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. 1516-1528

Exploring Eigth-Grade Students' Mathematical Literacy in PISA-Adapted Space and Shape Problem at Levels 3-5

[1]Dwi Arisma Wahyudi, [2]*Sufyani Prabawanto, [3]Al Jupri

[1]Master's Program of Mathematics Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

[2]Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

[3] Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia

*Corresponding Author e-mail: sufyani@upi.edu

Received: May 2026; Revised: June 2026; Published: July 2026

Abstract

This study explores the mathematical literacy profiles of 30 eighth-grade students in Bandung Barat Regency, focusing on their abilities during the formulating stage of PISA-adapted geometry tasks across Levels 3, 4, and 5. Utilizing a qualitative descriptive-exploratory design, data were collected through a Mathematical Literacy Test (MLT) focusing on rectangular area and perimeter alongside task-based clinical interviews. Student responses were mapped using a specialized representational action coding scheme (R1–R7). The empirical findings reveal a critical negative trend: as task complexity escalates, successful mathematical formulation plummets, leaving over 80% of students trapped in either absolute cognitive paralysis or unscientific guessing at Levels 4 and 5. Specifically, non-response status (R7) reached 46.67% at Level 4 due to severe reading literacy barriers and working memory overload under dense linguistic contexts. Meanwhile, subjective intuition (R6) was the most dominant pattern, affecting 50% of the cohort at Level 5, driven by a profound epistemological fragmentation where real-world scenarios are treated as isolated from formal mathematics. Dysfunctional visual scaffolding (R4) and rigid procedural dependencies (R3) further stalled progression. These systemic failures at the upstream formulating stage ultimately blocked students from reaching the employing or interpreting phases.

Keywords: Mathematical literacy; PISA; Geometric representation; Problem solving; Formulating stage

How to Cite: Wahyudi, D. A., Prabawanto, S., & Jupri, A. (2026). Exploring Eigth-Grade Students' Mathematical Literacy in PISA-Adapted Space and Shape Problem at Levels 3-5. *Prisma Sains: Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan IPA IKIP Mataram*, *14*(3), 1516–1528. https://doi.org/10.33394/j-ps.v14i3.20663

https://doi.org/10.33394/j-ps.v14i3.20663

INTRODUCTION

The Indonesian government is currently intensifying the Academic Ability Test (TKA) program for students, which aims to provide an objective and standardized measure of academic achievement on a national scale (Kemdikdasmen, 2025). A crucial component tested within the TKA framework is mathematics, which is intentionally designed to shift away from the mechanical memorization of formulas toward demanding that students apply logical and contextual problem-solving skills (Kemdikdasmen, 2025). The characteristics of these TKA tasks correlate closely with the mathematical literacy domain, which serves as a benchmark for student cognitive readiness in the modern era (OECD, 2023). Nevertheless, empirical field data reveals a stark quality disparity; based on the 2025 Education Report Card (*Rapor Pendidikan*) results, the mathematical literacy and numeracy skills of lower secondary school students in Indonesia remain stagnant in the moderate category, plateauing at 69.61% (Kemendikdasmen, 2025). The low achievement in mathematical literacy is of major concern because it undermines students' abilities to develop logical-analytical thinking and problem-solving skills, which are essential not only in academic settings but also for fostering global competitiveness in a technology-driven era. This foundational competence is affected by diverse cognitive, socio-economic, and instructional factors, and addressing these through effective, integrated educational strategies is critical (Kusmayadi et al., 2022; Hamidah et al., 2025; Shin et al., 2025)

One essential domain within the TKA that presents a formidable hurdle for most students is geometry and measurement, particularly concerning the perimeter and area of flat shapes such as rectangles (Pusmendik, 2025). Students struggle to visualize and manipulate 3D objects, which is critical for understanding geometric transformations and spatial relationships (Sagge, 2025; Ikhsan et al., 2024; Murni et al., 2025). Prior research confirms that these barriers stem from learning obstacles that are ontogenic—due to limitations in students' psychological development; didactical—resulting from instructional teacher strategies; and epistemological—caused by a restricted understanding of the overarching scientific context (Rahayu et al., 2023;Hendriyanto et al., 2024;Wardani & Prabawanto, 2025). These factors are further compounded by poor mathematical literacy, which leads to misinterpretation of information, errors in representation, and increased cognitive load (Rojas & Benakli, 2020; Rahayuningsih et al., 2025); Ratnaningsih & Hidayat, 2021). Consequently, students tend to resort to a defensive strategy of procedurally memorizing the formulas for perimeter ($K = 2 \times (p + l)$) and area ($L = p \times l$) without grasping their conceptual meaning, ultimately leading to fatal errors where the two concepts are frequently interchanged during application.

This problematic condition becomes even more pronounced when students' reasoning performance is evaluated using instruments that demand higher-order thinking skills (HOTS), such as contextual tasks adapted from the PISA framework. Students often struggle to identify real-world problems that can be mathematically modeled, especially those open to multiple solutions or requiring nuanced assumptions (Sevinc, 2025; Hu et al., 2026). Although studies surrounding mathematical literacy barriers and geometric problem-solving have been widely conducted in Indonesia, the vast majority of prior literature heavily concentrates on analyzing procedural errors, formal misconceptions, or computational mistakes within completed student responses. Consequently, A study on students' reasoning about geometric relationships (e.g. classifying triangles and quadrilaterals) revealed widespread misconceptions and confusion about hierarchical definitions of shapes. Students often provided incorrect or incomplete responses, indicating gaps in conceptual understanding (Anselmo et al., 2021; Rahaju et al., 2026). While this study does not explicitly address blank answers, it suggests that qualitative exploration of reasoning processes can uncover the roots of such non-responses. In fact, Early reading skills and literacy are closely tied to mathematical achievement. For instance, reading ability has been shown to predict performance on high-stakes math tests, even in early grades, suggesting that reading barriers can indirectly affect math outcomes by limiting comprehension of math problems (Anselmo et al., 2021; Kiss & Christ, 2019).

To bridge this research gap, this study aims to comprehensively profile the mathematical literacy structures of eighth-grade students during the formulating stage when solving PISA-adapted Space and Shape geometry problems. The novelty of this study lies in the implementation of a student mathematical representational action framework (coded from R1 to R7), specifically designed to map the anatomy of student thinking—ranging from those capable of critiquing a model, those trapped in subjective intuition, to those experiencing a complete cognitive impasse or non-response. Limiting the scope of the problem to PISA difficulty Levels 3, 4, and 5 was done purposively, as the stimulus characteristics within this range demand a radical cognitive transition from procedural thinking to multi-step conceptual reasoning. By combining the analysis of written artifacts based on the R1–R7 coding scheme with in-depth clinical interviews, this study is expected to uncover hidden cognitive obstacles among students regarding rectangular perimeter and area that trigger early-stage modeling failures.

METHOD

Research Type or Design

This study employs a qualitative approach with a descriptive-explorative design. This framework is utilized to uncover and describe, in comprehensive detail, the characteristics of students' mathematical literacy profiles based on representational phenomena that emerge naturally during the problem-solving process. The research focuses on exploring the underlying cognitive processes behind students' mathematical actions, specifically regarding the barriers encountered when transforming real-world situations into formal mathematical models. To balance the qualitative nature of this design, descriptive quantification (frequency and perecentage distribution) is integrated within a qualitative content analysis framework to map students' structural error patterns across each task item.

Participant, Sample, or Subject

The initial participants of this study consisted of eighth-grade students at a public secondary school in Bandung Barat Regency, Indonesia. Academic records confirmed that all 30 participants had completed identical classroom instruction on plane geometry, specifically covering the area and perimeter of quadrilaterals (rectangles). Subject selection for the subsequent stage was conducted using a purposive sampling technique based on variations in representational actions observed in the students' written response scripts. A total of 6 representative subjects were selected to participate in task-based clinical interviews.

Instruments

Mathematical Literacy Test (MLT). The primary written instrument consists of four essay items adapted from the PISA framework, specifically focusing on the "Space and Shape" content domain. These task items are designed hierarchically from Level 3 to Level 5 to capture the gradation of students' abilities across various contexts:

a. Item 1 - Level 3 (Occupational Context): *The Wood Flooring Project*; evaluating students' ability to select and implement simple problem-solving strategies involving rectangular areas.
b. Item 2 - Level 3 (Scientific Context): *Solar Panel Optimization*; testing students' flexibility in applying familiar geometric concepts to novel structural layouts.
c. Item 3 - Level 4 (Social Context): *Revitalization of Densely Populated Settlements*; assessing the ability to work effectively with explicit geometric models in complex, concrete social situations.
d. Level 5 (Personal Context): *Tablecloth Shopping*; examining the capacity to develop models and formulate constraints and state realistic spatial assumptions.

To ensure instrument validity, the MLT underwent an expert judgment process by three validators: two professors in mathematics education and one senior secondary school mathematics teacher.

Semi-Structured Interview Protocol. The interview protocol serves as a confirmatory tool (cognitive audit) to verivy the students' written work. The interviws lasted approximately 20-30 minutes per subject, were audio-recorded, and subsequently transcribed verbatim. This protocol utilizes open-ended questions designed to delve deeper into the rationale behind specific representational strategies, clarify the thought processes involved in transforming problem narratives into mathematical models, and investigate the psychological and linguistic factors leading to non-response phenomena or intuition-based answers.

Data Analysis Techniques

Data from the written tests and interview transcripts were analyzed using the qualitative thematic analysis model by Miles, Huberman, and Saldaña. To address the reviewers' concerns regarding coding validity and consistency, the predefined representational action framework (R1-R7) was strictly refined and operationalized prior to the analysis, as presented in Table 1.

Table 1. Operational Definitions of the Representational Action Coding Scheme (R1-R7)

Code	Action Category	Operational Definition/Indicators	Alignment
R1	Advanced Model Critique	- Identifying, evaluating, and explicitly critiquing the structural limitations or boundary constraints of a mathematical model within a complex context.	Advanced (Level 5)
R2	Structured Representation	- Successfully extracting contextual variables from the problem and mapping them accurately into formal geometric figures or algebraic equations.	Proficient (Level 4)
R3	Direct Formulaic Translation	- Directly inserting numbers from the problem text into standard area/perimeter formulas without checking for conceptual or contextual fit with real-world scenarios.	Procedural (Level 3)
R4	Incomplete/Inccurate Sketching	- Attempting to construct a spatial representation or model diagram, but resulting in structural distortions or missing critical dimensional attributes.	Low-Procedural
R5	Pragmatic Simplification	- Modifying or simplifying complex spatial variables into primitive geometric shapes to render the problem solvable, while remaining aware of the model's limitations.	Intermediate
R6	Subjective Intuition	- Providing a non-mathematical response based entirely on personal feelings, everyday experiences, or guesswork without any structural calculations.	Unscientific/Intuitive
R7	Non-Response Status	- Leaving the response space completely blank, or writing explicit statements of surrender (e.g., "I don't know," "Too confusing").	Zero-Engagement

Following the operationalization of the coding scheme presented in Table 1, the data analysis was systematically executed through the following mapping and triangulation procedures:

a. Process Mapping and Matrix Development: The frequencies and percentages of the assigned codes from all participants were cross-tabulated and mapped into a comprehensive mathematical literacy process matrix. This matrix was explicitly structured around the three core phases of the PISA modeling cycle: formulating, employing, and interpreting. At this stage, the researcher performed qualitative content analysis to identify behavioral patterns, structural breakdowns, and cognitive impasses, with a primary analytical focus on uncovering why specific representational failures occurred during the initial formulation phase as task complexity escalated from Level 3 to Level 5.

b. Technical Triangulation and Verification: To ensure the validity, objectivity, and descriptive accuracy of the identified mathematical literacy profiles, technical triangulation was rigorously applied. This was achieved by systematically cross-checking and corroborating the written artifacts of the 30 students against the verbatim interview transcripts of the 6 purposively selected subjects.

RESULTS AND DISCUSSION

To present a transparent and methodologically consistent profile of the participants, a systematic cross-tabulation of the assigned R1–R7 codes was executed across all four PISA-adapted geometry items. This descriptive quantification addresses prior mathematical inconsistencies and maps the students' structural breakdowns at the formulating stage as task complexity increases from Level 3 to Level 5.

Table 2. Distribution of Student Representational Actions Across PISA Tasks (N = 30)

Code	Action Category	Item 1 (Level 3)	Item 2 (Level 3)	Item 3 (Level 4)	Item 4 (Level 5)
R1	- Advanced Model Critique	0 (0%)	0 (0%)	0 (0%)	0 (0%)
R2	- Structured Representation	2 (6.67%)	0 (0%)	0 (0%)	0 (0%)
R3	- Direct Formulaic Translation	1 (3.33%)	1 (3.33%)	0 (0%)	0 (0%)
R4	- Incomplete/Inaccurate Sketching	4 (13.33%)	6 (20%)	3 (10%)	2 (6.67%)
R5	- Pragmatic Simplification	0 (0%)	1 (3.33%)	0 (0%)	0 (0%)
R6	- Subjective Intuition	14 (46.67%)	13 (43.33%)	13 (43.33%)	15 (50%)
R7	- Non-Response Status	9 (30%)	9 (30%)	14 (46.67%)	13 (43.33%)
Total		30 (100%)	30 (100%)	30 (100%)	30 (100%)

The empirical results in Table 2 demonstrate an inverse relationship between PISA task levels and successful mathematical formulation. The data reveals that the primary cognitive breakdown occurs at the very beginning of the modeling cycle, with more than 80% of the student population trapped in either unscientific guesswork (R6) or absolute cognitive paralysis (R7) when encountering Level 4 and Level 5 tasks. To unpack these phenomena, the findings are organized analytically into four distinct thematic characteristics of students' representational breakdowns.

Characteristics of Non-Response Status (R7): Total Cognitive Impasse

The most severe manifestation of formulating-stage failure is the high prevalence of non-response (R7), which reached its peak at 46.67% in the Level 4 task and remained extremely high at 43.33% for the Level 5 task. This state reflects an early-stage modeling paralysis where students fail to decode context-dense narratives, preventing them from entering the employing phase of computation.

Figure 1. Written artifact of Subject S-04 showing a complete non-response (R7) on the Level 5 task

Rather than a simple lack of effort, clinical interviews revealed that R7 is a byproduct of severe reading literacy barriers and language-induced anxieties. For instance, when analyzing the written artifact of Subject S-04 for Item 4 (*Tablecloth Shopping*), the response space was left entirely blank. The corresponding interview transcript exposes the roots of this complete disengagement:

Researcher : *"I noticed you didn't write anything down for Item 4. Can you describe what the text was asking you to do?"*

Subject S-04 : *"I read it twice, but I honestly got a severe headache just looking at the paragraphs. There were too many words about shopping, fabric options, and boundaries. I couldn't find the numbers I needed to calculate, so I just gave up... it was too confusing, Sir."*

Researcher : *"Did you think about drawing the table or the cloth to help you?"*

Subject S-04 : *"No, I didn't know where to start drawing because the sentences were twisted."*

This finding confirms that dense linguistic contexts deplete students' working memory before they can deploy mathematical reasoning, a phenomenon that strongly supports the Cognitive Load Theory. Cognitive Load Theory emphasizes the limited capacity of working memory and how excessive demands (e.g. from dense linguistic contexts) can impair learning and reasoning (Ekin et al., 2025; Munsell et al., 2018). When working memory is overloaded, students struggle to process and store information simultaneously, which is critical for mathematical reasoning (Barrouillet et al., 2011; Kotoka & Kriek, 2022). Furthermore, this structural disconnection between general text decoding and mathematical mathematization demonstrating that early-stage non-response behaves as a protective psychological coping mechanism when students face high linguistic density in spatial assessments.

Characteristics of Subjective Intuition (R6): Unscientific Real-World Guessing

As shown in Table 2, the single most dominant response pattern across all levels was Subjective Intuition (R6), affecting 50.0% of the cohort in the Level 5 task. When facing complex contextual constraints, the majority of students bypassed formal geometric abstractions entirely, defaulting instead to unscientific operations, random division, or qualitative declarations based on real-world estimations.

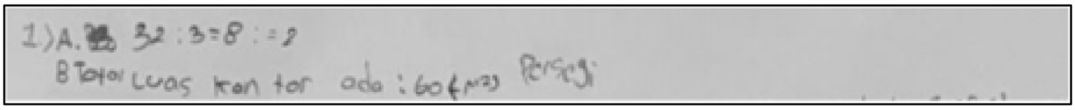

Figure 2. Written artifact of Subject S-18 displaying an intuition-based answer (R6) derived from real-world estimation rather than geometric modeling

A clear architectural example of this cognitive gap appears in the written work of Subject S-18 for Item 1. Faced with a 32-meter boundary problem, the student isolated the random dimensions provided in the text and forced a division operation without constructing any explicit geometric schema, writing:

1) A. $32 : 3 = 8 := 8$
B. Total luas kantor ada: 60 (m^2) Persegi

The clinical interview with this subject highlights how this intuitive behavior replaces formal structural modeling when students encounter contextual density:

Researcher : *"Looking at your script, you wrote " and estimated a total area of ". Where did these values and operations come from?"*

Subject S-18 : *"I didn't know how to turn the perimeter text into an equation, so I just took the numbers and from the story and divided them to see what would happen. The sixty square meters was just a guess based on what a normal office room looks like in real life."*

Researcher : *"Did you try to link the standard formula for a rectangle's area* ($L = p \times l$) *to the text?"*

Subject S-18 : *"No, the story felt like a reading comprehension test rather than a math test, so I just used basic logic and everyday common sense to make it fit."*

This reveals a profound fragmentation in the student's epistemological understanding of mathematical applications. Instead of utilizing context as a vehicle for mathematization, the student treated the real-world narrative as completely isolated from formal school mathematics. Students often struggle to integrate real-world narratives into mathematical reasoning, treating them as separate domains. This is evident in their difficulties with mathematization, where they fail to transition from contextual understanding to formal mathematical representation and vice versa (Jablonski, 2024; Ke et al., 2024; Upu et al., 2017). This finding directly corroborates the observations of (Haryanti et al., 2019; Jupri & Drijvers, 2016), who argued that Students face significant challenges in transforming word problems into mathematical models, such as equations, schemas, or diagrams. Errors in formulating these models are a primary obstacle, particularly in topics like linear equations and plane geometry.

Characteristics of Incomplete/Inaccurate Sketching (R4): Dysfunctional Visual Scaffolding

A smaller subset of students attempted to engage with the spatial demands of the questions by creating visual representations. However, their actions frequently resulted in Incomplete or Inaccurate Sketching (R4), ranging from 13.33% in Item 1 to 20.0% in Item 2. While these students successfully recognized that the problem belonged to the domain of geometry, they failed to construct dynamic, functional models that accounted for multi-step contextual shifts.

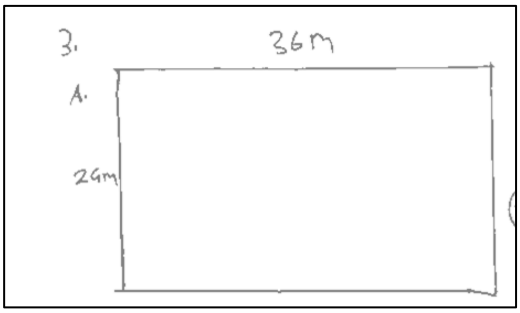

Figure 3. Written artifact of Subject S-27 demonstrating an inaccurate spatial representation (R4) with misplaced attributes

For Item 3 (*Urban Revitalization*), Subject S-27 demonstrated this transitional limitation. As shown in Figure 3, the student successfully constructed a clean, geometrically sound rectangle and accurately mapped the initial global measurements from the text, labeling the longer horizontal length as and the shorter vertical width as . However, the formulation process stalled completely at this baseline stage. The student failed to depict, label, or integrate the spatial boundary setbacks and internal structural constraints dictated by the urban social context, leaving the diagram as a hollow frame rather than a functioning mathematical model.

The clinical interview excerpt highlights this specific gap between static illustration and functional execution:

Researcher : *"You drew a very neat rectangle and labeled the sides as and based on the story. What was your next step to solve the land optimization?"*

Subject S-27 : *"I knew the problem was about a land area, so I drew a box to represent the field and put the big numbers on it. But when I read the next part of the text about subtracting the borders and access roads, I couldn't figure out how to*

	sketch or show those changes on my drawing. I just left it as a plain box so the space wouldn't look completely empty."
Researcher	**:** *"Does having this geometric drawing help you calculate the actual remaining land area?"*
Subject S-27	**:** *"No, it doesn't help further. It's just a picture of the original size. I still don't know how to link this drawing to the complex part of the math formula."*

This distinction is pedagogically critical: the student possesses a clear "image-based" recognition of the geometric shape but lacks the corresponding "functional" semantic understanding required to manipulate spatial boundaries dynamically when text density increases. Consequently, these incomplete visual representations fail to serve as effective cognitive mediators or operational stepping stones. Instead, they act merely as passive illustrations that stall the student's progress, cutting off any successful advancement into the employing or interpreting phases of the PISA modeling cycle. The distinction between "image-based" recognition and "functional" understanding aligns with the broader challenge of transitioning from surface-level recognition to deeper conceptual comprehension. This is evident in studies that differentiate between recognizing shapes visually and understanding their functional or semantic roles (Bokhovkin et al., 2021; Gschwind et al., 2007; Han et al., 2005).

Bottlenecks in Formulaic Translation (R3) and Spatial Simplification (R5)

Students who bypassed linguistic and visual traps were often stopped by procedural obstacles, categorizing them into Direct Formulaic Translation (R3) or Pragmatic Simplification (R5). These actions represent a mechanical jump directly into the employing phase without establishing proper contextual alignment during the formulation step.

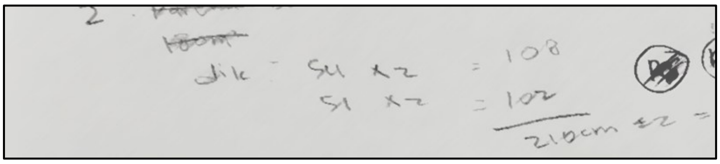

Figure 4. Written artifact of Subject S-09 showcasing a rigid, mechanical formula aplplication (R3) that detaches from context constraints.

In Item 2 (*Solar Panel Optimization*), Subject S-09 isolated the relevant numbers and immediately stuffed them into the standard area formula ($L = p \times l$), completely ignoring the scientific constraints regarding panel orientation and spacing. The interview transcript reveals this rigid procedural dependency:

Researcher	**:** *"Why did you immediately multiply these two numbers without considering the spacing gaps mentioned in the scientific context?"*
Subject S-09	**:** *"In school, if I see a geometry problem with two numbers, I always multiply them to find the area. I didn't think the spacing text mattered for the math. I just applied the formula I memorized."*

This behavior highlights a rigid reliance on rote-memorized formulas as a defensive shield against context-induced cognitive overload. Students view the employing stage merely as a mechanical calculation rather than a flexible process of translation. Consequently, the complete absence of any students reaching Advanced Model Critique (R1) across all items proves that when the formulating stage is fundamentally flawed or bypassed, the entire subsequent interpreting and evaluative phases collapse entirely, leaving students unable to achieve authentic mathematical literacy. This perception leads to a collapse of subsequent modeling phases—interpreting and evaluative critique—especially when the formulating stage is flawed or bypassed. The absence of students reaching Advanced Model Critique (R1) across all items underscores the critical importance of robust formulation for mathematical literacy (Berget, 2023; Kappassova et al., 2024; Temel, 2026).

The frequencies and percentages detailed in Table 2 provide a macro-level overview of student performance across the tasks. However, to understand the precise mechanics of the cognitive obstacles encountered by the students, these representational actions (R1-R7) must be mapped systematically onto the three core pillars of the PISA mathematical modeling cycle: formulating, employing, and interpreting. Figure 1 illustrates this structural tracking mechanism, charting the pathways through which students either successfully navigated or experienced a cognitive breakdown within the cycle.

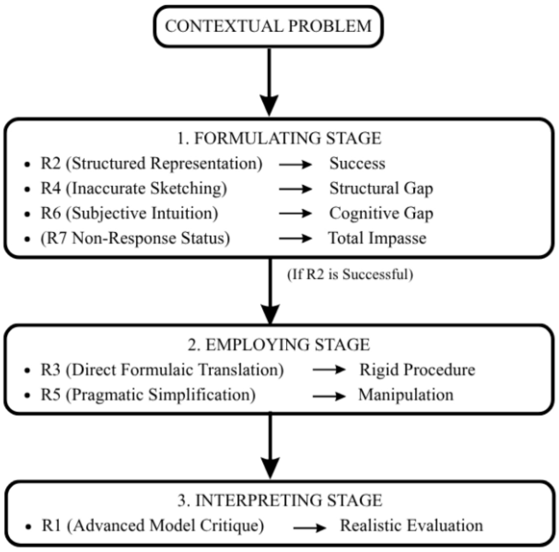

Figure 5. Cognitive roadmap of student representational pathways within the PISA mathematical modeling cycle.

As delineated in Figure 5, the formulating stage acts as the primary gatekeeper of mathematical literacy. A student can only progress into the employing stage (the phase of formal calculation) if they successfully demonstrate a Structured Representation (R2). If a student exhibits a structural gap through Inaccurate Sketching (R4), a cognitive gap via Subjective Intuition (R6), or a total impasse resulting in a Non-Response Status (R7), their progression within the modeling cycle is immediately terminated at the upstream level. Conversely, students who successfully formulated a model often encountered a secondary bottleneck during the employing stage, where they resorted to a mechanical, Direct Formulaic Translation (R3) that completely detached from the realistic boundaries of the context. Ultimately, the complete absence of any students reaching the interpreting stage via an Advanced Model Critique (R1) indicates a systemic collapse of higher-order reflective thinking, caused primarily by early-stage formulation failures. To unpack the specific qualitative characteristics of these structural disruptions, the following sections analyze each cognitive pathway in depth.

CONCLUSION

Based on the comprehensive analysis of student responses across various PISA literacy levels, it can be concluded that eighth-grade students' mathematical literacy in solving Space and Shape problems is characterized by significant structural gaps, particularly in the formulating phase. The empirical evidence reveals a concerning prevalence of non-responses (R7) and subjective intuition-based answers (R6), which together account for the vast majority of student outputs. This phenomenon is largely driven by a lack of linguistic-mathematical integration, where students experience a cognitive impasse when facing lengthy, context-rich narratives, leading to an early-stage modeling failure before formal mathematical procedures can be applied. While a small subset of students demonstrated the ability to use visual-spatial tools—such as sketching rectangles—they frequently failed to achieve representational accuracy, indicating that their conceptual understanding of geometry remains fragmented and disconnected from the functional requirements of mathematical modeling.

Furthermore, the descriptive frequency distribution patterns across the tasks reveal a clear negative trend between the complexity of PISA proficiency thresholds and successful formulation. As the tasks progressed from Level 3 to Level 5, the frequency of accurate mathematical transformation plummeted, while reliance on unscientific intuition and total non-response rose substantially. This trend underscores a critical deficit in strategic competence and mathematical reasoning, where students struggle to independently identify constraints or formulate necessary assumptions within non-routine scenarios. Ultimately, the findings suggest that without a solid mastery of fundamental geometric concepts and the ability to "mathematize" diverse real-world contexts, students remain unable to navigate the full modeling cycle, highlighting an urgent need for pedagogical shifts that prioritize context-based reasoning over rote procedural memorization.

RECOMMENDATION

Despite its insightful qualitative findings, this study possesses several limitations that must be acknowledged. First, the research was conducted within a limited scope involving a small sample size of $N = 30$ students from a single public secondary school in Bandung Barat Regency, which restricts the broad generalizability of the findings to wider demographic areas. Second, the task instruments were strictly confined to the content domain of *Space and Shape*, specifically focusing on the area and perimeter of rectangular dimensions. Therefore, future research should expand the sample sizes across multiple schools with diverse socio-economic backgrounds and explore other mathematical content domains, such as *Change and Relationships* or *Quantity*. Additionally, integrating a mixed-methods design in future investigations could provide a more robust statistical validation of the representational action coding scheme (R1-R7) developed in this study.

ACKNOWLEDGMENTS

The authors would like to express their sincere gratitude to the school, mathematics teacher, and eighth-grade students in Bandung Barat Regency, West Java, who participated in this study. The authors also thank the velidators for their valuable suggestions in improving the research instruments.

FUNDING INFORMATION

The author expresses sincere gratitude to the Indonesia Endowment Fund for Education (LPDP) for providing the financial support necessary to conduct this research. This study was made possible through the funding scheme granted by LPDP, which has significantly facilitated the entire investigation process. The author also acknowledges the indispensable contribution of this institution in advancing the quality and completion of this academic work.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dwi Arisma Wahyudi	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Sufyani Prabawanto	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	
Al Jupri	✓			✓	✓					✓	✓	✓		

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, SP, upon reasonable request.

REFERENCES

Anselmo, G. A., Yarbrough, J. L., & Tran, V. V. N. (2021). To screen or not to screen: Criterion-related validity of math and reading curriculum-based measurement in relation to high-stakes math scores. *Journal of Psychoeducational Assessment, 39*(2), 153–165. https://doi.org/10.1177/0734282920950141

Barrouillet, P., Portrat, S., & Camos, V. (2011). On the law relating processing to storage in working memory. *Psychological Review, 118*(2), 175–192. https://doi.org/10.1037/a0022324

Berget, I. K. L. (2023). Identifying positioning and storylines about mathematical modelling in teacher–student dialogues in episodes from two upper secondary classrooms. *Teaching Mathematics and Its Applications, 42*(3), 289–303. https://doi.org/10.1093/teamat/hrac020

Bokhovkin, A., Ishimtsev, V., Bogomolov, E., Zorin, D., Artemov, A., Burnaev, E., & Dai, A. (2021). Towards part-based understanding of RGB-D scans. *Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, 7480–7490. https://doi.org/10.1109/CVPR46437.2021.00740

Ekin, M., Krejtz, K., & Krejtz, I. (2025). Cognitive load and oculometrics in the educational scenarios: A systematic review and meta-analysis. *Proceedings of the ACM on Human-Computer Interaction, 9*(3). https://doi.org/10.1145/3725832

Gschwind, M., Brettel, H., & Rentschler, I. (2007). Prior knowledge and learning in 3D object recognition. In N. Osaka, I. Rentschler, & I. Biederman (Eds.), *Object recognition, attention, and action* (pp. 105–117). Springer. https://doi.org/10.1007/978-4-431-73019-4_8

Hamidah, I., Zulkardi, Putri, R. I. I., & Pramuditya, S. A. (2025). Developing a mathematical literacy learning environment for students through educational game assistance. *Mathematics Education Journal, 19*(1), 141–162. https://doi.org/10.22342/jpm.v19i1.pp141-162

Han, D., You, B.-J., Kim, Y. S., & Suh, I. H. (2005). A generic shape matching with anchoring of knowledge primitives of object ontology. In *Lecture Notes in Computer Science* (Vol. 3656). https://doi.org/10.1007/11559573_59

Haryanti, M. D., Herman, T., & Prabawanto, S. (2019). Analysis of students' error in solving mathematical word problems in geometry. *Journal of Physics: Conference Series, 1157*(4). https://doi.org/10.1088/1742-6596/1157/4/042084

Hendriyanto, A., Suryadi, D., Juandi, D., Dahlan, J. A., Hidayat, R., Wardat, Y., Sahara, S., & Muhaimin, L. H. (2024). The didactic phenomenon: Deciphering students' learning obstacles in set theory. *Journal on Mathematics Education, 15*(2), 517–544. https://doi.org/10.22342/jme.v15i2.pp517-544

Hu, Q., Guo, Y., Zhang, Z., & Ye, Q. (2026). High school students tend to pose what kinds of mathematical modeling problems and how they solve them in free situations: Evidence from modeling reports in China. *International Journal of Science and Mathematics Education, 24*(5). https://doi.org/10.1007/s10763-026-10671-1

Ikhsan, M., Rochaminah, S., & Mastura, A. (2024). Development of Geo-Math application by integrating Geo-Gebra applets to improve students' spatial ability. *Jurnal Ilmiah Peuradeun, 12*(3), 1129–1154. https://doi.org/10.26811/peuradeun.v12i3.1492

Jablonski, S. (2024). Challenges in geometric modelling: A comparison of students' mathematization with real objects, photos, and 3D models. *Eurasia Journal of Mathematics, Science and Technology Education, 20*(3). https://doi.org/10.29333/ejmste/14321

Jupri, A., & Drijvers, P. (2016). Student difficulties in mathematizing word problems in algebra. *Eurasia Journal of Mathematics, Science and Technology Education, 12*(9), 2481–2502. https://doi.org/10.12973/eurasia.2016.1299a

Kappassova, S., Abylkassymova, A., Zhadyrayeva, L., & Tuyakov, Y. (2024). Methodological aspects of the development of functional literacy of schoolchildren in mathematics | Методичні аспекти розвитку функціональної грамотності школярів у процесі навчання математики. *Scientific Herald of Uzhhorod University. Series Physics, 55*, 2372–2382. https://doi.org/10.54919/physics/55.2024.237bu2

Ke, F., Dai, C.-P., West, L., Pan, Y., & Xu, J. (2024). Using mathematizing supports for applied problem solving in a game-based learning environment. *Journal of Educational Computing Research, 62*(2), 468–500. https://doi.org/10.1177/07356331231206990

Kemdikdasmen. (2025). *Perkaban tentang Kerangka Asesmen TKA SD/MI dan SMP/MTs*. Kementerian Pendidikan Dasar dan Menengah.

Kemendikdasmen. (2025). *Rapor Pendidikan Indonesia 2025*.

Kiss, A. J., & Christ, T. J. (2019). Screening for math in early grades: Is reading enough? *Assessment for Effective Intervention, 45*(1), 38–50. https://doi.org/10.1177/1534508418766410

Kotoka, L., & Kriek, J. (2022). Prediction of the correlation between problem-solving skills and conceptual reasoning in stoichiometry. *Journal of Baltic Science Education, 21*(4), 615–637. https://doi.org/10.33225/jbse/22.21.615

Kusmayadi, T. A., Sahara, S., & Fitriana, L. (2022). Application of Newman errors analysis theory related to mathematical literacy problems: A case study of secondary students in class 11. *AIP Conference Proceedings, 2566*. https://doi.org/10.1063/5.0117183

Munsell, J., Zu, T., & Rebello, N. S. (2018). Validating a survey for self-reporting cognitive load. *Physics Education Research Conference Proceedings, 2018*.

Murni, S., Suryadi, D., & Prabawanto, S. (2025). Lower secondary students epistemological obstacle in solving mathematical literacy task: Focus on plane geometry. *Journal of Engineering Science and Technology, 20*(3), 49–56.

OECD. (2023). *PISA 2022 assessment and analytical framework*. OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en

Rahaju, E. B., Khabibah, S., Rosyidi, A. H., Prihartiwi, N. R., & Lestariningsih, L. (2026). Students' critical reasoning on justifying properties of quadrilaterals. *Multidisciplinary Reviews, 9*(6). https://doi.org/10.31893/multirev.2026294

Rahayu, G., Rosjanuardi, R., & Yulianti, K. (2023). Students' learning obstacles in the understanding inverse function. *AIP Conference Proceedings, 2734*(1). https://doi.org/10.1063/5.0156060

Rahayuningsih, S., Anggriani, A. E., Mardhatillah, Faizah, S., Yuniawatika, & Kamarudin, N. (2025). The relationship between cognitive flexibility and mathematical literacy: Insights from Indonesian elementary students. *International Electronic Journal of Elementary Education, 17*(3), 367–381.

Ratnaningsih, N., & Hidayat, E. (2021). Error analysis and its causal factors in solving mathematical literacy problems in terms of habits of mind. *Journal of Physics: Conference Series, 1764*(1). https://doi.org/10.1088/1742-6596/1764/1/012104

Rojas, E., & Benakli, N. (2020). Mathematical literacy and critical thinking. In *Teaching college level disciplinary literacy strategies and practices in STEM and professional studies*. https://doi.org/10.1007/978-3-030-39804-0_8

Sagge, R. G. (2025). Beyond static textbook illustrations: Development of augmented reality-based materials (ARM) for geometry. *International Journal of Information and Education Technology, 15*(8), 1687–1697. https://doi.org/10.18178/ijiet.2025.15.8.2370

Sevinc, S. (2025). Pre-service mathematics teachers' challenges in their first attempt at posing geometry modelling problems. In *International perspectives on the teaching and learning of mathematical modelling* (Part F744). https://doi.org/10.1007/978-3-031-53533-8_16

Shin, M., Park, J., Lee, J. Y., & Meador, A. (2025). Mathematics instruction for students with learning disabilities. In *Springer international handbooks of education* (Part F910). https://doi.org/10.1007/978-3-031-60258-0_6

Temel, H. (2026). Assessment of high school students' formulating skills: A framework proposal. *SAGE Open, 16*(2). https://doi.org/10.1177/21582440261431848

Upu, H., Djadir, & Asyari, S. (2017). The fifth graders' mathematisation process in solving contextual problems. *World Transactions on Engineering and Technology Education, 15*(2), 195–199.

Wardani, A. K., & Prabawanto, S. (2025). Students' epistemological obstacle in solving mathematical literacy tasks: Focusing on ratio and proportion. *AIP Conference Proceedings, 3333*(1). https://doi.org/10.1063/5.0290848