solids	– Solving mathematical problems involving the surface area of geometric solids.	9
		– Solving mathematical problems involving the volume of geometric solids.	10

Validity testing was performed on the initial geometry proficiency test, encompassing both content and empirical validity. Content validity was established through expert judgment by two lecturers in mathematics education, who evaluated the instrument based on content, construction, and linguistic aspects. The results of the expert judgment indicated that the baseline proficiency instrument was suitable for use following revisions. Expert feedback specifically suggested linguistic refinements for several test items. Following the revisions, the instrument was administered to a pilot group comprising 31 Grade 9 students at SMP Negeri 1 Kediri who were not included in the primary research sample.

Empirical validity for this instrument was assessed through item-total correlation analysis using the point-biserial correlation coefficient. This method was selected to evaluate the relationship between dichotomous item scores and total test scores. The point-biserial correlation formula is defined as follows:

$$r_{pbis} = \frac{M_p - M_t}{S_t}\sqrt{\frac{p}{q}}$$

Using a significance level of $\alpha = 0.05$ with $N = 31$ and $d_f = 29$, the critical value for the correlation coefficient was determined to be $r_{critical}$= 0.355. The obtained point-biserial correlation coefficients (r_{pbis}) for each test item are presented in table 5.

Table 5. Item Validity Results Using Point-Biserial Correlation Coefficients

Item Number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Test Result	r_{pbis}	0.839	0.461	0.692	0.464	0.692	0.430	0.754	0.646	0.411	0.571
	$r_{critical}$	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355	0.355
	Interpretation	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid	Valid

Based on the results presented in Table 5, it can be concluded that all test items are valid, as the obtained point-biserial correlation (r_{pbis}) exceeded the critical value (($r_{critical}$).

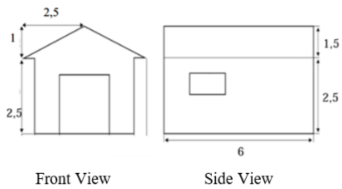
The reliability of the initial geometry proficiency test was estimated using the Kuder-Richardson Formula 20 (KR-20), which is appropriate for instruments utilizing a dichotomous multiple-choice format. The KR-20 formula is defined as follows:

$$r_{11} = \left[\frac{k}{k-1}\right]\left[\frac{{S_t}^2 - \sum p_i q_i}{{S_t}^2}\right]$$

The obtained reliability coefficient was interpreted according to Guilford's criteria. The reliability analysis yielded a Kuder-Richardson Formula 20 (KR-20) coefficient of $r_{11} =$ 0.799.Based on the Guilford's criteria, this value indicates that the initial geometry proficiency assessment instrument possesses high internal consistency.

The mathematical literacy instrument for the Space and Shape content domain consists of two open-ended items adapted from the Programme for International Student Assessment (PISA). Item 1 was adapted from the 2006 PISA Space and Shape unit entitled 'Pizzas' (OECD, 2006). This item represents Level 4 mathematical literacy and focuses on the core topic of circles. Item 2 was adapted from the 2012 PISA Space and Shape unit entitled 'Garage' (OECD, 2012), which corresponds to Level 6 mathematical literacy. The mathematical content for Item 2 includes triangles, the Pythagorean theorem, and quadrilaterals. The specifications for the mathematical literacy instrument within the Space and Shape content domain are detailed in Table 6.

Table 6. Specifications of the Mathematical Literacy Instrument For Space and Shape

No	Indicators	PISA Context	PISA Theme	PISA Level	Level Descriptor	Item Format	Item
1.	Solving contextual problems by utilizing the area of a circle	Personal	Pizzas	4	Students can work effectively with explicit models for complex concrete situations	Open-ended	 A pizza shop offers two pizza options with the same thickness but different sizes. The first pizza is 30 cm in diameter and costs Rp 30,000.00, while the second pizza is 40 cm in diameter and cists Rp 40,000.00. Which pizza is cheaper? Give your reasons. Source: (OECD, 2006)
2.	Utilizing the Pythagorean theorem and area of quadrilateral s to solve contextualiz ed mathematica l problems	Occupational	Garage	6	Students can work through abstract problems and demonstrat e creativity and flexible thinking to develop solutions	Open-ended	The two designs below illustrate the dimensions, in meters, of the garage designed by George. The roof consists of two identical rectangular sections. Determine the total area of the roof !  Source: (OECD, 2012)

Fundamentally, PISA items undergo a rigorous development process, including international content and construct validity testing; therefore, they typically do not require re-validation. However, because Item 1 was adapted to align with the Indonesian context—specifically by adjusting prices to reflect realistic Indonesian Rupiah values—and Item 2 involved modifications to the garage height dimensions, further testing was necessary to ensure the instrument's content suitability. Consequently, this study employed content validity through expert judgment, involving two mathematics education lecturers from two different universities.

The two adapted PISA items provide a robust justification for assessing mathematical literacy within the Space and Shape domain, as they encompass a broad spectrum of spatial and geometric dimensions. The first item, centered on pizza pricing, requires students to analyze the relationship between circular area and cost-efficiency, reflecting a deep understanding of two-dimensional properties. Meanwhile, the second item regarding garage roof designs necessitates the visual interpretation of two-dimensional representations (front and side views) to construct an understanding of three-dimensional structures, alongside the application of the Pythagorean theorem and quadrilateral area formulas. The integration of shape manipulation, spatial visualization, and geometric reasoning within these real-world contexts effectively represents the Space and Shape domain, which emphasizes pattern recognition, visual representation mastery, and the practical application of geometric properties in everyday life. Table 7 presents the assessment aspects and mathematical literacy indicators within the space and shape content domain.

Table 7. Indicators of Mathematical Literacy Skills in the Space and Shape Content

No	Assessment Aspects	Indicators	Code
1	Formulate	Able to formulate what is known and what is asked	F1
		Able to transform real-world contexts into mathematical forms	F2
2	Employ	Able to design strategies to find mathematical solutions	E1
		Able to apply mathematical formulas or concepts to find mathematical solutions	E2
3	Interpret	Able to interpret the obtained mathematical results and transform them back into the real-world problem context (I).	I

The scoring rubric was developed based on the evaluation aspects and indicators presented previously in Table 8. Specifically, Table 8 outlines the comprehensive scoring rubric for each indicator.

Table 8. Assessment Rubric

Assessment Aspects	Indicators	Score 3	Score 2	Score 1	Score 0
Formulate	Able to formulate what is known and what is asked (F1).	Writes all essential information completely and accurately, and clearly defines what is asked.	Writes most of the essential information, but some parts are incomplete or inaccurate.	Writes information incompletely and demonstrates a lack of understanding regarding what is asked.	Unable to determine either the known information or what is asked.
	Able to transform real-world contexts into mathematical forms (F2).	Demonstrates the ability to construct an accurate mathematical model appropriate to the problem context.	The mathematical model is partially correct but contains conceptual errors.	The mathematical model is inaccurate and contextually inappropriate.	Unable to transform the problem into a mathematica l form.
Employ	Able to design strategies to find mathematical solutions (E1).	The solution strategy is systematic, logical, and efficient.	The strategy is moderately appropriate but lacks systematic structure.	The strategy is inappropriate and incomplete.	Lacks any viable solution strategy.

Assessment Aspects	Indicators	Score 3	Score 2	Score 1	Score 0
	Able to apply mathematical formulas or concepts to find mathematical solutions (E2).	Applies formulas or concepts accurately with correct calculations.	Applies the correct formula but exhibits minor procedural or calculation errors.	Applies an inappropriate formula and exhibits numerous calculation errors.	Unable to utilize mathematica l formulas or concepts.
Interpret	Able to interpret the obtained mathematical results and transform them back into the real-world problem context (I).	Interprets results accurately and logically, utilizes appropriate units of measurement , and provides contextual reasoning.	Interprets results with moderate accuracy, but the reasoning is incomplete.	The interpretation of results is contextually inappropriate to the problem.	Unable to interpret the mathematica l results.

Research Procedures and Ethical Considerations

This study commenced with an expert validation of the research instruments, which included an initial geometry ability test, a mathematical literacy test for the "space and shape" content domain, and interview protocols. Following revisions based on the experts' feedback, a pilot study of the initial geometry ability test was conducted. This pilot study involved 31 students from Class IX A (a non-research class). The pilot results were utilized to determine the empirical validity of each item and the overall reliability of the test. Once all items were validated and the instrument was proven reliable, the initial geometry ability test was administered to the research class on October 20, 2025. Based on these test results, the students were categorized into three groups: high, moderate, and low ability, from which three students were selected for each category.

Subsequently, the researcher sought ethical clearance from the three selected students and their parents or guardians, which was secured on October 27, 2025. The Informed consent document explicitly outlined the study's title, the researcher's identity, the research location, objectives, benefits, and procedural framework. Furthermore, the document clarified the participants' rights, potential risks, and data confidentiality protocols.

Subsequently, the student representatives from each category were assessed using a mathematical literacy test focused on the "space and shape" content domain, followed by face-to-face interviews conducted in the classroom on October 28, 2025. The interviews were performed by the researcher, assisted by the mathematics subject teacher. Conducted in accordance with the pre-established interview protocols, these interviews aimed to explore in depth the students' mathematical literacy skills in solving PISA tasks within the space and shape domain. The interviews were administered 1 hour after the students completed the written test. Each interview session lasted approximately 10 to 20 minutes per research subject, covering the formulate, employ, and interpret stages. This duration was flexibly adjusted to each student's condition and responses to ensure a comfortable interview environment and minimize any psychological pressure.

During the data collection process, audio recording techniques were employed. The recorded interview data were subsequently transcribed into written text. The researcher documented the entire conversation completely and verbatim from the recordings. The transcription process involved listening to the audio repeatedly and systematically transcribing the dialogue between the researcher and the subjects. To maintain anonymity, each subject was assigned a specific code, such as H, M, and L.

Data Analysis

Data analysis in this study was conducted by comparing data obtained from the mathematical literacy written test with data derived from the participants' interview transcripts. The written test results and interview data served as the primary basis for identifying and examining students' mathematical literacy skills, particularly in understanding, formulating, and interpreting problems within the space and shape content domain.

RESULTS AND DISCUSSION

Result

1. Analysis of Mathematical Literacy Skills of High-Ability Students (H)

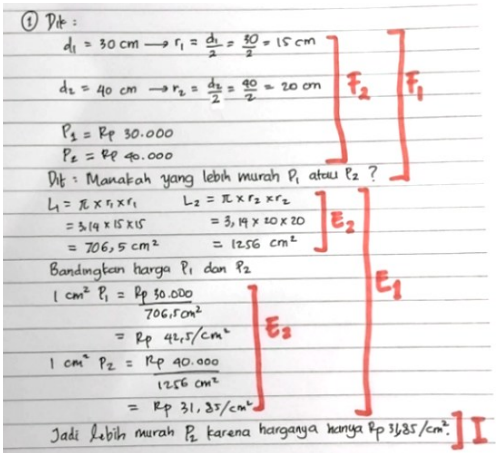


Figure 1. H's Response to Task 1

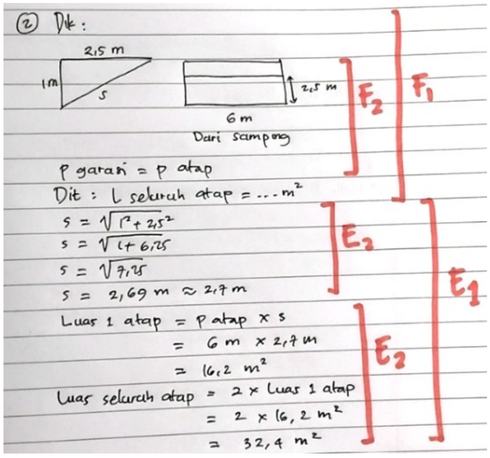


Figure 2. H's Response to Task 2

1.1 Analysis of Task 1: High-Ability Student (Subject H)

Aspect: Formulate (Task 1)

In Task 1, Subject H was able to assume that the pizza size corresponded to the area of a circle, as evidenced by directly determining the radius of the pizza using the standard geometric formula (diameter divided by 2). Based on the interview results, Subject H further clarified that the task inquired about the price per unit area of the pizza rather than merely the retail price stated in the problem description. This indicates that Subject H mathematically conceptualized "cheaper" as the ratio of price to surface area. The transcript excerpt of the interview with Subject H is presented below :

(Q): What is being asked in this problem?

(H): Whether Pizza 1 or Pizza 2 is cheaper when comparing the price to its area.

Based on the written test and interview results, Subject H successfully wrote all essential information completely and accurately, and clearly defined what was asked (F1). Furthermore, Subject H demonstrated the ability to construct an accurate mathematical model appropriate to the problem context (F2). This proficiency was demonstrated by Subject H's ability to assume that the pizza was circular and to represent the structural information from the task using mathematical symbols. For instance, in Task 1, Subject H utilized the mathematical symbols "d" for diameter, "r" for radius, and "P" for the price of the pizza.

Aspect : Employ (Task 1)

In terms of the employing indicators, the strategy utilized by Subject H was systematic, logical, and efficient, thereby satisfying indicator E1. This proficiency was evidenced by the sequential steps taken by the subject: first, calculating the area of each pizza, and subsequently comparing the price per square centimeter (cm^2) between Pizza 1 and Pizza 2. Furthermore, Subject H applied formulas and concepts accurately with correct calculations, fulfilling indicator E2. This was demonstrated by the subject's ability to correctly calculate the pizza's area using the area of a circle formula ($A = \pi \times r \times r$). The calculations were executed precisely, despite involving squared numbers and decimals. Additionally, Subject H accurately computed the price-to-area ratio by dividing the retail price of the pizza by its previously determined surface area. These computational procedures were performed correctly, even though they required division by decimal values.

Aspect : Interpret (Task 1)

In terms of the interpreting indicators, Subject H was able to conclude that the second pizza was the more economical option. This was evidenced by the subject's written response: "Therefore, P2 is cheaper because the price is only Rp 31.85/cm^2" This finding was further supported by an excerpt from the interview with Subject H:

(Q): What conclusion did you derive from the problem you just solved?

(H): Pizza 2 is cheaper because the price per cm^2 is only 31.85.

This response demonstrates that Subject H interpreted the results with moderate accuracy, yet the underlying reasoning remained incomplete. Ideally, Subject H was expected to elaborate on the concluding statement by connecting it back to the problem context; specifically, by articulating that although Pizza 2 has a higher nominal cost, it offers better value for money when evaluated against its total surface area.

1.2 Analysis of Task 2: High-Ability Student (Subject H)

Aspect: Formulate (Task 2)

Subject H demonstrated the ability to transform visual imagery into a mathematical model. This process was illustrated in the following interview excerpt with Subject H:

(Q): How did you transform the relevant information given and asked in this problem?

(H): I drew a right-angled triangle to represent one side of the garage roof, where the roof height is 1 m and half of the base length is 2.5 m. After that, I drew a rectangle to represent the side view of the garage, with a garage length of 6 m and a structure height of 2.5 m. I also added a note indicating that the garage length equals the roof length. Then, what is being asked is the total roof area in m^2.

Subject H recognized that the value of 1.5 in the side-view diagram was a distractor or redundant information regarding the roof. From this, it can be inferred that Subject H was capable of connecting and integrating visual information from both the front-view and side-view diagrams. Furthermore, the problem formulation constructed by Subject H was clear. Based on the written test and interview results, Subject H successfully wrote all essential information completely and accurately, clearly defined what was asked, and thereby fulfilled indicator F1.

Subject H transformed the information from the front-view diagram into a right-angled triangle, while the information from the side-view diagram was transformed into a rectangle. Subject H demonstrated the ability to transform visual diagrams into representative and context-appropriate mathematical models. Consequently, Subject H effectively demonstrated the ability to construct an accurate mathematical model appropriate to the problem context, satisfying indicator F2.

Aspect : Employ (Task 2)

The strategy and sequential steps executed by Subject H were correct, beginning with calculating s, representing the roof width, using the Pythagorean theorem. This approach was chosen because Subject H recognized that the roof width constituted the hypotenuse of a triangle, which necessitated the application of the Pythagorean formula. Subsequently, Subject H calculated the area of a single roof section using the area of a rectangle formula, indicating a clear understanding that the roof was rectangular. Finally, Subject H determined the total roof area using the formula: $Total\ Area = 2\ x\ area\ of\ a\ single\ roof\ section$. This demonstrates that Subject H understood that the roof consisted of two symmetrical rectangular panels. Consequently, the solution strategy proposed by Subject H was systematic, logical, and efficient, thereby fulfilling indicator E1.Subject H successfully applied both the Pythagorean theorem and the area of a rectangle formula accurately, resulting in correct calculations. Although extracting the square root of a non-perfect square can be mathematically challenging, Subject H successfully computed the precise value. Furthermore, when determining the area of a single roof section, Subject H accurately inputted the value of the roof width, which led to a correct computational outcome. Ultimately, Subject H demonstrated the ability to apply formulas or concepts accurately with correct calculations, satisfying indicator E2.

Aspect : Interpret (Task 2)

Subject H did not formulate a written conclusion, merely stating that the total roof area equaled 32.4 m^2. This omission indicates that Subject H's interpretation remained superficial, lacking critical evaluation or reflection regarding the computational results. Consequently, Subject H interpreted the results with moderate accuracy, but the reasoning is incomplete.

2. *Analysis of Mathematical Literacy Skills of Moderate-Ability Students (M)*

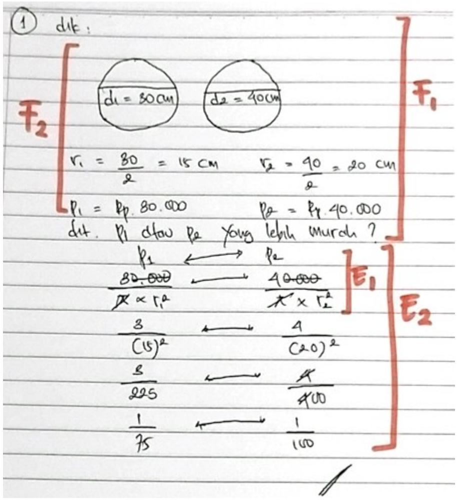


Figure 3. M's Response to Task 1

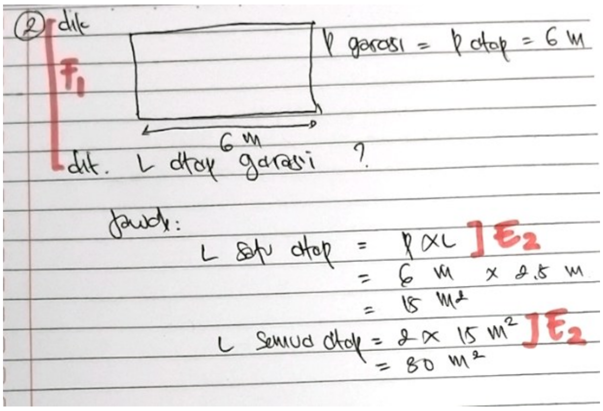


Figure 4. M's Response to Task 2

2.1 Analysis of Task 1: Moderate-Ability Student (Subject M)

Aspect : Formulate (Task 1)

In Task 1, Subject M immediately modeled the pizza as a circular shape and directly calculated the pizza's radius using the standard geometric radius formula. This approach indicates that Subject M was capable of assuming that the pizza's size corresponded to the area of a circle. Indirectly, Subject M recognized that the size of the pizza influenced its pricing structure.Based on the written test results, Subject M successfully wrote all essential information completely and accurately, and clearly defined what was asked, thereby fulfilling indicator F1. In addition, Subject M effectively translated the contextual information from the task into both a geometric representation a circle and mathematical symbols. Consequently, it can be concluded that Subject M demonstrated the ability to construct an accurate mathematical model appropriate to the problem context, satisfying indicator F2.

Aspect: Employ (Task 1)

In terms of the employing indicators, the approach executed by Subject M was correct, characterized by directly comparing the quotient of the pizza price divided by its area for both Pizza 1 and Pizza 2. The transcript excerpt of the interview with Subject M is presented below:

(Q):What strategy will you utilize to solve this problem?

(M):Comparing the quotient of the price divided by the area for each pizza. If the price of the pizza is divided by the area of the circle, the lower value represents the cheaper option.

(Q):Could you explain the sequential steps of applying your chosen formulas until you obtained the final result?

(M): I compared the quotient of the pizza price divided by its area. I represented Pizza 1 as P_1 and Pizza 2 as P_2. $P_1 = \frac{30.000}{\pi \times 15^2}$. Meanwhile $P_2 = \frac{40.000}{\pi \times 20^2}$. Because we are comparing the ratio between P_1 and P_2, the value of π can be disregarded, and the common zeros on both sides can be canceled out. Consequently, $P_1 = \frac{1}{75}$ and $P_2 = \frac{1}{100}$

Based on the interview excerpt above, the approach executed by Subject M was rational, specifically aiming to find the smaller quotient, as a lower quotient value indicated a more economical pizza price per unit area. This demonstrates that the solution strategy was systematic, logical, and efficient, thereby satisfying indicator E1.Furthermore, Subject M successfully applied the area of a circle formula correctly. The subject also recognized that the constant value of π could be disregarded and efficiently canceled out the common zeros—effectively dividing both sides of the ratio by 10,000—to streamline the computational process. Consequently, Subject M applied formulas or concepts accurately with correct calculations, fulfilling indicator E2.

Aspect: Interpret (Task 1)

Based on the written test results, Subject M did not provide any written conclusion regarding the problem presented in the task. The transcript excerpt of the interview with Subject M is detailed below:

(Q): Why did you not write a conclusion?

(M): I forgot, but I think I know which one is cheaper. The second one, right? I hesitated because the final result was a fraction.

During the interview session, Subject M stated that the omission was due to forgetfulness and appeared hesitant, tentatively guessing that Pizza 2 was the cheaper option. Although the subject's conjecture was correct, they lacked the confidence to formulate a definitive conclusion because the final computation resulted in a fractional value. Subject M experienced difficulties in understanding the concept of ratios, which served as the foundation for interpretation. Consequently, it can be inferred that Subject M was unable to interpret the mathematical results, and therefore, indicator Interpret (I) was not fulfilled.

2.2 Analysis of Task 2: Moderate-Ability Student (Subject M)

Aspect : Formulate (Task 2)

Subject M was incomplete in documenting the given information, leaving out several critical data points. However, the subject successfully identified and recorded the information being asked. Consequently, Subject M wrote most of the essential information, but some parts remained incomplete or inaccurate.Furthermore, Subject M relied solely on the side-view diagram and demonstrated an inability to connect or integrate the structural information between the front-view and side-view diagrams. As a result, the mathematical model constructed by Subject M was only partially correct and contained conceptual errors.

Aspect : Employ (Task 2)

Subject M successfully identified that the roof consisted of two rectangular panels. Consequently, the approach utilized by Subject M involved applying the area of a rectangle formula (length multiplied by width). However, the geometrical information regarding the triangle in the front-view diagram was neglected; hence, Subject M failed to employ the Pythagorean theorem to determine the roof width. As a result, the solution strategy proposed by Subject M was inappropriate and incomplete.Furthermore, Subject M inputted an incorrect value for the roof width, substituting a value of 2.5 m, which subsequently led to an erroneous computational result. In this context, the actual roof width should have been the hypotenuse of the triangle, which required calculation via the Pythagorean formula. Consequently, Subject M applied the correct formula but exhibited procedural or calculation errors. In this task, Subject M demonstrated an established procedural foundation but exhibited weaknesses in geometric representation and mathematical modeling.

Aspect :Interpret (Task 2)

Subject M did not formulate a written conclusion, merely stating that the total roof area equaled 30 m^2, a result that was mathematically incorrect. This outcome was caused by errors in geometric representation and strategic missteps during the preceding stages of problem-solving. It was evident that Subject M's final result was incorrect and lacked any underlying reasoning, argumentation, or contextual justification appropriate to the problem. Consequently, Subject M was unable to interpret the mathematical results, thereby failing to fulfill indicator Interpret (I).

3. *Analysis of Mathematical Literacy Skills of Low-Ability Students (L)*

3.1 Analysis of Task 1: Low-Ability Student (Subject L)

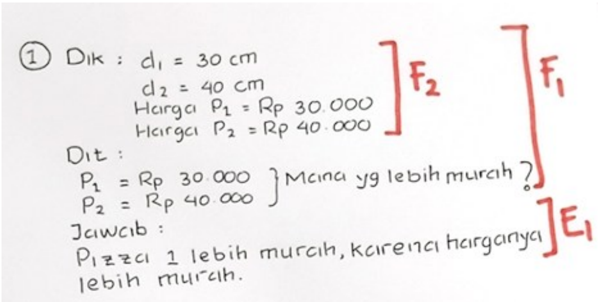


Figure 5. L's Response to Task 1

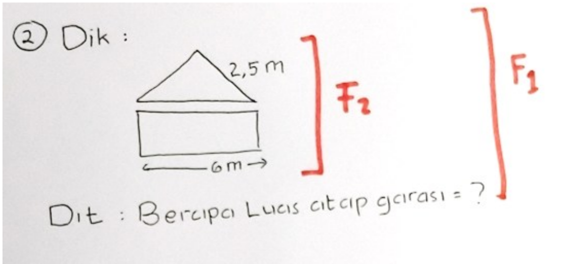


Figure 6. L's Response to Task 2

Aspect : Formulate (Task 1)

In Task 1, Subject L recorded the dimensions of the diameter and the corresponding retail price for each pizza. Subject L also wrote a questioning statement as follows: "P_1 = Rp 30,000 and P_2 = Rp 40,000, which one is cheaper?" Based on this written response, Subject L appeared to misunderstand the problem context, focusing primarily on the nominal price of the pizzas. Consequently, it can be concluded that Subject L wrote most of the essential information, but some parts remained incomplete or inaccurate, thereby partially satisfying indicator F1. Furthermore, although Subject L was capable of transforming the contextual information into mathematical symbols, the subject failed to utilize the previously recorded diameter values to determine the radius, which was essential for linking the problem to the concept of pizza size or circular area. This indicates that the conceptual framework applied by Subject L was flawed, as it relied directly on a price comparison without considering the geometric area of the circle. Therefore, it can be inferred that the mathematical model constructed by Subject L was only partially correct but contained significant conceptual errors.

Aspect: Employ (Task 1)

In Task 1, the solution strategy utilized by Subject L was inappropriate and incomplete. Because of the misunderstandings that occurred during the preceding formulating stage, Subject L's strategy was limited to a direct comparison of the nominal pizza prices to determine the more economical option. Consequently, Subject L failed to satisfy indicator E1. Furthermore, Subject L did not employ any mathematical formulas. Although the subject had initially recorded the dimensions of the pizza diameters, they demonstrated a lack of understanding regarding how to utilize this structural information to calculate the area of the circle. This indicates that Subject L was unable to utilize mathematical formulas or concepts accurately, and therefore, indicator E2 was not fulfilled.

Aspect: Interpret (Task 1)

In Task 1, Subject L merged the problem-solving process and the final conclusion into a single statement, writing: "Pizza 1 is cheaper, because the price is lower." Low-ability students tend to draw conclusions without a sound mathematical foundation, relying merely on superficial observation. Consequently, the conclusion formulated by the subject was not analysis-based. This indicates that Subject L was unable to interpret the mathematical results, and therefore, indicator interpret (I) was not fulfilled.

3.2 Analysis of Task 2: Low-Ability Student (Subject L)

Aspect : Formulate (Task 2)

Subject L sketched a front-view diagram of the garage, representing the roof as a triangle with a noted slant height of 2.5 m, and depicting a rectangle labeled with a length of 6 m. However, the 6 m dimension actually corresponded to the length of the garage in the side-view diagram. Furthermore, critical information was omitted, specifically the roof height of 1 m. Based on Subject L's drawing, the subject experienced difficulties in connecting the structural information between the front-view and side-view diagrams. Consequently, Subject L wrote most of the essential information, but some parts remained incomplete or inaccurate, thereby only partially satisfying indicator F1.Subject L misunderstood the contextual problem presented in the task; from the outset, the subject presumed that the roof of the garage was triangular, whereas it was actually rectangular. This indicates that Subject L was unable to transform the "garage roof" context into the correct geometric model. As a result, Subject L was unable to transform the problem into a mathematical form, and therefore, indicator F2 was not fulfilled.

Aspect: Employ (Task 2)

Subject L was unable to demonstrate any strategy or systematic steps for problem-solving. Consequently, the sketches of the triangle and rectangle, along with their numerical labels, were meaningless because they were not utilized in any calculation. This finding aligns with the interview excerpt with Subject L detailed below:

(Q): What strategy will you use to solve this problem?

(L): I do not know. I am confused, Ma'am.

Based on the written test results and the interview, Subject L lacked any viable solution strategy, thereby failing to satisfy indicator E1. Furthermore, Subject L did not apply any mathematical formulas or concepts to find a solution, as the subject lacked a problem-solving strategy from the outset. It can be concluded that Subject L was unable to utilize mathematical formulas or concepts, and therefore, indicator E2 was not fulfilled.

Aspect: Interpret (Task 2)

Subject L did not formulate any written conclusion because, from the outset, the subject did not know which strategy or formula should be deployed to resolve the problem. Consequently, no conclusion could be structured. This indicates that Subject L was unable to interpret the mathematical results, and therefore, indicator interpret (I) was not fulfilled.

Based on the elaboration of the research findings above and the assessment rubric, the summary of students' ability characteristics based on the PISA Mathematical Literacy Aspects (Formulate, Employ, Interpret) can be synthesized in Table 9.

Table 9. Characteristics of Students' Abilities Based on the Three Aspects

Ability Category	Assessment Aspects		
	Formulate	**Employ**	**Interpret**
High	1. Writes all essential information completely and accurately, and clearly defines what is asked. 2. Demonstrates the ability to construct an accurate	1. The solution strategy is systematic, logical, and efficient.	Interprets results with moderate accuracy, but

	mathematical model appropriate to the problem context.	2. Applies formulas or concepts accurately with correct calculations.	the reasoning is incomplete
Moderate	1. Students demonstrated a proficient ability to identify critical information and determine the core question within the problem context. In simpler tasks, they were capable of formulating the problem completely and accurately; however, in more complex problem-solving scenarios, several data points remained unrecorded or were presented with minor inaccuracies. 2. Students demonstrated a proficient ability to construct mathematical models. In one specific task, they were capable of formulating the mathematical model accurately. However, in a more complex problem requiring the integration of spatial-geometric representations, the constructed model was only partially correct.	1. Students demonstrated varying degrees of ability in designing solution strategies. In one specific task, they were capable of employing a systematic, logical, and efficient strategy; however, they encountered difficulties in another task. This outcome indicates that the students' capacity to construct solution strategies remained inconsistent when confronted with problem contexts where the mathematical concepts were presented implicitly, thereby requiring the students to discover the underlying concepts independently. 2. Students' ability to apply relevant mathematical formulas and concepts remained inconsistent. In one specific task, the conceptual application and subsequent calculations were accurate; however, in another task, the computational outcomes were incorrect due to an initial misunderstanding of the mathematical concepts.	Unable to interpret the mathematical results.
Low	1. In one task, students recorded critical information, whereas in another task, they provided only partial information that remained incomplete and inaccurate. 2. Students demonstrated a limited ability to construct mathematical models. In one specific task, they developed a mathematical model, albeit one that contained conceptual errors; conversely, in a more complex task that required the integration of spatial-geometric representations, the students were unable to formulate a complete model.	1. Students demonstrated a low level of ability in designing strategies to find mathematical solutions. The strategy employed in the first task was neither accurate nor complete; conversely, in the second task, students were unable to determine an appropriate solution strategy. 2. Unable to utilize mathematical formulas or concepts	Unable to interpret the mathematical results.

DISCUSSION

Based on the research findings presented above, it was revealed that the high-ability student (Subject H) was capable of recording and linking all critical information using appropriate mathematical representations, employing effective solution strategies and procedures, and generating accurate solutions. High-ability students interpreted the results reasonably well, although their reasoning remained somewhat incomplete. This occurred because, within the interpret indicator, students are required to reflect upon mathematical solutions or conclusions; they must not only provide correct answers but also interpret them within real-world problem contexts and evaluate whether the obtained results or conclusions are reasonable (Alagumalai & Buchdahl, 2021).

The lack of comprehensive justification or argumentation within the interpret aspect may stem from students' inattention and misunderstanding of the task instructions (Pavlovicova et al., 2023). In fact, the prompt in Task 1 explicitly stated, "Give your reasons." This omission could be attributed to the reality that most students are accustomed to a learning environment that heavily emphasizes procedures and final outcomes. Classroom practices often condition students to believe that once a numerical result is obtained, the problem-solving process is complete (Papadopoulos & Dagdilelis, 2008). Consequently, students focus primarily on formula application; however, they are unaccustomed to explaining the meaning behind their numerical findings and rarely evaluate whether their answers are reasonable within the problem context.

Another contributing factor is the lack of justification practices during routine instruction. In typical classroom settings, students frequently receive full marks simply by demonstrating correct steps and computations. Procedural fluency is often assessed solely based on numerical representations or the final results produced by the students (Cartwright, 2023). As a result, students perceive no necessity to write down reasons, are unhabituated to formulating conclusions, and lack the practice to defend their answers with logical arguments. When confronted with PISA tasks that demand qualitative explanations, they are at a loss for what to write, despite having generated accurate computational results.

Furthermore, this omission may stem from the fact that students rarely conduct sanity checks on their final answers (Papadopoulos & Dagdilelis, 2008). Students frequently accept computational results at face value without verification (Kontorovich, 2019). Within the interpretation stage, students are expected to evaluate whether the obtained outcomes are reasonable or plausible. For instance, in Task 2, Subject H determined that the roof length was 6 m and the roof width was approximately 2.69 m to 2.7 m, resulting in a single roof area of around 16.2 m^2. However, Subject H failed to provide a justification demonstrating that the total roof area of approximately 32.4 m^2 constituted a realistic outcome in light of the existing data and prior calculations. Empirical evidence from Deslis & Desli (2023) corroborates this finding, indicating that students systematically experience difficulties when evaluating whether a computational result is reasonable within a given problem context.

Conversely, the moderate-ability student (Subject M) performed well in identifying critical information and formulating the mathematical problem in Task 1, but failed to do so in Task 2. Subject M was also capable of constructing an appropriate mathematical model in one task, although minor inaccuracies or overlooked information remained present in specific problems. Regarding the formulate indicator in Task 2, the moderate-ability student provided incomplete information. Subject M only utilized the side-view diagram and was unable to link the information from the front-view and side-view representations. This omission could stem from the student's error in identifying relevant information from visual representations. Moderate-ability students often focus more on visual similarity rather than the underlying mathematical information (Thomaneck et al., 2025). In this case, Subject M focused on the rectangular side-view diagram and disregarded the front-view diagram, which contained substantial mathematical information. Task 2 presented information in a three-dimensional layout consisting of front-view and side-view diagrams. Students were required to extract multiple data points simultaneously, specifically: building length = 6 m, half of the building width = 2.5 m, and roof height = 1 m. The moderate-ability student (Subject M) only extracted partial, visually conspicuous information, such as the building length of 6 meters or the wall height of 2.5 meters. However, the subject ignored other essential data required to construct a mathematical model, such as the roof height of 1 meter and the half-width of the building of 2.5 meters.

Another contributing factor is the difficulty in integrating information from two distinct representations. This obstacle occurs because students struggle to determine the relationships between geometric elements and to connect visual representations with the appropriate mathematical concepts (Ramdjid et al., 2022). Task 2 requires students to simultaneously connect information from two different visual perspectives. The front-view diagram is used to determine the slant height of the roof, whereas the side-view diagram is utilized to determine the length of the roof plane. The moderate-ability student (Subject M) was capable of reading a single diagram in isolation; however, the subject encountered difficulties when required to combine both representations into a unified geometric model. Consequently, the identified information was not recorded completely, and the spatial relationships between dimensions were not fully understood. Furthermore, this issue may be attributed to routine instructional practices that are primarily procedure-oriented. In standard classroom settings, students frequently solve problems where the information is explicitly stated, the geometric shapes are pre-identified, and the required formulas are immediately apparent. Conversely, PISA tasks demand that students independently determine the critical information, the relevant geometric shapes, and the structural relationships between dimensions. Due to a lack of familiarity with the mathematization process, students consistently experience difficulties during the formulate stage.

In Task 2, the strategy employed was inaccurate and incomplete. This deficiency can be attributed to the incomplete recording of critical information and errors in mathematical modeling during the formulate stage; consequently, these conceptual errors carried over to the subsequent employ stage, which involves designing a problem-solving strategy (Poch et al., 2015). During the formulate stage, Subject M ignored essential information required to construct the mathematical model, such as the roof height of 1 meter and the half-width of the building of 2.5 meters. As a result, Subject M failed to consider utilizing the Pythagorean theorem to determine the roof width, which constituted a vital component of the problem-solving (employ) strategy.

During the problem-solving process, Subject M's consistency in strategy selection and precision in executing computational procedures still require improvement, as evidenced by errors identified across different problem contexts. In Task 2, the strategy employed was inaccurate and incomplete. This deficiency can be attributed to the incomplete recording of critical information and errors in mathematical modeling during the formulate stage; consequently, these conceptual errors carried over to the subsequent employ stage, which involves designing a problem-solving strategy. Specifically, during the formulate stage, Subject M ignored essential information required to construct the mathematical model, such as the roof height of 1 meter and the half-width of the building of 2.5 meters. As a result, the subject failed to consider utilizing the Pythagorean theorem to determine the roof width, which constituted a vital component of the problem-solving (employ) strategy.

Another contributing factor is the partial nature of the students' conceptual understanding. Moderate-ability students typically recognize some of the required concepts, such as utilizing the area formula for a rectangle to calculate the roof area, yet they disregard other necessary concepts, such as the Pythagorean theorem derived from the front-view diagram. Consequently, this oversight leads to subsequent cascading errors, including computational inaccuracies, incorrect final answers, and flawed conclusions. Furthermore, the difficulty in integrating multiple mathematical concepts serves as an underlying reason, given that during the employ stage, subjects are frequently required to employ a combination of several concepts simultaneously rather than relying on a single one. In the geometric task (Task

2), students must connect the concept of a right-angled triangle with that of a rectangular area. The moderate-ability student (Subject M) was only capable of applying one of these concepts and encountered significant difficulties when required to combine multiple concepts into a single, cohesive solution sequence.

Within the interpretation aspect, the moderate-ability student (Subject M) experienced difficulties in interpreting and communicating the obtained mathematical results within the problem context. In Task 1, Subject M exhibited hesitancy in drawing a definitive conclusion primarily because the final result was a fractional value. This outcome can be attributed to students' general difficulties in connecting final solutions to real-world contexts and a lack of understanding regarding the concepts of ratio and proportion. Consequently, Subject M struggled to explain the contextual meaning of the solution within the problem scenario.

Low-ability students (Subject L) tend to experience difficulties at every stage of the mathematical literacy problem-solving process. They struggle to record information accurately, demonstrate weaknesses in mathematical modeling and strategy selection, are unable to apply formulas or concepts correctly, and fail to draw conclusions or interpret final results. The errors and failures exhibited by low-ability students across all three mathematical literacy processes—namely formulating, employing, and interpreting—indicate that these students encounter obstacles from the very initial phase of problem-solving.

During the formulate stage, Subject L was unable to identify critical information, comprehend visual representations, and construct an appropriate mathematical model in accordance with the problem context, particularly in Task 2. This deficiency directly impacted the subsequent employ stage, wherein the student was unable to determine an appropriate solution strategy, correctly execute mathematical concepts and procedures, and integrate the various required concepts. Subject L's failure during this employ stage occurred in both Task 1 and Task 2.

Consequently, the compounding failures in the two preceding stages left the low-ability student unable to interpret the obtained outcomes, whether in terms of interpreting results, evaluating the plausibility of solutions, or providing contextual reasons and justifications. These findings reveal that a low level of mathematical literacy is not merely caused by computational weaknesses; rather, it is driven by limitations in interconnected mathematical capabilities—specifically mathematization, reasoning, representation, and communication—within the problem-solving process.

CONCLUSION

The findings of this study demonstrate that students' mathematical literacy skills vary according to their proficiency levels. High-ability students successfully identified essential information, constructed accurate mathematical models, and systematically applied relevant concepts and strategies. This indicates that high-ability students effectively met the indicators for the formulating and employing stages, although they still demonstrated deficiencies in providing justifications and evaluating the reasonableness of outcomes during the interpreting stage. Moderate-ability students exhibited adequate capabilities within specific problem contexts; however, they displayed inconsistency when confronted with more complex geometric representations (as evidenced in Task 2). In these complex tasks, moderate-ability students struggled to integrate information from multiple representations, construct comprehensive mathematical models, and combine diverse mathematical concepts. These limitations led to errors during the employing stage, which subsequently hindered their ability to interpret results accurately.

Meanwhile, low-ability students experienced pervasive difficulties across all dimensions of mathematical literacy, spanning from identifying information and modeling problems to selecting and executing solution strategies, as well as interpreting outcomes. Furthermore, low-ability students tended to draw conclusions lacking a mathematical foundation, relying merely on surface-level visual observations (as evidenced in Task 1); consequently, their conclusions were not grounded in rigorous analysis. These findings reveal that the three core PISA mathematical literacy processes (formulating, employing, and interpreting) are deeply interconnected, suggesting that deficiencies in the initial phases inevitably compromise student success in subsequent stages. Across all three aspects, the interpreting aspect was the process most frequently unmet by all three participants, primarily because proficiency in interpretation is highly contingent upon the successful execution of the preceding two stages.

The finding that students experience difficulties in the dimensions of formulating, employing, and interpreting underscores the critical need for mathematics instruction oriented toward the comprehensive development of mathematical literacy. Educators must condition students to identify essential information, comprehend visual representations, and construct mathematical models from contextual situations prior to performing calculations (formulate). In geometry instruction specifically, learning should be designed to provide students with extensive experience in diagram and visual interpretation, including two-dimensional drawings, geometric shapes, floor plans, sketches, and contextual models. Through these activities, students can develop the spatial-visual skills necessary to understand the relationships between geometric elements and recognize relevant information within a problem.

Furthermore, teachers must not only ensure that students master formulas and computational procedures but also understand when, why, and how these concepts are utilized across diverse problem contexts (employ). Instruction should provide opportunities for students to independently construct solution strategies through non-routine and contextual problems that require multi-step solutions (employ).

In the instructional process, educators must look beyond computational mechanics or the accuracy of the final numerical answer to focus heavily on the quality of students' explanations, reasoning, and explicit conclusion-making. This implies that teachers must deliberately train students to interpret the qualitative meaning of their final results rather than merely generating numbers. Within this interpreting stage, targeted training in unit rate reasoning is essential—as evidenced by the challenges faced by moderate-ability students in Task 1. Teachers need to foster learning environments that build a robust conceptual understanding of ratios and proportional relationships, which serve as the foundation for solving various mathematical literacy tasks, including PISA items. Additionally, students must be trained to evaluate the reasonableness of their solutions and provide appropriate arguments, reasoning, and justifications aligned with the problem context (interpret).

Several limitations should be acknowledged in the present study. First, the evaluation of mathematical literacy within the Space and Shape content domain was limited to only two items. Although these instruments were adapted from validated, authentic PISA tasks with minor modifications, the limited item coverage remains a constraint. Second, the study involved a small sample size of only three participants. Future research would benefit from employing a larger sample and expanding the item coverage; such methodological adjustments are critical to enhance the stability, accuracy, and generalizability of the findings.

RECOMMENDATION

Consequently, the optimization of problem-based learning, contextual teaching and learning, mathematical discussions, visual representations, and reflective activities is imperative to ensure that students not only derive answers but also understand, apply, and communicate the significance of mathematics in real-world situations. Moreover, teachers should implement scaffolding strategies by providing gradual assistance, such as utilizing prompting questions tailored to each dimension (formulating, employing, and interpreting).

This study focuses on students' mathematical literacy within the PISA content domain of Space and Shape. Therefore, recommendations for future research include examining mathematical literacy through PISA tasks in other content domains, namely (1) Change and Relationships, (2) Quantity, and (3) Uncertainty and Data. Additionally, future studies would benefit from utilizing a broader range of PISA tasks, involving a larger sample of research participants, and employing a design-based intervention to systematically address and mitigate students' documented mathematical difficulties.

ACKNOWLEDGMENTS
The author thanks everyone who helped finish this study. In particular, I extend my appreciation to the participating school and to the LP2M of the University for their facilitation and support. The author is also grateful to my colleagues for their constructive suggestions and technical assistance. Without the support and collaboration of all parties, this research would not have been successfully completed.

FUNDING INFORMATION
The Article Processing Charge (APC) was funded by the 2025 Publication Assistance Program for Reputable Journals.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Karina Nurwijayanti	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Tri Kurniah Lestari		✓		✓	✓					✓	✓	✓		

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

INFORMED CONSENT
We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY
The data that support the findings of this study are available on request from the corresponding author. The data, which contain information that could compromise the privacy of research participants, are not public.

REFERENCES

Adams, J., Resnick, I., & Lowrie, T. (2023). Supporting Senior High-School Students' Measurement and Geometry Performance: Does Spatial Training Transfer to Mathematics achievement? *Mathematics Education Research Journal*, *35*(4), 879–900. https://doi.org/10.1007/s13394-022-00416-y

Aini, I. N. (2022). Developing PISA-Like Math Problems in The Content of Space and Shape ThroughThe Context of Historical Buildings. *Journal on Mathematics Education*, *13*(4), 723–738. https://doi.org/10.22342/jme.v13i4.pp723-738

Alagumalai, S., & Buchdahl, N. (2021). PISA 2012 : Examining The Influence of Prior Knowledge , Effects on Achievements in Mathematical Literacy Processes – Interpret , Employ and Formulate. *Australian Journal of Education*, *65*(2), 173–194. https://doi.org/10.1177/00049441211031674

Borgonovi, F., Choi, A., & Paccagnella, M. (2021). The Evolution of Gender Gaps in Numeracy and Literacy Between Childhood and Young Adulthood. *Economics of Education Review*, *82*(November 2019), 1–24. https://doi.org/10.1016/j.econedurev.2021.102119

Börner, K., Bueckle, A., & Ginda, M. (2019). *Data Visualization Literacy : Definitions , Conceptual Frameworks , Exercises , and Assessments*. *116*(6), 1857–1864. https://doi.org/10.1073/pnas.1807180116

Cartwright, K. (2023). Observing Mathematical Fluency Through Students' Oral Responses. *The Journal of Mathematical Behavior*, *69*(March 2023). https://doi.org/10.1016/j.jmathb.2023.101047

Clarke, M., & Bazaldua, D. (2021). *Primer on Large-Scale Assessments Of Educational Achievement*. World Bank Group. https://doi.org/10.1596/978-1-4648-1659-8

Dagdelen, M., & Yildiz, A. (2022). The Relationship between the Secondary Students ' Mathematics Anxiety and Mathematical Literacy Self-Efficacy. *Journal of Computer and Education Research*, *10*(20), 636–655. https://doi.org/10.18009/jcer.1165625

Deslis, D., & Desli, D. (2023). Does this Answer Make Sense ? Primary School Students and

Adults Judge the Reasonableness of Computational Results in Context - Based and Context - Free Mathematical. *International Journal of Science and Mathematics Education*, *21*, 71–91. https://doi.org/10.1007/s10763-022-10250-0

Dewi, N., & Maulida, N. (2023). The Development of STEM-nuanced Mathematics Teaching Materials to Enhance Students ' Mathematical Literacy Ability Through Information and Communication Technology-Assisted Preprospec Learning Model. *International Journal of Educational Methodology*, *9*(2), 409–421. https://doi.org/10.12973/ijem.9.2.409

Faizatunnisa, Tayeb, T., Syah, F. A., Khaerani, F. N., & Saraswati. (2023). Didaktic Analysis of Junior High School Students Mathematical Literacy Skill On Space and Shape. *Alauddin Journal of Mathematics Education*, *5*(2), 160–180.

Gal, I., Grotlüschen, A., Tout, D., & Kaiser, G. (2020). Numeracy , Adult Education , and Vulnerable Adults : A Critical View of A Neglected Field. *ZDM Mathematics Education*, *52*(3), 377–394. https://doi.org/10.1007/s11858-020-01155-9

Japa, N., Suarjana, & Widiana. (2017). Media Geogebra dalam Pembelajaran Matematika. *International Journal of Natural Science and Engineering*, *1*(2), 40–47. https://doi.org/10.23887/ijnse.v1i2.12467

Kabael, U., & Baran. (2023). An Investigation of Mathematics Teachers ' Conceptions of Mathematical Literacy Related to Participation in a Web-Based PISA Course. *Bartın University Journal of Faculty of Education*, *12*(2), 315–324. https://doi.org/10.14686/buefad.1053557

Kontorovich, I. (2019). Why Do Students Not Check Their Solutions to Mathematical Problems ? A Field-Based Hypothesis on Epistemological Status. *International Journal of Mathematical Education in Science and Technology*, *50*(7), 1–13. https://doi.org/10.1080/0020739X.2019.1650304

Lane, D., Lynch, R., & Mcgarr, O. (2018). Problematizing Spatial Literacy Within The School Curriculum. *International Journal of Technology and Design Education*, *September*. https://doi.org/10.1007/s10798-018-9467-y

Lane, D., & Sorby, S. (2021). Bridging The Gap : Blending Spatial Skills Instruction Into a Technology Teacher Preparation Programme. *International Journal of Technology and Design Education*, *0123456789*. https://doi.org/10.1007/s10798-021-09691-5

Liu, M., Xiao, G., & He, H. (2025). Research on the Solution of Solid Geometry Problems in College Entrance Examination Mathematics — Take the National I / II / III Test from 2018 to 2022 as an Example. *Journal of Educational Research and Policies*, *07*(3), 118–125. https://doi.org/10.53469/jerp.2025.07(03).20

Machromah, I. U., Prayitno, H. J., & Faiziyah, N. (2020). Designing PISA-like Mathematics Task to Assess Students ' Mathematical Literacy. *Universal Journal of Educational Research*, *8*(10), 4986–4995. https://doi.org/10.13189/ujer.2020.081072

Maharani, R. A., & Aini, I. N. (2021). Deskripsi Tahapan Problem Solving Siswa Pada Soal Bertipe Pisa Space and Shape Content. *Jurnal Cendekia: Jurnal Pendidikan Matematika*, *05*(02), 1193–1200.

Masfufah, R., & Afriansyah, E. A. (2021). Analisis Kemampuan Literasi Matematis Siswa melalui Soal PISA. *Mosharafa: Jurnal Pendidikan Matematika*, *10*(2), 291–300.

Morgan, C., & Volante, L. (2016). A review of the Organisation for Economic Cooperation and Development ' s international education surveys : Governance , human capital discourses , and policy debates. *Policy Futures in Education*, *14*(6), 775–792. https://doi.org/10.1177/1478210316652024

Munfarikhatin, A., & Natsir, I. (2020). Analisis Kemampuan Literasi Matematika Siswa Pada Konten Space And Shape. *Histogram : Jurnal Pendidikan Matematika*, *4*(1), 128–138. https://doi.org/10.31100/histogram.v4i1.569

Nasution, R. S., Muhammad, K., Fauzi, A., & Syahputra, E. (2019). *Developing Mathematics*

Problem Based on PISA Level of Space and Shape Content to Measure Student ' s Mathematics Problem Solving Ability. *7*(10), 660–669. https://doi.org/10.12691/education-7-10-1
Ng, D. T. K., Tsui, M. F., & Yuen, M. (2022). Exploring the use of 3D printing in mathematics education : A scoping review. *Asian Journal for Mathematics Education*, *1*(3), 338–358. https://doi.org/10.1177/27527263221129357
OECD. (2006). *PISA Released Items - 2006* (Issue December).
OECD. (2012). *PISA Released Items 2012*.
OECD. (2018). *PISA for Development Assessment and Analytical Framework*. OECD Publishing. https://doi.org/10.1787/9789264305274-en
OECD. (2022). *PISA 2022 Assessment and Analytical Framework*. OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en.
OECD. (2024). *New PISA Results on Creative Thinking : Can Students Think Outside The Box?*
Ozdemir, Y., & Polat, S. (2024). Teachers With a Refugee Background Work as Educators in Germany. *Journal of Education and Learning (EduLearn)*, *18*(4), 1394–1404. https://doi.org/10.11591/edulearn.v18i4.21738
Ozgen, K. (2019). Problem-Posing Skills for Mathematical Literacy: The Sample of Teachers and Pre-Service Teachers. *Eurasian Journal of Educational Research*, *19*(84), 177–212. https://doi.org/10.14689/ejer.2019.84.9
Papadopoulos, I., & Dagdilelis, V. (2008). Students' Use of Technological Tools For Verification Purposes in Geometry Problem Solving. *The Journal of Mathematical Behavior*, *27*(4), 311–325. https://doi.org/10.1016/j.jmathb.2008.11.001
Pavlovicova, G., Gonda, D., Tirpakova, A., & Duris, V. (2023). Interpretation of Mathematical Tasks Misunderstanding in the Context of Disciplinary Literacy of University Students Gabriela. *European Journal of Contemporary Education*, *12*(3), 962–976. https://doi.org/10.13187/ejced.2023.3.962
Poch, A. L., Garderen, D. Van, & Scheuermann, A. M. (2015). Students ' Understanding of Diagrams for Solving Word Problems : A Framework for Assessing Diagram Proficiency. *Sage Journals*, *47*(3), 153–162. https://doi.org/10.1177/0040059914558947
Qadry, I. K. (2022). Dalam Menyelesaikan Soal PISA Konten Space And Shape Pada Kelas IX SMP Negeri 13 Makassar. *Infinity: Jurnal Matematika Dan Aplikasinya (IJMA)*, *2*(2), 78–92.
Ramdjid, N., Sukestiyarno, S., Rochmad, R., & Mulyono, M. (2022). Students' Difficulties in Solving Geometry Problems. *Cypriot Journal of Educational Sciences*, *17*(12), 4628–4640. https://doi.org/10.18844/cjes.v17i12.7039 Received
Schmidt, W. H., Burroughs, N. A., Zoido, P., & Houang, R. T. (2015). The Role of Schooling in Perpetuating Educational Inequality: An International Perspective. *Educational Researcher*, *44*(7), 371–386. https://doi.org/10.3102/0013189X15603982
Silitonga, R. H., Molle, J. S., & Ngilawajan, D. A. (2023). Increasing Mathematical Problem-Solving Abilities Using Video Tutorials Of The Three-Dimensional Coordinate System In Spatial Analytic Geometry. *JOHME : Journal of Holistic Mathematics Education*, *7*(2), 212–226. https://doi.org/10.19166/johme.v7i2.7575 E-ISSN:
Sinclair, N., Bussi, M. G., De Villiers, M., Jones, K., Ulrich, K., Allen, L., & Owens, K. (2016). Recent Research on Geometry Education : An ICME - 13 Survey Team Report. *ZDM: International Journal on Mathematics Education*, *48*, 691–719. https://doi.org/10.1007/s11858-016-0796-6
Song, Y. (2024). Investigating The Relationship Between Math Literacy and Linguistic Synchrony in Online Mathematical Discussions Through Large-Scale Data Analytics. *British Journal of Educational Technology*, *55*(5), 2226–2256. https://doi.org/10.1111/bjet.13444
Sugiarti, T., Suwito, A., & Ummah, F. R. (2022). Representasi Matematis Siswa dalam

Menyelesaikan PISA Konten Space and Shape Ditinjau dari Adversity Quotient. *PYTHAGORAS: Jurnal Matematika Dan Pendidikan Matematika*, *17*(2), 425–434. https://doi.org/10.21831/pythagoras.v17i2.47686

Suprapto, E., Suryani, N., Siswandari, & Mardiyana. (2023). Students' Mathematical Literacy Skill in Term of Gender Differences : A comparative Study. *International Journal of Evaluation and Research in Education (IJERE)*, *12*(4), 2280–2285. https://doi.org/10.11591/ijere.v12i4.27224

Tekin, E., & Pinar, Y. (2023). Preschool Attendance, School Starting Age and Cultural-Financial Resources as Predictors of Adolescent's Reading Comprehension : Evidence From PISA 2025 and 2028. In *Sage Journals* (pp. 1–15). https://doi.org/10.1177/21582440231207690

Thomaneck, A., Vollstedt, M., & Schindler, M. (2025). Exploring Causes of the Graph-as-picture Error in Students ' Graph Interpretation : Insights from an Eye-tracking Study with Ninth Graders. *Journal Für Mathematik-Didaktik*, *46*(13), 1–33. https://doi.org/10.1007/s13138-025-00264-w

Wang, T., & Yang, D. (2016). A Comparative Study of Geometry in Elementary School Mathematics Textbooks from Five Countries. *European Journal of STEM Education*, *1*(3), 1–10. https://doi.org/10.20897/lectito.201658