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Exploring Lower Secondary Students' Mathematical Literacy in Number Content Through the Lens of Logical Mathematical Intelligence

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Abstract

Although research on mathematical literacy and multiple intelligences has advanced significantly, studies that specifically examine the characteristics of junior high school students' mathematical literacy in PISA number content through logical mathematical intelligence remain very limited. This study aims to describe the characteristics of junior high school students' mathematical literacy with different levels of logical mathematical intelligence in solving PISA equivalent problems, as well as to analyze the relationship between the level of logical mathematical intelligence and the problem solving strategies demonstrated by students. This study was designed using a descriptive qualitative approach and involved thirty four junior high school students selected through purposive sampling based on high, medium, and low levels of logical mathematical intelligence;research instruments included a multiple intelligence test, number content questions adapted from PISA, and a semi-structured interview guide;data analysis was conducted through the stages of data reduction, data presentation, and drawing conclusions using the triangulation method. The results of the study indicate that logical mathematical intelligence is related to mathematical literacy:students with high intelligence demonstrated comprehensive problem formulation accompanied by multivariable evaluation strategies;students with medium intelligence were able to identify relevant information but were limited to a single variable without thorough verification; and students with low intelligence still relied on procedural intuition accompanied by fundamental misunderstandings. These findings support the premise that logical mathematical intelligence not only determines the accuracy of the final answer but also shapes the depth of students' overall mathematical cognitive processes. Further research is recommended to expand the content beyond numbers.

Keywords: Logical mathematical intelligence; Lower secondary students' mathematical literacy; Number content; PISA.

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INTRODUCTION

Mathematical literacy is a person's ability to formulate, employ, and interpret mathematics in various everyday contexts, reflecting the ability to think logically, reason critically, and make decisions based on careful consideration (OECD, 2023a). In relation to the PISA 2022, mathematical literacy may be described as reasoning mathematically and using mathematical skills, procedures, facts, and tools in order to describe, explain, and predict phenomena (OECD, 2023a). This is reflected in the framework which emphasizes the importance of formulate, employ, and interpret/evaluate dimensions of mathematical literacy, suggesting that it involves more than procedural knowledge; rather, it includes the ability to represent real-world situations mathematically and analyze them before presenting them back within the initial context. As for the definition of the key competencies involved in math literacy, these are grouped into four categories quantity; change and relationships; space and shape; and uncertainty and data which are supplemented with three main cognitive processes: formulates, employs, and interprets/evaluates (OECD, 2023b). In terms of today's rapidly progressing digitalization and globalization, there is no doubt regarding the growing importance of math literacy in that citizens require sophisticated skills and knowledge to make data-based evidence-informed decisions in their lives (Pablo Javier Ortega-Rodríguez, 2025).

In accordance with the theory of multiple intelligences by Gardner (1983), logical-mathematical intelligence can be viewed as the most prominent in terms of developing logical and math reasoning abilities and proficiency in working with numbers, abstract concepts, patterns, and systems. There are three main reasons explaining the choice to use the logical-mathematical intelligence as a grouping variable in this research project. Firstly, from the constructivist standpoint, it should be acknowledged that logical-mathematical intelligence has the highest level of operational consistency among the multiple intelligences dimensions because of its potential to be measured using such variables as deductive and inductive reasoning ability, numerical patterns' recognition, and math problems' logical solutions (Bracero-Malagón et al., 2022). Secondly, from a theoretical point of view, logical-mathematical intelligence has a direct correlation with the three key aspects of the mathematical literacy process of PISA formulates, employs, and interprets, which imply structured reasoning, exact calculations, and evaluation of the outcomes (Hidayatulloh et al., 2025). Thus, using logical-mathematical intelligence scores as a grouping variable implies not merely a theoretical approach but rather a constructive methodological one. Based on the mentioned above, a hypothesis may be made stating that logical-mathematical intelligence plays a critical role in students' performance in math literacy in content areas requiring advanced quantitative reasoning.

According to PISA 2022 data, students from Indonesia received scores amounting to 366 points in the field of mathematics literacy, significantly lower than the OECD average score which is 472 points (OECD, 2023a). According to the rankings, Indonesia ranks 69th among the 81 countries, hence pointing out that there is a system crisis when it comes to the quality of math education in lower secondary schools (Hidayatulloh et al., 2025). In the international scope, current researches have indicated several predictors for math literacy, including self-efficacy in math, parents' participation, socio-economic status, and quality of cognitive instruction in class (Niu et al., 2025). According to Kappassova et al. (2025), in a review of the last decade's trends on mathematics literacy, internal cognitive predictors of math literacy performance, specifically logical intelligence, are consistent indicators of math literacy performance despite their underrepresentation in developing countries' PISA researches.

Analysis by content domain also shows that the number content is one of the areas with a relatively lower achievement level compared to other domains (Mallillin, 2020). These findings are supported by Greeno (1991) who state that the quantity domain has important implications given that numbers serve as the foundation and prerequisite for mastering other conceptual domains, including testing changes and relationships, describing and measuring various objects, space, and shape, as well as organizing, interpreting, measuring, and evaluating uncertainty and data. This situation indicates that students still face challenges in understanding, modeling, and interpreting numerical concepts within various real-life problem contexts (Tasarib et al., 2025) Therefore, issues in mathematical literacy are not limited to computational skills but also encompass cognitive aspects related to the thinking processes involved in constructing and interpreting problem solutions.

In Indonesia, Isnani et al. (2023) have revealed significant differences in the nature of mathematical literacy attributes in students with high, medium, and low logical intelligence when solving problems, without being focused specifically on the PISA numeracy test content. Likewise, M. Allo et al. (2021) showed that students with high logical mathematical intelligence in junior high schools met all mathematical literacy criteria, while those with medium and low intelligence showed diverse and inconsistent profiles. Muslimah and

Ladyawati (2023) studied numeracy literacy in terms of logical mathematical intelligence and linguistic intelligence; however, they restricted their investigation to the Minimum Competency Assessment questionnaire. According to Hidayatulloh et al. (2025), using general problems, students with high logical mathematical intelligence met all mathematical literacy criteria, including the interpretation process, while those with low intelligence only attained some criteria of formulate and use. With respect to problem-solving strategies, according to investigations by Lestari and Prayitno (2025) in the adversity quotient approach and by Almarashdi and Jarrah (2023) in grade ten, students' skills during the formulation process were always inferior to those during the interpretation process, with varying strategies depending on the cognitive profiles of individuals. Harisman et al. (2023) observed that the capabilities of junior high school students in cities to solve mathematical literacy problems divided into three different groups based on the students' prior knowledge, whereby most continued struggling to explain mathematical procedures effectively and comprehensively for PISA questions.

According to the systematic review by Alvarez-Tinajero et al. (2025) using the PRISMA approach on mathematical literacy studies conducted between 2019 and 2025, it is essential to consider incorporating mathematical competencies and critical thinking. However, this has been partially implemented since it has not yet considered individual intelligence variables as moderators. While bibliometric trends show a global increase in mathematical literacy research between 2014 and 2024, there are few empirical studies examining logical mathematical intelligence and performance on PISA numeracy content in junior high schools (Alghar & Hidayatulloh, 2024). In the examination of the correspondence of the Vietnamese curriculum with PISA 2022, Truong and Nguyen (2025) argue that the differences in numeracy literacy should be analyzed not only from the curriculum perspective but also from students' internal cognitive competencies.

Overall, the literature review reveals a substantial research gap, namely most of the research conducted to date has focused on comparing achievement levels and general correlations between these two variables, without delving deeply into the characteristics of the thinking processes and strategies that emerge at each stage of formulate, employ, and interpret/evaluate, particularly in the context of number based content using PISA instruments. This situation represents a gap that warrants attention, given that differences in logical mathematical intelligence have the potential to influence the problem solving strategies students employ when modeling and interpreting contextual numerical problems. Numerical content has been chosen since it is a critical field of study that poses a vulnerability problem amongst Indonesian learners (Simbolon & Nurjanah, 2024). In view of the above background, this paper aims to explore, critically:

1. How do the mathematical literacy characteristics of junior high school students with different levels of logical mathematical intelligence differ in solving PISA numeric content problems?
2. What is the relationship between the level of logical mathematical intelligence and the problem-solving strategies demonstrated by students?

From a theoretical perspective, this study is expected to enrich the discussion of mathematical literacy through the lens of multiple intelligences. In contrast, from a practical perspective, the results may have implications for the development of instructional designs that are more adaptive to students' cognitive characteristics.

METHOD

Research Design

This study uses a qualitative method with a descriptive design. This choice of design matches the purpose of this research, which is to describe and compare the characteristic of students' mathematical literacy and the strategy used by the students to solve PISA number content problems based on different levels of logical mathematical intelligence. It is important to note that using a qualitative descriptive design is fitting since this method allows researchers to have a broad knowledge of the processes of students' thinking while solving PISA number content items, something that cannot be accomplished using quantitative methods alone (Creswell & Poth, 2017). The unit of analysis is the individual student who will be divided into three groups depending on his/her logical mathematical intelligence score: high, medium, and low level. In each group, there will be three to four students who come from the same grade eight class, providing equivalent experience in the learning process.

Participant

The study subjects consisted of 34 eighth grade students enrolled at a school in East Java. All subjects took a mathematics literacy test and multiple intelligence test, for the in depth interview phase, 11 students were selected using purposive sampling, a method for selecting subjects based on specific criteria (Helaluddin & Hengki Wijaya, 2019). Classification is based on the results of the multiple intelligences test and further classified into three levels: high logical mathematical intelligence level, medium logical mathematical intelligence level, and low logical mathematical intelligence level (see Table 1). This classification has been made to ensure a rich and relevant dataset for the study.

Table 1. Classification of Levels of Logical Mathematical Intelligence

Range of student scores	**Category**
$Score > \bar{x} + SD$	High
$\bar{x} - SD \leq Score \leq \bar{x} + SD$	Medium
$Score < \bar{x} - SD$	Low

The standard deviation (SD) can be calculated using the formula

$$SD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(X - \bar{x})^2}$$

Thus, the standard deviation was found to be 29, and the overall mean score was 55

Table 2. Results of the Classification of Logical Mathematical Intelligence Levels

Range of student scores	**Category**
$Score > 84$	High
$26 \leq Score \leq 84$	Medium
$Score < 26$	Low

Based on this grouping, a student with a high level of logical mathematical intelligence and a student with a low level of logical mathematical intelligence were selected as interview subjects to assess students' mathematical literacy in solving PISA questions on number content. Moreover, the selection of participants was made based on how clearly their thinking process can be understood from their answer sheets and their ability to verbalize it, thus guaranteeing that the selected participants can provide valuable and meaningful data. The profiles of the research participants are shown in Table 3, including their gender and dominant types of multiple intelligence, especially logical mathematical intelligence. The presentation of these characteristics aims to provide an overview of the participants and to explain the basis for selecting research subjects, focusing on students with high, medium, and low levels of logical mathematical intelligence.

Table 3. Participant Characteristics

Number	**Aspect**	**Category**	**N**	**Percentage (%)**
1	Gender	Man	19	57,57
		Woman	14	42,43

Number	Aspect	Category	N	Percentage (%)
2	Dominant multiple intelligence (logical mathematical)	– High logical mathematical $Score > \bar{x} + SD$	5	15,15
		– Medium logical mathematical $\bar{x} - SD \leq Score \leq \bar{x} + SD$	25	75,75
		– Low logical mathematical $Score < \bar{x} - SD$	3	9,10

Data Collection

Data collection was conducted in a regular classroom without any special instructional interventions. In the course of this, the researcher was within the class where the students were sitting on their desks as they normally would be while taking part in conventional instruction activities. This was done in order to make sure that the surroundings of the children while conducting the study remained realistic and reflected their normal routine. Before the test started, the students were introduced to the nature of the task and how to carry it out. Then, every single child took a 90-minute math test about numbers. Students were allowed to ask questions if anything was unclear; however, no questions were asked during the test because the test instructions were clearly written and informative. Thus, the students completed the test independently without outside assistance.

Research Procedures

The teaching procedures in this study are defined as mechanisms for conducting research in regular classrooms, rather than as the implementation of a new teaching model. The research was conducted sequentially as follows:

- Preparation: This included a preliminary study of number concepts, instrument development, expert validation (two individuals), and limited testing to ensure instrument quality.
- Test Administration: Students took the mathematics literacy test on number concepts individually for 90 minutes following a brief instruction. The questions were designed to measure the processes of formulating, employing, and interpreting/evaluating in accordance with PISA standards.
- Selection and Interviews: Based on the test results, three students were purposively selected as research subjects representing high, medium, and low levels of logical-mathematical intelligence. In relation to the interviews carried out before, the research ethics process was carried out in a very thorough manner as outlined below. First of all, in terms of children's consent, the participants were clearly made aware of the fact that their participation in the research was optional and withdrawing at any point would not attract any form of penalties. Secondly, as far as anonymization goes, the identity of all the participants was substituted with initials in order to maintain confidentiality and protect the participants' privacy both during and even after the research period. Lastly, in relation to data preservation, all the data collected through interviews was stored by the researcher and only accessed by him or her. After conducting the ethics processes, semi-structured interviews were conducted among all the participants in order to get more into their thinking processes as opposed to what was achieved through writing.

Instrument

The mathematics literacy test instrument was developed from scratch by researchers, drawing on the characteristics of PISA questions and adapting them to the Indonesian educational context for the topic of numbers. The instrument takes the form of an essay question, consisting of a single main question and four sub-questions. It is designed to assess the processes of formulation, employing, interpreting, reevaluating, and evaluating. This instrument has been validated by two mathematics education experts and deemed suitable for use.

1. Rani wants to buy a bag that normally costs Rp250,000.00.
Rani has been saving for 5 weeks, putting aside Rp40,000.00 each week.
Rani's total savings is the amount she can use for shopping.
Rani found promotions for the same bag at the following stores:

Store A
20% discount plus an additional 5% if using a digital wallet.

Store B
50% discount with a minimum purchase of Rp300,000.00 in a single transaction.

Store C
30% discount + 20%

Store D
Buy 1, get 1 free (B1G1)

Questions:

1. Which promotions can Rani use based on her savings balance and the promotion terms? Explain.
2. Of the promotions she can use, which one is the most advantageous for Rani if she buys only one bag? Explain the mathematical reasoning.
3. Are there any promotions that seem attractive but are actually less advantageous? Explain.
4. Explain the strategy you used to determine the best choice.

Figure 1. Mathematics Literacy Test Instrument (PISA)

The instrument above presents a contextual question based on a real life shopping scenario, in which students are asked to analyze promotional offers based on the amount of savings available. These questions are organized into four sub-questions (Q1-Q4) that are intentionally designed to engage students in the three OECD mathematical literacy processes: formulate, employ, and interpret and evaluate. Each sub-question demands an increasingly higher level of cognitive engagement, starting with problem identification in Q1, continuing with the systematic application of mathematics in Q2, and culminating in critical evaluation and strategic reflection in Q3 and Q4. To ensure methodological transparency and alignment between the instrument and the theoretical framework, the following table presents an explicit mapping of each sub-question to the corresponding OECD process codes, mathematical literacy indicators, and logical mathematical intelligence sub-indicators as outlined in the research framework.

Table 4. Alignment of Sub-Questions with OECD Mathematical Literacy Processes and Logical Mathematical Intelligence Indicators

Sub-Question	OECD Process	Code	ML Indicator	LMI Indicators	Code
Q1	Formulate	F1	– Identify the problem by outlining what is known and what is being asked in the question.	– Students can perform mathematical calculations and solve the given math problems.	LM1
	Employ	E1	– Developing strategies to correctly solve mathematical problems.	– Students can think logically and reason, so that the problem-solving process and the answers they provide are correct.	LM2
Q2	Employ	E1	– Developing strategies to correctly solve	– Students can think logically and reason, so that the problem-solving	LM2

Sub-Question	OECD Process	Code	ML Indicator	LMI Indicators	Code
			mathematical problems.	process and the answers they provide are correct.	
		E2	– Applying mathematical rules and concepts by breaking down the steps to systematically find a solution.	– Students can provide accurate solutions to problems, ensuring that the steps taken to arrive at the answer and the conclusion drawn are correct.	LM3
Q3	Interpret and Evaluate	I1	– Interpreting the results of mathematical calculations by applying the conclusions drawn to the context of the problem.	– Students can think deductively and inductively, enabling them to draw conclusions and make accurate statements.	LM4
Q4	Interpret and Evaluate	I2	– Critiquing and reviewing problem-solving approaches.	– The student correctly outlines the steps for solving a math problem, and the answer provided is correct.	LM5

The instruments used in this paper were developed to pose relatively difficult items requiring multi-stage reasoning about percentages, conditionals, and comparison in the context of realistic shopping decisions. Concerning the compatibility of the problem with PISA proficiency levels, the task corresponds to the Level 4 on PISA mathematics because it requires effective use of models to solve problems in complex concrete settings, apply mathematical reasoning to consider several conditions at once, and make a critical reflection on the results (OECD, 2023a). The idea for the task in the promotional-discount context was borrowed from the PISA quantity domain and personal context, since the problem reflects the real-life situation in which junior high school students in Indonesia find themselves regularly (Vos, 2018). At the same time, adaptations have been made in terms of the promotion of the Indonesian currency and digital wallets reflecting modern consumer behavior, while keeping the difficulties typical for PISA-type problems as stated by Stacey and Turner (2015).

The second instrument used was aimed at measuring the students' dominant multiple intelligences. It was a multiple intelligences inventory adapted from the work by Gardner (1999) and operationalized according to Armstrong (2018). The validity of the instrument was tested in a pilot study involving 15 students not included in the sample. The psychometric characteristics of this adaptation conform to the measurement model suggested by Cuban (2004); it has proven its reliability ($\alpha = 0.78 - 0.85$) in a similar sample of students. Students are considered to have a dominant logical-mathematical profile if their score is higher on this dimension than on any other intelligence scale, based on the definition of intelligence offered by Gardner (1983). The inventory consists of 80 statements rated on a scale from 1 to 5; it is used for defining students' multiple intelligences. For this study, an analysis of students' logical-mathematical intelligence was emphasized. The last instrument used in this paper was the interview based on the formulation of mathematical literacy: formulate, employ, interpret/evaluate.

Interviews with Students

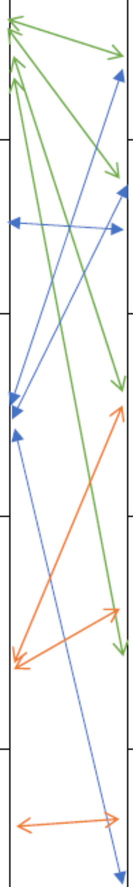
Semi-structured interviews were conducted with selected students on the day of the exam to ensure the accuracy of their thought processes. This structure was chosen because it allowed the researcher to combine the formalities of guiding questions with flexibility for conducting an exploratory investigation by formulating subsequent questions or conducting probes based on the responses provided by the students. The objectives of the interviews were to uncover context, quantify data, strategize, operationalize, and assess the rationality of findings. This approach aimed to clarify the written data while revealing dimensions of logical mathematical reasoning that are not always evident on the answer sheets.

Data Analysis Techniques

The research data obtained from the mathematics literacy tests and interviews were analyzed qualitatively using the model (Miles & Huberman, 1994). This study consisted of three major steps, namely data reduction, data presentation, and conclusion. Data reduction involved the process whereby the researchers selected and focused on data gathered from the test and interviews related to the indicators listed in Table 5 below. Disagreements between the two authors were resolved through discussion until a mutual agreement was reached. Next, the data were organized into narratives, tables, or matrices to facilitate the identification of patterns in students' responses and problem-solving strategies. The final stage concluded with the formulation of an integrated description of eighth-grade students' mathematical literacy based on a synthesis of test and interview analysis results. The mathematical literacy indicators are presented in Table 5.

Table 5. Correlation Between Mathematical Literacy Indicators and Logical Mathematical Intelligence Indicators

Mathematical literacy	Code	Indicator
Formulate	F1	Identify the problem by outlining what is known and what is being asked in the question
Employ	E1	Developing strategies to correctly solve mathematical problems
	E2	Applying mathematical rules and concepts by breaking down the steps to systematically find a solution
Interpret and evaluate	I1	Interpreting the results of mathematical calculations by applying the conclusions drawn to the context of the problem
	I2	Critiquing and reviewing problem-solving approaches



Indicators of Logical-Mathematical Intelligence	Code	Sub-indicator of Logical-Mathematical Intelligence
Mathematical calculation	LM1	Students can perform mathematical calculations and solve the given math problems
Thinking logically and rationally	LM2	Students can think logically and reason, so that the problem-solving process and the answers they provide are correct
Problem solving	LM3	Students can provide accurate solutions to problems, ensuring that the steps taken to arrive at the answer and the conclusion drawn are correct
Deductive and inductive reasoning	LM4	Students can think deductively and inductively, enabling them to draw conclusions and make accurate statements
The clarity of patterns and relationships	LM5	The student correctly outlines the steps for solving a math problem, and the answer provided is correct

RESULTS AND DISCUSSION

The results from the mathematical literacy test were first analyzed through a descriptive analysis to establish the position of students' logical mathematical ability in the spectrum relative to the pre-defined criteria in the test. From Table 6, it was established that the larger percentage of students (75.75%) belonged to the medium group; hence, most of the students had a decent logical mathematical ability to handle questions on numerical literacy. Only 15.15% were found to be in the high ability group, while the remaining 9.10% belonged to the low ability group. Based on these results, research subjects representing each category (high, medium, and low) were selected for further analysis to uncover differences in the characteristics of thinking processes and problem-solving strategies in mathematical literacy regarding number content, which were subsequently examined through an analysis of students' written work.

Table 6. Results of Score Clustering

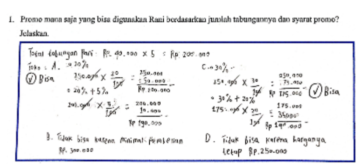
Number	Category	Literacy mathematics	n	%
1.	Logic mathematics intellegence	High	5	15,15
		Medium	25	75,75
		Low	3	9,10

From Table 6, it can be seen that the majority of the students fall under the category of medium logical mathematical intelligence (75.75%), while the percentage for high and low logical mathematical intelligence stands at 15.15% and 9.10%, respectively. This means that students' skills using the language of mathematics are generally moderate, without significant deviation towards extremes. This distribution forms an important background for future research work, particularly with regard to comparisons of thinking styles within categories. Therefore, research subjects representing the high, medium, and low categories were selected for in depth analysis through students' written work. Table 7 provides information on the results of the mathematics literacy tests for each research subject .

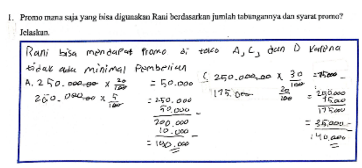
Table 7. Research Subject

No	Category	Literacy mathematics	Students' name	Score
1.	Logic mathematics intellegence	High	DAA	90
			ASW	90
			NES	85
			KAG	90
		Medium	AZR	75
			MNS	65
			SPN	55
			MND	45
		Low	NMS	24
			MNA	25
			NESM	25

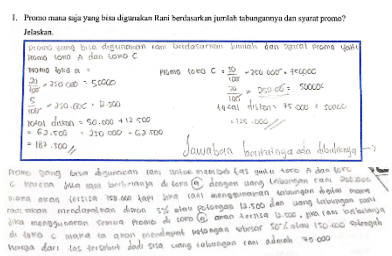
Mathematical Literacy Question 1



1a) DAA



1b) AZR



1c) NMS

Rani's total savings $Rp40.000 \times 5 = Rp200.000$ Store A = 20% $\rightarrow 250.000 \times \frac{20}{100} = 50.000$ $250.000 - 50.000 = 200.000$ $20\% + 5\%$ $\rightarrow 200.000 \times \frac{5}{100} = 10.000$ $200.000 - 10.000 = 190.000$ Store B = I can't because the minimum purchase is Rp300.000 Store C = 30% $\rightarrow 250.000 \times \frac{30}{100} = 75.000$ $250.000 - 75.000 = 175.000$ $30\% + 20\%$ $\rightarrow 175.000 \times \frac{20}{100} = 35.000$ $175.000 - 35.000 = 140.000$ Store D = I can't because the price is fixed Rp250.000	Rani can get discounts at stores A, C, and D because there is no minimum purchase requirement. Store A $\rightarrow 250.000 \times \frac{20}{100} =$ 50.000 $200.000 \times \frac{5}{100} = 250.000$ 50.000 − 200.000 10.000 − 190.000 Store C $250.000 \times \frac{30}{100} = 75.000$ $175.000 \times \frac{20}{100} = 250.000$ 75.000 − 175.000 35.000 − 140.000	The promotions that Rani can use, based on the number and terms of the promotions, are the promotions from Store A and Store C. Store A Promotion = $\frac{20}{100} \times 250.000 = 50.000$ $\frac{5}{100} \times 250.000 = 12.500$ total discount $= 50.000 + 12.500$ $= 62.500 = 250.000 - 62.500$ $= 187.500$ Store C Promotion = $\frac{30}{100} \times 250.000 = 75.000$ $\frac{20}{100} \times 250.000 = 50.000$ total discount =75.000+50.000 $= 125.000$ The promotions Rani can use to buy a bag are available at Store A and Store C. If Rani shops at Store A using her savings of 200,000, she will have 150,000 left. However, if Rani uses her digital savings, she will receive a 5% discount or a 12,500 discount on top of her savings. If she uses all the promotions at Store A, she'll have 12,500 left. If Rani shops at Store C, she'll get a 50% discount or 150,000, which is half the price of the bag so the remaining balance in Rani's savings will be 75,000

Figure 2 (1a,1b,1c). Answers to Question 1 for students DAA, AZR, and NMS

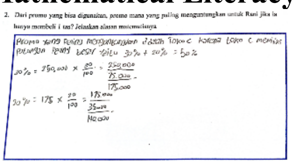
In Question 1, the students' three answers indicate that the quality of the answer is determined by the quality of the formulation process, specifically, the depth and stability of that process, rather than solely by the correctness of the final result. In the first finding, the students of the DAA course who had high logical mathematical intelligence displayed a thorough formulation process. This can be demonstrated through the calculation of total savings reaching Rp200,000; choosing Store A and Store C; dismissing Store B since the minimum purchase was Rp300,000; and disregarding Store D since the cost of purchasing one bag was greater than total savings. This response aligns with DAA's interview statement, "I calculated Rani's savings of Rp200,000 first, then checked each remaining promotion one by one. Store A and Store C were viable because they fit Rani's budget, while the others did not meet the criteria". The second discovery is that students who have medium logical mathematical intelligence stayed engaged in formulation work but only through reductionism.

In particular, student AZR demonstrated an appreciation for the importance of minimum purchases, but the issue became simpler because the absence of a minimum allowed for automatic application of the promotion and therefore considered Store D as one of the alternatives. This is consistent with the account given by student AZR in the interview, who stated, "I focused on promotions that did not have a minimum purchase requirement. Since Stores A, C, and D did not set such a limit, I assumed all three could be used". For the third observation, the students who were diagnosed with low logical mathematical intelligence opted for the right choices; these included Stores A and C. The students have been able to identify some important information within the scenario, but their use of mathematical terms is still unstable. They have also been able to make relevant decisions, but they still seem unsure about how to solve a problem that involves a 30% + 20% discount on the original price. This aligns with a quote from student NMS's interview: "I realized Stores A and C could be used, so I calculated the discounts from the original price to determine the final result. As far as I am concerned, the phrase "30% plus 20%" suggests an addition of the percentages. Three students managed to display their ability to develop criteria for "worthy promotions," based on the principle of the evaluation of the cost of products relative to the amount of money saved by Rani, while meeting the requirements of the promotional offer.

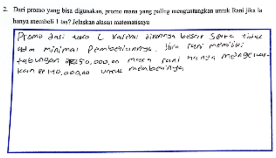
Formulate

Upon comparing this data, one comes to the conclusion that the students who possess greater logical mathematical intelligence use a wider range of formulation of their knowledge; however, this pattern is not always applicable. On the other hand, students with medium logical mathematical skills may recognize relevant information but are unable to check all mathematical criteria. Students with low logical mathematical intelligence still exhibit less robust formulations, particularly in translating the problem context into an appropriate mathematical representation. Therefore, the essence of the formulation aspect in the task is the ability of the students to recognize important variables, set up the relevant constraints, find the relationships between different aspects of the problem, and represent the information in mathematical form. This study is also in agreement with the PISA theory that defines formulating a situation mathematically as the ability to recognize the mathematics of a real-world situation, choose the best representation, and transform it into mathematical form. Therefore, in the context of problem based number content, differences in students' mathematical literacy characteristics are most clearly evident during the formulation stage. In this study, this trend was observed more consistently among students with high logical mathematical intelligence than among those with lower levels of intelligence. Therefore, in the realm of problem based numerical knowledge, differences in the traits of mathematical literacy possessed by students will be most noticeable during the process of problem formulation. This phenomenon is more evident in students who have high logical mathematical intelligence as compared to those with low logical mathematical intelligence.

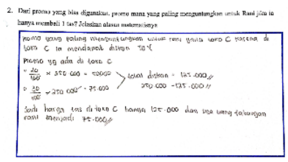
Mathematical Literacy Question 2



2a) ASW



2b) MNS



2c) NMS

The most advantageous promotion is at Store C because Store C offers the biggest discount, which is 30% + 20% $30\% = 250.000 \times \frac{30}{100} = 250.000$ 75.000 – 175.000 $20\% = 175.000 \times \frac{20}{100} = 175.000$ 35.000 – 140.000	A promotion from Store C because the discount is significant and there's no minimum purchase requirement. If Rani has Rp250,000.00 in her savings, she'll only spend Rp140,000.00 to buy it.	The most advantageous promotion for Rani is at Store C, because at Store C she gets a 50% discount The promotion available at Store C $\frac{20}{100} \times 250.000 = 50.000$ $\frac{30}{100} \times 250.000 = 75.000$ total discount = 125.000 $250.000 - 125.000$

		So the price of the bag at Store C is only 125,000, and Rani has 75,000 left in her savings.

Figure 3 (2a,2b,2c). Answers to Question 2 for students ASW, MNS, and NMS

In question number 2, all three students' answers indicate that the quality of the application process primarily determines the quality of the answer, namely the ability to apply mathematical concepts, facts, procedures, and reasoning to select the most advantageous offer. In this case, the first response clearly shows that the student ASW chose Store C and followed an operational comparative technique, whereby he/she sequentially used discount calculations to finally come up with the discount amount of Rp140,000. This is evident in the student's statement where he/she says, "I first discounted 30 percent of the original cost and came up with the new price, thereafter I deducted another 20 percent from that price and came up with the final price of Rp140,000, hence, I'm sure Store C has the least price." From this statement, one is able to see that the student had excellent mathematical understanding of the procedure involved. In addition, the student made a procedural error regarding the calculation of the purchase price with the discount.

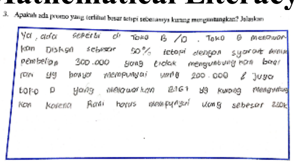
In the second case, the MNS student gave the right answer, whereby he/she decided that Store C is the cheapest store because of the biggest discount available. However, his/her mathematical justification was inadequate as he/she based the decision on assumptions only. This is in line with the interview excerpt "I chose Store C because the discount is the biggest and there's no minimum requirement, so I can use it right away". This statement indicates that MNS students have the right intuition for which store to choose, but are not yet able to verify their decisions through explicit, structured mathematical calculations.

However, responses by NMS students also showed that Store C was applicable. However, there was also evidence that tiered discounts had been wrongly applied. The 30 percent and 20 percent discounts had been seen as two individual reductions applied to the original price and not as tiered discounts. This assertion is proven by the student's response: "I subtracted 30 percent of the original price and then I subtracted another 20 percent of the original price. So in all it is 50 percent off." It clearly shows that tiered discounts should be calculated as a sequence of deductions and not as direct reduction from the original price.

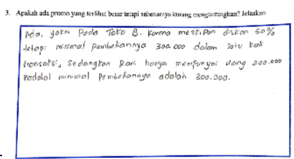
Employ

Therefore, all three approaches have shown the use of the concept in varying degrees of effectiveness: the use of ASW's answer shows a good application of the concept; while the answer to MNS indicates a good application of the concept in the decision-making aspect, yet poor mathematical reasoning; and the answer by NMS shows an error in the basic conception of the structure of tiered discount, yet the selected answer produces the right solution. In conclusion, this comparison shows that the essence of the use of the concept in answering Question 2 is basically in the students' comparison of the available options, the identification of the strategy involved, and the proper use of the concept of discount as the basis for decision-making. This framework aligns with the PISA definition of employ as the application of mathematical concepts, facts, procedures, and reasoning to produce solutions to contextual problems.

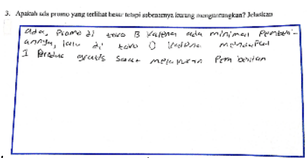
Mathematical Literacy Question 3



3a) NES



3b) SPN



3c) MNA

There's a promotion at Store B because there's a minimum purchase requirement, and at Store D because you get one free item with your purchase	There is one, namely Store B, because even though there's a 50% discount, the minimum purchase is 300,000 per transaction, whereas Rani only has 200,000, even though the minimum purchase is 300,000.	Yes, there are options like at Stores B and D. Store B offers a 50% discount, but with a minimum purchase requirement of 300,000, which isn't beneficial for Rani since she only has 200,000. Store D offers a "Buy One, Get One Free" deal, which is also less advantageous because Rani would need to have 250,000.

Figure 4 (3a,3b,3c). Answers to Question 3 for NES, SPN, and MNA students

In question 3, the students' three answers indicate that the quality of their responses was primarily determined by the interpret and evaluate process, that is, the ability to relate mathematical results or information back to the problem's context and assess whether the promotion was truly beneficial for Rani. In the first finding, reflecting the most comprehensive interpretation, where student MNA assessed not only Store B but also Store D as promotions that seemed attractive but were less beneficial, the student understood that the Buy 1 Get 1 Free scheme was not automatically beneficial for Rani because she still had to spend Rp250,000 on the first bag; this reflects critical thinking skills that go beyond surface-level information. An MNA student's statement also reinforces this: "Store B will not work because the minimum requirement is Rp300,000, while Rani only has Rp200,000. Store D is not a good deal either because even though one bag is free, Rani still has to pay Rp250,000 upfront for her first bag, which is more than her savings". This statement shows that the student was able to verify each promotional condition mathematically and integrate it thoroughly with Rani's financial constraints.

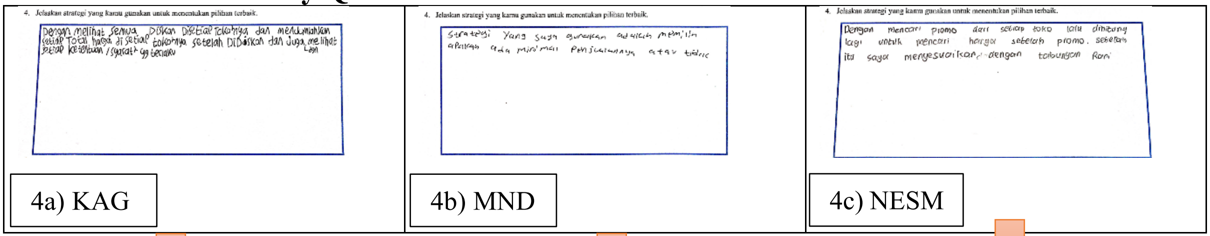
The second finding reveals that SPN students' written answers have provided more definite interpretations: "Promotion from Store B will be disadvantageous because the discount is 50%, yet the minimum price required is Rp300,000 while Rani only has Rp200,000." This finding is further supported by the students' answers in their interviews: "Store B cannot be profitable because the discount offered for Store B is 50%, which can be enjoyed only when the minimum price required is Rp300,000, but Rani only has Rp200,000." It can be seen here that the student is capable of using mathematics to analyze an issue, although his or her analysis is still inadequate since the student did not provide analysis on other stores that might also incur losses.

On the other hand, the third result, based on the students' answers in NES, shows that the promotion of Store B is quite strong and promising, but its limitations are tied to the minimum purchase amount. Store D is also mentioned. A student in the NES group confirmed this: "Store B is not very profitable because of the minimum purchase requirement, and Store D does not seem very good either, but I am not sure why." This statement indicates that the students relied on general knowledge of the information rather than being able to construct verified, specific mathematical arguments.

Interpretation and evaluate

Thus, all three responses simultaneously demonstrate the interpret and evaluate process, albeit at varying levels of depth: the first response is general in nature, the second is precise and focuses on a single dominant contextual constraint. At the same time, the third offers a broader interpretation by simultaneously evaluating two promotions based on their suitability for Rani's actual circumstances. The comparison emphasizes what is important for the interpretation and evaluation in Question 3 that is, the ability of the students to think not just about the amount of the discount, but also the sensibility and relevance of the promotion itself in terms of practical purchasing behavior. This finding aligns with the PISA framework, which defines formulate, employ, and interpret/evaluate mathematical results as the ability to reflect on mathematical results, reconnect them to the problem context, and determine their reasonableness and usefulness in real world situations.

Mathematical Literacy Question 4



by reviewing all the discounts at each store and adding up the total price at each store after the discount, and by reviewing the applicable terms and conditions	The strategy I use is to check whether there is a minimum sales requirement or not	by looking for deals at each store and then recalculating the price after the discount. After that, I adjust it based on Rani's savings

Figure 5 (4a,4b,4c). Answers to Question 4 for KAG, MND, and NESM students

Based on the analysis of the three student answers, it becomes evident that different levels of interpretive and evaluative understanding are reflected in the meanings expressed. So, the answer from KAG includes several elements, including (a) checking all the discounts offered by each store, (b) determining the price after the discount, and (c) identifying the terms and conditions attached to the promotion. It means that KAG students did not consider the decision based on the actual discount rate but also estimated the final price and promotions, which allowed extending the list of possible options for the strategies to choose. The following quote confirms the idea that KAG students take into account much more than simply using the discount offered: "I check all the discounts, then determine the final price, and only then check if there are some terms because even though there are terms, it doesn't mean that they will use them."

On the other hand, the second solution, which belongs to an MND student, outlines a tactic that is premised on validating the minimum purchase requirement. From the above explanation, it is clear that there is a limited evaluation of the context since only one variable has been considered. This correlates with the statement of the MND student: "I only consider the minimum purchase requirement as it is the main determining condition, so I analyze the minimum purchase requirement; if my Rani Savings is not sufficient, then I would not be able to select such a store." Here we can see that the student takes into account the budget limitations of Rani, but her logical thinking skills have not developed enough to consider other dimensions of the promotion carefully. Likewise, the third answer offered by a NESM student reveals a procedure of analyzing promotions, recalculating the prices based on the promotions, and matching them to Rani's savings. It implies that the student uses the calculated information in a practical manner. Thus, it is in line with the statement of the NESM student: "I will recalculate the price after the promotion in every store, and then compare it with Rani's money; if it is sufficient for her, then she can purchase this product." The logic here implies that the student follows an orderly set of procedures without questioning the logic and validity of the promotion scheme used. All these answers reveal different types of interpretation and evaluation processes applied by students. The most developed one is found in the first answer as it involves both evaluation based on calculations and conditions; the second one is partial as it is limited to the minimum purchase condition; while the third one is more developed as it involves a contextual evaluation of promotions based on their agreement with the budget available.

In contrast to the previous example, the key point of the interpret-and-evaluate process demonstrated in Question 4 is reflected in students' skills to critically evaluate various strategies not just as procedural but as a means of verification that the decision is adequate to the conditions presented in the problem. Otherwise said, the level of quality achieved through interpret-and-evaluate process is seen when students go further than just calculating the discount, evaluating whether the most reasonable promotion could be selected by Rani.

Articulation Strategic

The revealed differences suggest that students with better developed interpret and evaluate skills evaluate multiple conditions, namely the price itself, the promotion conditions, and the availability of sufficient savings; while those with lower proficiency limit themselves to just one condition. As we can conclude, these observations correlate with PISA's framework in describing interpret and evaluate as the reflection and evaluation of mathematical results in context.

Overall, an analysis of the three students' responses to questions 1 through 4 reveals distinct patterns in their fulfillment of the indicators for mathematical literacy and logical mathematical intelligence, as summarized in the table. Students with high logical mathematical intelligence successfully met all indicators comprehensively in the formulation aspect (F1) students comprehensively identified problems by accurately detailing known and requested information, which relates to sub-indicator LM1 through accurate calculation and problem-solving skills; in the application aspect (E1 and E2), students design appropriate strategies and employ mathematical principles systematically, in line with LM2 and LM3, where the solution process and resulting conclusions are proven to be valid and structured. On the other hand, under the aspects of interpretation and evaluation (I1 and I2), learners can successfully interpret the results of calculations based on real-life situations coupled with critical evaluation of their solutions, showing mastery of LM4 and LM5. The learners who demonstrate moderate amounts of logical mathematical intelligence will meet the requirements of F1 and will partially meet those of E1, but will not fully meet those of E2 because of their lack of mathematical knowledge and proof. Concerning interpretation and evaluation, learners cannot successfully achieve I1 and I2 because interpretation of real-life situations lacks the ability of deductive and inductive reasoning according to LM4 and LM5.

Meanwhile, students with low logical mathematical intelligence only partially meet indicators F1 and E1 procedurally, with inconsistent identification of information and intuitive strategies lacking systematic steps, resulting in a shallow connection with LM1; indicators E2, I1, I2, as well as sub-indicators LM3, LM4, and LM5 are not strongly met, due to fundamental misunderstandings in the representation of complex mathematical structures, an inability to draw valid conclusions from the problem context, and a failure to construct a logical and verified sequence of solutions.

Discussion

The results of this study indicate that the level of logical mathematical intelligence has a consistent, gradual influence on the quality of junior high school students' mathematical literacy in solving PISA number content problems, as reflected in formulation, mathematical proof, problem-solving strategies, and contextual interpretation. Students who have high logical mathematical intelligence can develop multivariable thinking skills through proper information detection, conditions' verification, and proper assessment of all possibilities. Medium level intelligent students are normally good at information detection, but they do not think beyond one variable in the absence of overall verification, hence their rigidity in reasoning. Low level intelligent students sometimes come up with the right answer, but through intuitions and procedures. They normally make very basic mistakes while solving complicated mathematical problems. These findings confirm that logical mathematical intelligence not only determines the accuracy of the final answer but also shapes the depth and robustness of students' overall mathematical thinking processes.

Several previous studies have reported findings consistent with those of this study. Kaiser (2020) emphasizes that the formation of accurate mathematical representations is a major obstacle in mathematical modeling and that students' cognitive competence strongly influences this in connecting empirical contexts with abstract mathematical concepts. As Passolunghi et al. (2019) found out, students' logical mathematical intelligence plays a critical role in determining their ability to choose and apply suitable approaches in dealing with math problems. According to Tasarib et al. (2025), through an experiment carried out in Indonesia, mathematical modeling skills training is essential in increasing students' abilities to convert contextual issues to more meaningful mathematical equations. On the contrary, according to Bolstad (2023) advanced mathematical literacy requires not only math intelligence but also skills in evaluating the appropriateness of the answers in a particular context. These findings reinforce the postulate that optimal formulations in mathematics are not limited to theoretical understanding alone but also encompass the ability to critically and objectively evaluate real-world situations.

These findings are consistent with several previous studies. First, Hidayatulloh et al. (2025) concluded that junior high school students with high logical mathematical intelligence were able to meet the indicators for employ and interpret/evaluate, as well as several indicators for formulate. In contrast, students with low intelligence met only some of the indicators for formulate and employ. This reinforces the argument that the higher the level of logical mathematical intelligence, the broader the range of mathematical literacy components mastered. Moreover, Iskandar et al. (2024) have found that those students who fall under the category of logical mathematical intelligence showed better results during the implementation phase of the PISA test compared to those students belonging to other categories of intelligence. This supports the dominance of evaluative and verifiable methods used by top-performing students in this research. Third, Bolstad (2023) found that middle school students' engagement with mathematical literacy in the school environment is largely dominated by an emphasis on mathematical knowledge within a school context, without sufficient exploration of real-world contexts, which helps explain why students with lower intellectual abilities struggle to represent real-world contexts mathematically. Additionally, Alagumalai & Buchdahl (2021) revealed that each of the OECD processes involves different degrees of cognitive complexity, whereby the formulate process entails the highest degree of cognitive complexity, implying that students with poor capabilities have challenges in advancing significantly to the employ and interpret processes. In terms of content, Murtiyasa & Asiyah (2022) highlighted the basic problems experienced by junior high school learners in expressing complex mathematical expressions in the PISA quantity area, which is in line with findings obtained from this study: students with poor logical-mathematical intelligence cannot generate logical and reliable responses in the employ, interpret, and evaluate processes.

Nevertheless, several studies also present contrasting perspectives on the relationship between logical mathematical intelligence and the quality of mathematical problem solving. According to Passolunghi et al. (2019) despite the fact that logical mathematical intelligence has its symbolic significance, the actual development of successful problem-solving skills is more strongly associated with social and pedagogical components, such as the process of learning in the classroom. Geiger et al. (2018) emphasize that even individuals who have high cognitive abilities often experience challenges in their interpretation of the context properly due to their lack of experience with situations involving mathematics. Chasanah (2021), proves that good instructional models will provide equality for students with various types of intelligence in mathematical literacy since the development of high logical-mathematical intelligence is not the only requirement for formulation, implementation, interpretation, and evaluation processes. Likewise, in their study conducted in 2024, Huang et al. prove using a machine-learning algorithm that mathematical self-efficacy, rather than cognitive intelligence, is the main factor predicting students' literacy in mathematics, thus questioning the idea that high logical-mathematical intelligence is the key factor for developing strategic depth. Interventions in the field were investigated in an article written by Almarashdi & Jarrah (2022) and proved that PISA-based enrichment programs positively impact students' mathematical literacy regardless of their previous academic performance, thus allowing for modifications of intelligence gradients with appropriate interventions. Moreover, the findings of Zhang et al. (2025) after conducting cognitive diagnostics with PISA confirmed that differences in students' mathematical competency accomplishment were caused by contextual and regional factors rather than individuals' cognitive capabilities. Therefore, none of the above studies contradict the findings of the current research since they confirm the multidimensional nature of mathematical literacy and prove that logical-mathematical intelligence is one of its important but independent determinants. In this regard, future research may aim at integrating all the interactions between cognitive, affective, and contextual factors to better understand the process of mathematical literacy development. This means that logical-mathematical intelligence per se will not provide sufficient problem-solving capabilities and will require additional learning experience.

There are a number of limitations to the current study that should be considered. First of all, the sample used in this study was quite small, which does not allow for statistically reliable generalization. Secondly, the process of collecting data in this research took place within only one PISA content domain, so one could wonder about the similarities between the findings of this research and findings in other areas. With this in mind, future studies could consider the following areas of study: (1) Increasing the sample size using a mixed methods research design in order to increase the validity of the results obtained; (2) Studying the profile of mathematical literacy based on logical mathematical intelligence in other fields covered by PISA assessments; (3) The effect of mediating factors including mathematical self-efficacy and cognitive styles on mathematical literacy and (4) Creating an individualized teaching plan for improving mathematical literacy that would take into consideration the profile of logical mathematical intelligence. To help readers analyze the research results, Table 8 is provided below as a summary across cases.

Tabel 8. Case Overview

Level of Logical Mathematical Intelligence	**Formulate**	**Employ**	**Interpret and Evaluate**
High	Identify the problem thoroughly and provide precise and complete details of the known information and the questions asked.	Developing appropriate and systematic problem-solving strategies and drawing valid and structured conclusions.	Conduct a critical evaluation of the accuracy of the solution and be able to validate the answer with mathematical reasoning.
Medium	Able to understand the general context of the question, even if it is not always complete.	Designing a strategy that is only partially correct, focusing solely on one variable without considering all aspects of the problem.	Interpreting the results in a limited way, the contextual interpretation is not supported by adequate reasoning.
Low	Identifies inconsistent information; is only able to copy data from	Intuitive strategies lacking systematic steps and fundamental	Unable to interpret the results in a real-world context; unable to

Level of Logical Mathematical Intelligence	Formulate	Employ	Interpret and Evaluate
	the question without understanding its meaning.	misunderstandings in developing a sequence of solutions.	draw valid conclusions from the problem.

CONCLUSION

This study shows that logical mathematical intelligence makes a significant contribution to the quality of junior high school students' mathematical literacy regarding number-related content. This contribution is evident not only in the accuracy of answers but also in the quality of mathematical thinking processes, particularly in understanding context, modeling problems, selecting solution strategies, and justifying results. The findings reveal that students with high logical mathematical intelligence tend to demonstrate more systematic, analytical, and comprehensive reasoning; students in the medium category can identify important information but are not yet consistent in verifying and integrating various variables; whereas students in the low category still tend to use superficial procedures and less accurate reasoning. Thus, differences in levels of logical mathematical intelligence are closely related to differences in the quality of reasoning and problem solving strategies in mathematical literacy. Although this study is limited to a small sample size and a single PISA content domain, these findings have important implications: the development of mathematical literacy needs to be designed in a more differentiated manner, taking into account variations in students' logical mathematical intelligence.

The characteristics in the Formulate process were different for high, medium, and low logical mathematical intelligence students. High intelligence students showed the ability to identify the problem comprehensively and accurately, while moderate intelligence students successfully identified key information but in a less comprehensive way than high intelligence students. On the other hand, low logical mathematical intelligence students only managed to identify pieces of information. In the Employ process, high logical mathematical intelligence students designed and implemented mathematical strategies and performed the required mathematical computation accompanied by the validation process of their computations. Medium logical mathematical intelligence students were able to apply strategies partially to solve mathematical problems and focused more on one variable but did not conduct any in-depth validation process. Lastly, low logical mathematical intelligence students used intuitive approaches but did not perform any procedural steps.

Furthermore, there was a correlation between logical mathematical intelligence and the quality of the strategy employed to solve quantity-based mathematical literacy problems. Strategically, a strategy was a set of cognitive actions that students performed as they moved among the processes defined by OECD. A strategy involved the organization and sorting of relevant information in the formulating process, the use of mathematical procedures to solve problems in the employing process, and the critical analysis and communication of solutions within the problem context in the interpreting and evaluating process. Students with high logical mathematical intelligence always employed layered and validated strategies in all three stages of the OECD processes. Students with moderate intelligence applied their strategies only to the formulating stage and somewhat to the employing stage. Lastly, students with low intelligence only applied intuitive and unvalidated strategies and did not develop further from the formulating stage.

RECOMMENDATION

It would be useful for further research to be conducted in three main areas. Firstly, replicating the study by using a wider variety of schools and students in order to determine the extent to which the results can be generalized is necessary. Secondly, it would be important to include concepts in the PISA number content that relate to space & shape and change & relationships in order to gain a better understanding of the students' math proficiency level. Finally, creating an appropriate graduated prompting system that will help resolve the students' issues with discount calculation is important.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dina Nur Aisiya	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓
Sri Suryanti	✓	✓		✓				✓		✓		✓		

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

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

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [SS]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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