



Investigating Students' Mathematical Literacy in PISA Tasks Using Newman's Theory

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ABSTRACT

This study investigates the gap between technological ubiquity and stagnant mathematical literacy among Indonesian students. The research objective was to identify and analyze specific cognitive hurdles hindering students' ability to solve contextual, PISA-adapted problems. Utilizing a qualitative descriptive design, the study involved 34 ninth-grade students in Kabupaten Bandung Barat. Subjects for semi-structured interviews were selected via purposive sampling, targeting those demonstrating representative error patterns across high, moderate, and low proficiency tiers. Data were analyzed using Newman's Error Analysis (NEA) and validated through methodological triangulation. Results revealed that 52.94% of students possess low mathematical literacy, with the most critical barrier being transformation errors (58.36%), followed by comprehension (27.94%) and reading (14.70%). Qualitative findings indicate that these errors stem from three primary factors: contextual unfamiliarity with non-routine tasks, a detrimental dependency on teacher scaffolding, and conceptual deficits in processing decimal notation. The study concludes that students struggle to bridge the gap between narrative contexts and mathematical formalization. To mitigate these barriers, the research recommends the implementation of incremental scaffolding and explicit instructional strategies focusing on linguistic-to-mathematical translation to foster learner autonomy and higher-order thinking skills in the Indonesian educational framework.

Keywords: Mathematical Literacy, PISA test, Newmann Error Analysis

ABSTRAK

Penelitian ini mengkaji kesenjangan antara pesatnya perkembangan teknologi dengan stagnasi literasi matematis siswa di Indonesia. Penelitian ini bertujuan untuk mengidentifikasi dan menganalisis hambatan kognitif spesifik yang menghalangi kemampuan siswa dalam menyelesaikan soal kontekstual adaptasi PISA. Dengan menggunakan desain deskriptif kualitatif, penelitian ini melibatkan 34 siswa kelas IX di Kabupaten Bandung Barat. Subjek untuk tahap wawancara semi-terstruktur dipilih melalui teknik purposive sampling, yang berfokus pada siswa dengan pola kesalahan representatif pada tingkat kemahiran tinggi, sedang, dan rendah. Data dianalisis menggunakan kerangka Newman's Error Analysis (NEA) dan divalidasi melalui triangulasi metodologis. Hasil penelitian menunjukkan bahwa 52,94% siswa memiliki literasi matematis kategori rendah. Hambatan paling kritis ditemukan pada kesalahan transformasi (57,36%), diikuti oleh kesalahan pemahaman (27,94%) dan kesalahan membaca (14,70%). Temuan kualitatif mengindikasikan bahwa kesalahan tersebut bersumber dari tiga faktor utama: ketidakbiasaan terhadap konteks masalah non-rutin, ketergantungan yang tinggi terhadap bantuan guru (*scaffolding*), serta defisit konseptual dalam memproses notasi desimal. Studi ini menyimpulkan bahwa siswa mengalami kesulitan dalam menjembatani kesenjangan antara konteks naratif dan formalisasi matematika. Sebagai upaya mitigasi, penelitian ini merekomendasikan



penerapan scaffolding bertahap dan strategi instruksional eksplisit yang berfokus pada penerjemahan aspek linguistik ke model matematika guna menumbuhkan kemandirian belajar dan keterampilan berpikir tingkat tinggi dalam kerangka pendidikan di Indonesia.

Kata Kunci: Literasi Matematis, Soal PISA, Teori Kesalahan Newmann

INTRODUCTION

The disparity between the widespread availability of 21st-century technology and the stagnation of students' mathematical literacy underscores a critical gap in the current educational framework. This societal context necessitates individuals who can not only compute effectively but also implement mathematical understanding to navigate complex information landscapes and solve real-world problems. In this regard, mathematical literacy transcends basic arithmetic; it encompasses the fundamental ability to utilize mathematics in managing everyday scenarios and making informed decisions, thereby reinforcing its pivotal role in promoting civic participation and economic engagement (Fauzan et al., 2024; Harisman et al., 2023; Hopkins & O'Donovan, 2019).

Mathematical literacy requires students to communicate and explain the phenomena they encounter using mathematical concepts (Indahwati et al., 2024). It is recognized as a fundamental skill that empowers students to effectively communicate and interpret mathematical concepts within various contexts. It involves the ability to formulate, utilize, and interpret mathematics in a wide range of real-world scenarios and is essential for the development of critical thinking and problem-solving skills (Aulia et al., 2024; Aini et al., 2023; Purwanti et al., 2020). This capability not only facilitates academic success but also equips learners with the necessary tools to navigate everyday challenges and complexities in life (Song et al., 2024; Nurhanurawati et al., 2022).

A central aspect of mathematical literacy is the communication component, which requires students to articulate their mathematical reasoning and the steps taken to reach conclusions (Purwanti et al., 2020; Maryati et al., 2021). The process of mathematical reasoning includes not just computation but also the ability to explain phenomena using mathematical ideas and real-world applications (Aini et al., 2023; Song et al., 2024; Nurhanurawati et al., 2022). Study conducted by Kusuma (2024) stated that students are more motivated and enthusiastic about participating in learning because they feel that mathematical concepts are related to real life and their culture.

The role of context in learning mathematical literacy cannot be overstated. Effective mathematics education integrates real-life contexts into curricula, allowing students to see the relevance of mathematical concepts (Aulia et al., 2024; Aini et al., 2023). Research indicates that when students are engaged in tasks that mirror real life situations, their ability to apply mathematics meaningfully is enhanced, thereby improving their mathematical literacy (Wardani et al., 2023; Huang et al., 2024).

Data from the OECD's PISA reveals that student mathematics performance dropped to 366 points in 2022, down from 317 in 2018 (OECD, 2023). This result aligns with the 2024 Minimum Competency Assessment (AKM) for junior high schools, where numeracy achievement stood at

69.61%. While this represents a 4.61% improvement over the previous year, overall student ability is still classified as moderate (Kemendikbudristek, 2024). Such persistent challenges in numeracy outcomes underscore the need for prioritized intervention by relevant authorities.

One of the factors contributing to the low level of mathematical literacy is the limited implementation of teaching methods that promote critical thinking and problem-solving among students (Noor et al., 2025; Widodo et al., 2025). Research indicates that many students are only able to solve tasks at the lower levels (1,2, and 3), while only a small proportion can successfully complete tasks at the higher levels (4, 5, and 6) (Adawiyah et al., 2023; Kusmaryono & Kusumaningsih, 2023). This finding suggests that Indonesian students' still encounter difficulties in addressing problems that require deep conceptual understanding and the application of mathematical concepts in real-world contexts.

Another research from Afriyanti et al. (2021) empirical results from the mathematical literacy assessment revealed a concerning trend: out of the 25 students tested, only 8 (32%) achieved proficiency at Level 1c, while mere 2 (8%) and 1 (4%) reached Levels 1b and 1a, respectively. Notably, no students demonstrated competency at Levels 2 or 3. Several contributing factors to this low literacy performance include students' unfamiliarity with contextualized problem-solving, difficulties in decoding information within complex prompts, and significant limitations in fundamental arithmetic operations, particularly in multiplication and division.

Building upon these findings and aligning with previous research, this study employs Newman's Error Analysis (NEA) to comprehensively describe the specific types of students' errors across each developmental stage. This framework allows for a rigorous diagnostic assessment of why students fail to bridge the gap between real-world contexts and mathematical formalization.

METHOD

This study employs a qualitative descriptive method to provide a comprehensive analysis of students' mathematical literacy errors. The research subjects consisted of 34 ninth grades from SMPN (State Junior High School) in Kabupaten Bandung Barat during the 2024/2025 academic year. The subjects for the interview phase were selected using purposive sampling, focusing on students who demonstrated representative error patterns at various proficiency levels.

The primary instruments utilized in this study were a validated mathematical literacy test consisting of PISA-adapted contextual problems and semi-structured interview guide based on the Newman's Error Analysis (NEA) framework to diagnose specific students' errors. To ensure the rigor and credibility of the findings, data validation was conducted through two distinct phases. First, the mathematical literacy test instrument underwent expert judgement by a senior mathematics education specialist to verify its content validity and alignment with PISA standards and Newman's levels. Second, the study employed methodological triangulation by cross-referencing students' written test responses with semi-structured interview transcripts. This process was essential to confirm the consistency of the identified errors and to ensure that the researcher's interpretation accurately reflected the students' cognitive processes during the problem-solving stages.

Table 1. Classification of Students' Mathematical Literacy Levels

Literacy Level	Score Range (Average)	Competency Descriptors
High	$3.26 \leq x \leq 4.00$	Demonstrates the ability to model complex problems, employ advanced strategies, and articulate systematic mathematical arguments and interpretations.
Moderate	$2.50 \leq x \leq 3.25$	Capable of executing tasks with clear instructions and selecting standard problem-solving strategies, yet exhibits limited depth in reflective thinking or nuanced interpretation.
Low	$0.00 \leq x \leq 2.49$	Limited to addressing explicit instructions; encounters significant difficulty in mathematical modelling and frequently commits fundamental procedural errors.

The data analysis followed an iterative process, initiated by data reduction, which involved categorizing student responses based on their respective levels of mathematical literacy. The participants' performance was categorized into three distinct proficiency levels based on their mean scores, ranging from 0 to 4. As delineated in Table 1, this classification serves to differentiate the cognitive characteristics of the students. This distribution provides the foundational data for the subsequent Newman's (1977) error analysis framework to identify specific cognitive hurdles across different literacy tiers. These five distinct categories of errors identified by this theory as occurring during the problem-solving process are detailed in Table 2. After the data display, the final stage involved conclusion drawing, which focused on identifying the fundamental root causes of the students' low mathematical literacy levels based on the evidence synthesized in the preceding phases.

Table 2. The Five Indicators of Newman Error Analysis

Indicator	Description
Reading	The ability to recognize and decode the textual words and mathematical symbols presented in the problem.
Comprehension	The capacity to grasp the underlying meaning and requirements of the problem after the initial reading.
Transformation	The process of translating the interpreted problem into an appropriate mathematical model, strategy, or operative formula.
Process Skills	The execution of computational procedures and mathematical algorithms required to solve the transformed model.
Encoding	The final stage of formulating and documenting the solution in a manner that aligns with the initial context of the inquiry.

Three subjective items served as the primary tools for data collection in this phase of the research. Each item was carefully adapted from the PISA framework to maintain alignment with international evaluation standards. The specific details regarding how these items were structured are presented in Table 3.

Table 3. Question Description

Task Number

Task 1

Question

Tania intends to purchase a new vehicle and aims to estimate the total cost of ownership (TCO) for the initial year of operation. To facilitate this, she utilizes an Online Cost estimator based on the following computational parameters:

- Annual Mileage: Approximately 20,00 km.
- Average Fuel Price: 1.54 zed per liter.
- Maintenance Expenses: Estimated at 250 zed for the first year.

The table below delineates the purchase price and fuel efficiency for four prospective car models. Fuel consumption is defined as the volume of fuel (in liters) required to cover a distance of 100 kilometers, representing a standardized estimate for combined city and highway driving.

Car specification	Car A	Car B	Car C	Car D
Purchase Price (zed) (Inclusive of all taxes and registration fees)	8,000	8,700	9,900	10,500
Fuel Consumption (L/100 km)	18.9	15.7	12.4	14.1

Referencing the “Car Purchase” data above and utilizing the specified cost parameters, determine which vehicle represents the most economical option (lowest total cost) regarding the combined purchase price and operational expenses for the first year.

A. Car A
B. Car B
C. Car C
D. Car D

Task Number

Task 2

Question

The Maya family is planning to relocate and intends to lease a moving truck. They are presented with two distinct vehicle dimensions for selection. The internal storage dimensions for both options are specified in the table below. It is noted that all interior walls and floors of the storage compartments are rectangular in shape.

Truck Size	Floor Length	Floor Width	Height
Truck A	4.0 meters	2.0 meters	2.0 meters
Truck B	6.6 meters	2.3 meters	2.3 meters

Furthermore, three standardized crate sizes are available for packing, with their respective dimensions delineated as follows:

Crate Size	Length	Width	Height
Small	0.4 meters	0.3 meters	0.3 meters

Task Number	Question			
	Medium	0.5 meters	0.5 meters	0.5 meters
	Large	0.5 meters	0.5 meters	0.75 meters

Internal Storage Compartment Dimensions

Truck Size	Floor Length	Floor Width	Height
Truck A	4.0 meters	2.0 meters	2.0 meters

Standardized Crate Dimensions

Crate Classification	Length	Width	Height
Medium	0.5 meters	0.5 meters	0.5 meters

Referencing the “Moving Truck” technical data provided above, the Maya family has elected to lease Truck A. Based on the spatial constraints of the storage compartment and the dimensions of the medium-sized crates, calculate the maximum quantity of crates that can be efficiently accommodated within Truck A.

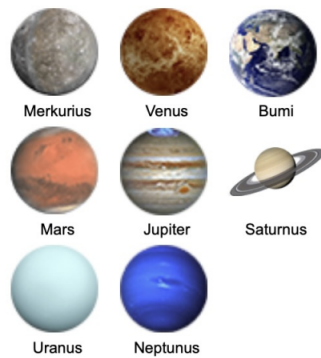
- A. 320
- B. 128
- C. 26
- D. 16

Task 3 The following data set represents the mean orbital distances of the primary planets in our Solar System from the Sun, expressed in Astronomical Units (au). For context, 1 au is approximately equivalent to 150 million kilometers.

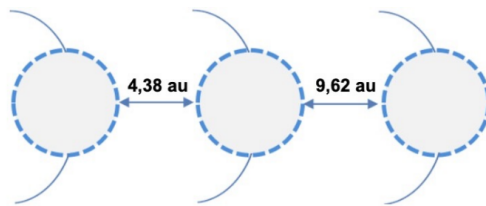
Planet	Mean Distance (au)
Mercury	0.39
Venus	0.72
Earth	1.00
Mars	1.52
Jupiter	5.20
Saturnus	9.58
Uranus	19.20
Neptune	30.05

Referencing the “Solar System” data provided, consider the linear model below which illustrates the relative distances between three specific planets. Note that neither the planets nor the model are rendered to scale.

Task Number	Question
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The model depicted below illustrates the mean distances between three specific planets.



Based on the numerical distances delineated in the model, identify the planets that correspond to Position 1, Position 2, and Position 3.

RESULT

A detailed statistical representation of mathematical literacy and the resulting frequencies of Newman's error categories is presented in Table 4. These findings facilitate a structured evaluation of the specific difficulties students face, ranging from reading comprehension to process skills. By establishing this empirical baseline, the research can accurately isolate the root causes of poor performance in contextualized mathematics and propose targeted interventions.

Table 4. Distribution of Mathematical Literacy Levels and Newman's Error Categories

Category	Indicator	Percentage (%)	Description of Findings
Literacy Level	Low	52.94%	Majority of students demonstrate functional but inconsistent literacy skills.
	Moderate	47.06%	A significant portion of students possess mid-tier analytical capabilities.
Newman Error Type	Reading	14.70%	Minor difficulty in identifying mathematical symbols or keywords.
	Comprehension	27.94%	Students fail to grasp the specific requirements of the contextual problems.
	Transformation	57.36%	The most critical hurdle: students cannot convert problem into mathematical models.

Analysis of Subject with transformation errors

Subjects are given question in test; they are asked the cost of purchasing and operating a car during the first year (Task 1). To solve this type of problem, students are required to understand the instructions provided in the question. They must be able to interpret the comparison of price and fuel consumption that presented on the table. In addition, students must be able to comprehend the information related to the estimated cost values provided, such as the annual travel distance, the average fuel cost per liter, and the estimated maintenance expenses during the first year. Strong mathematically literacy skills are essential to solve this problem effectively. However, the students coded with A16 was only able to write down the given information completely and identify what was being asked. Nevertheless, the student unable to answer the question according to the proper problem-solving procedure and provided only a brief written explanation.

Students A16's answer sheet

Given: Tania plans to purchase a new vehicle. She intends to evaluate the total cost of acquisition and operation for the first year of ownership.

Data specifications:

Vehicle A:	Vehicle B:
Price: 8,000	Price: 8,700
Fuel Consumption (L/100 km): 18,9	Fuel Consumption (L/100 km): 15.7
Vehicle C:	Vehicle D:
Price: 9,900	Price: 10,500
Fuel Consumption (L/100 km): 12.4	Fuel Consumption (L/100 km): 14.1

Problem Statement: Which vehicle offers the highest cost-efficiency during the initial year?

Response: The selection is based on the premise that Vehicle A has the lowest initial acquisition cost, and its fuel efficiency is deemed sufficient to cover 100 kilometers within the established budgetary constraints.

Based on the students' response, the researcher conducted a deep interview to confirm the answer and to gain a deeper understanding of the errors made.

A16 : I only rewrote the information provided in the question because that was only part I understood.

R : Why did not you answer the question?

A16 : I was confused about what to do first.

R : What made you feel confused when working on the problem?

A16 : I have never been given a question like this before, so I did not know how to solve it.

Analysis of Subject with comprehension errors

Moving to the section analyzing students who experienced errors in comprehension. To solve this problem, students need to interpret the information presented in the tables by comparing the dimensions of truck A and the medium-sized boxes (Task 2). They must understand how to relate the truck's capacity to the size of the boxes and determine how many boxes can fit within the available space. This requires the ability to comprehend spatial relationships and apply logical reasoning to

estimate the maximum number of boxes that can be loaded into the truck based on the given dimensions.

The data shows that student A4 submitted a minimal response that lacked a clear explanation of the underlying mathematical operations. Beyond the missing calculation process, the student's work did not include a summary of the known information or constraints presented in the task. Consequently, the response appears incomplete as it bypasses the essential; phase of organizing problem-related data before attempting a solution.

Students A4's answer sheet

Given: Maya's family is in the process of residential relocation. They intend to procure a moving truck and are evaluating two distinct vehicle capacity options.

Problem Statement: Based on the available options, the family elects to utilize Truck A.

Response: C. 26 boxes.

To gain deeper insights into the difficulties encountered by the students, researcher conducted the following interview.

A4 : The question was too long, so I could not understand the information provided in it. I also found it difficult to understand the purpose of the table and how it was supposed to be used.

R : How do you usually solve problems like this?

A4 : I often assisted by my teacher solving problem. When working independently, I feel confused, not knowing what to do first or what steps to take next.

Analysis of Subject with reading errors

In this section, students are required to solve problems related to the solar system (Task 3). The procedure for solving this problem begins by carefully examining the table that presents the average distance of each planet from the Sun, expressed in astronomical units. This information serves as the foundation for identifying the relative positions of the planets. The next step is to observe the given model, which illustrates the average distances between three planets. Based on this model, it is necessary to determine which planets correspond to each position by comparing the relative distances indicated in the table. The reasoning process involves analyzing the sequential order of the planets and selecting those whose distances logically fit the relationships shown in the model. Finally, the planets that best represent the given conditions are identified according to the data from the solar system table.

Student A14 struggled to isolate the critical data and keywords needed to understand the core of the problem. This difficulty in the early stages of analysis meant that the student could not formulate to carry out a valid mathematical operation. Because the foundation of the problem was misunderstood, the subsequent steps of the procedure could not be completed accurately.

Students A14's answer sheet

Given: The table provided below illustrates the mean data (average values) for the observed variables.

Problem Statement: -

Response: -

After conducting an interview with the students, they admitted that they did not understand the meaning of the illustration.

A14 : I do not understand the relationship between the picture and the table. Moreover, the numbers are presented in decimal form, which made me even more confused about how to solve the problem.

R : How have you been learning mathematics or solving problems so far?

A14 : Because I feel confused, I usually do not attempt to solve the problem; instead, I often just rewrite the question.

DISCUSSION

The analysis identified three primary factors that significantly hinder a student's ability to solve the provided mathematical problems. These drivers were uncovered by examining the students' written work and were further validated through direct semi-structured interviews. Together, these sources offer a clear explanation of the cognitive and procedural barriers that prevent students from achieving successful outcomes. First, contextual unfamiliarity poses a significant analytical barrier. Students exhibit a lack of exposure to non-routine problem types, which impedes their ability to conduct a comprehensive task analysis and subsequently inhibits the formulation of mathematical models from narrative-based prompt. Consequently, students remain unable to navigate the procedural stages of problem-solving effectively. This behavior suggests a deficiency in their problem-solving strategies, as supported by research indicating that many students prefer solving conventional problems for which they have learned straightforward algorithms and methodologies (Salsabila et al., 2024; Yulia et al., 2021).

Second, teacher dependence contributes to diminished learner autonomy. While independent problem-solving is essential for interpreting complex inquiries, frequent pedagogical assistance has fostered a negative dependency. This prevents students from cultivating the self-regulated learning skills necessary to manage the resolution process autonomously. Learner autonomy is crucial for lifelong learning and involves students taking responsibility for their own learning, organizing their learning activities, and evaluating their progress (Gocic & Jankovic, 2021; Bukhteeva et al., 2022; Duarte, 2020). It is seen as a pre-condition for self-efficacy and higher achievement in learning (Raitskaya et al., 2021). Also, the scaffolding provided by teachers, although necessary, can lead to students becoming overly reliant on such support, diminishing the self-regulatory skills necessary for problem-solving (Tay & Toh, 2023; Kusmaryono et al., 2020).

Third, conceptual deficits in processing information led to synthesize disparate cues within a problem statement, which is further exacerbated by a lack of proficiency in handling decimal notation, ultimately impairing their ability to execute solutions systematically. Study conducted by Sterner that focuses on the use of graphical representation as a means of nurturing students' understanding of mathematical patterns and relationships. This research underscores that when students develop their ability to identify and structure problems visually, they can improve their correspondence

relationships and covariational thinking (Sterner, 2024). The ability to understand and use mathematical symbols and conventions, such as those in decimal notation, is crucial for solving mathematical problems. Deficits in this area can lead to difficulties in arithmetic, algebra, and problem-solving (Douglas, 2020). Moreover, the critical role of mathematical thinking is addressed by Yanuari and Turmudi, who note that fostering critical thinking skills is essential for enhancing students' overall mathematical competency Yanuari & Turmudi (2023).

These barriers are inherently interconnected, forming a detrimental cycle that hinders mathematical literacy. Specifically, a student's unfamiliarity with complex narratives exacerbates interpretation difficulties. This frustration subsequently increases the demand for teacher intervention, thereby reinforcing a cycle of dependence that prevents the development of autonomous cognitive strategies required for higher-order thinking.

To mitigate these issues, this study suggests several practical implications for educators. It is recommended that teachers implement incremental scaffolding, a method where support is gradually withdrawn as students gain confidence in their analytical capabilities. Furthermore, incorporating explicit instructional strategies-specifically focusing on the linguistic-to-mathematical translation of narrative problems-is crucial for fostering the independent mathematical literacy necessary for solving real-world challenges.

CONCLUSION

In conclusion, this study reveals that students' struggles with mathematical literacy are rooted in a self-reinforcing cycle of contextual unfamiliarity, excessive teacher dependence, and conceptual deficits. These barriers collectively impede a student's ability to transition from narrative prompts to formal mathematical models. To break this cycle, it is recommended that educators shift toward fostering learner autonomy through incremental scaffolding. By integrating visual aids and explicit interpretation strategies-while systematically reducing direct assistance-teachers can empower students to navigate complex, non-routine problems with greater independence and systematic precision.

DECLARATION OF THE USE OF AI

Statement: "During the preparation of this work, the author did not use AI services, except for the use of basic tools such as Google Translate and Grammarly which were used to check grammar and spelling."

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