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Epistemological Obstacles of Secondary School Students in Solving PISA-Standard Mathematical Literacy Problems Related to Functions

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Abstract: Mathematical literacy is an essential 21st-century competency that students must possess to address global challenges. However, results from the Programme for International Student Assessment (PISA) show that Indonesian students' mathematical literacy remains low. This study aims to explore the epistemological obstacles experienced by students in understanding and solving PISA-standard mathematical literacy problems related to functions. Employing a qualitative approach through Didactical Design Research (DDR), this study focused on identifying epistemological obstacles among four 8th-grade students at a public secondary school in Bandung. Data were collected using tests, interviews, and documentation. The research findings revealed epistemological obstacles related to both conceptual knowledge and practical application, which were detailed in five main issues: understanding the concept of functions, representing functions in the form of equations, graphs, and tables, and solving context-based problems. These obstacles arose due to limited foundational knowledge, such as the concepts of domain, range, and variables, as well as a lack of practice in solving contextual problems.

Keywords: epistemological obstacles, mathematical literacy, PISA, function, mathematic education.

▪ INTRODUCTION

As an effort to improve the quality of education, the Government of Indonesia, through the Ministry of Education and Culture, has introduced the Merdeka Curriculum, which focuses on developing core competencies, including critical thinking, creativity, collaboration, and communication skills. These competencies align with 21st-century skill demands to prepare students for global challenges (Astuti et al., 2024). The 21st-century skills that students need to possess encompass various aspects, including mathematical literacy, as it involves essential abilities required to apply mathematics in everyday life (Retnawati & Wulandari, 2018).

Mathematical literacy encompasses various aspects related to an individual's ability to manage and respond to the demands of mathematics in daily life, whether in practical, social, or professional contexts (Genc & Erbas, 2019). Mathematical literacy is a crucial element in supporting the advancement of human civilization and the rapid development of technology and information. It is closely connected to the ability to read and understand diverse types of information and data presented in various forms, such as tables, diagrams, and graphs (Jungjohann et al., 2022). The term mathematical literacy is not only related to numbers or the understanding of mathematical concepts. It focuses on an individual's ability to utilize conceptual mathematical knowledge and skills in a variety of social contexts. This includes the application of mathematics to analyze, understand, and solve real-world problems, as well as to support decision-making in everyday life (Umbara & Suryadi, 2019). Mathematical literacy consists of two main components: knowledge and competence. Knowledge includes conceptual aspects such as facts, principles, formulas, and mathematical concepts, as well as procedural aspects that involve using mathematical

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procedures, interpreting symbols, and presenting data in the form of graphs or tables. Competence, on the other hand, refers to a student's ability to apply mathematical knowledge and skills in real-life situations. This competency involves understanding problems, selecting relevant knowledge, planning solutions, solving problems with logical reasoning, and checking the obtained solutions (Sumirattana et al., 2017). Based on this, it is important to assess mathematical literacy by measuring this ability, one method being through the assessments conducted by the Programme for International Student Assessment (PISA).

PISA is an international assessment program designed to evaluate foundational literacy skills, including students' competencies in mathematics, conducted by countries worldwide. This program examines the mathematical literacy of students aged around 15 years, aiming to determine how individuals respond to various future situations involving mathematics. It focuses on their ability to rely on mathematical reasoning (both deductive and inductive) and problem-solving to comprehend and address these situations effectively. In the context of assessment, PISA defines mathematical literacy through the analysis of three interrelated domains: process, content, and context. The process domain refers to the steps an individual takes to solve problems using mathematics as a tool. This ability encompasses three main aspects: formulating mathematical situations (formulate), employing concepts, facts, procedures, and reasoning in mathematics (employing), and interpreting, applying, and evaluating the outcomes of the mathematical process (interpreting). Furthermore, the content domain refers to the mathematical material taught in schools, encompassing four main areas: "change and relationships, space and shape, quantity, and uncertainty and data (OECD, 2023b). The mathematical literacy firamework PISA can be seen in figure 1 below.

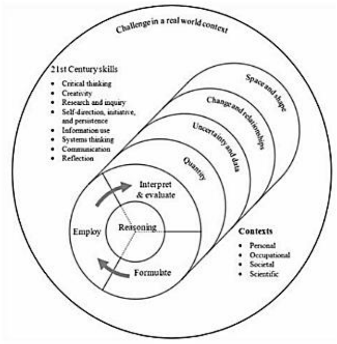

Figure 1. The mathematical literacy framework PISA

The image above illustrates the mathematical literacy framework, highlighting the relationship between mathematical reasoning and problem-solving. In the context of PISA, mathematical literacy is defined as an individual's ability to reason mathematically, as well as to formulate, use, and interpret mathematics to solve problems in various real-world contexts (Nurgabyl et al., 2023).

The evaluation results from the Programme for International Student Assessment (PISA) indicate that Indonesian students' mathematical literacy remains relatively low compared to students in other countries. As of 2022, Indonesia ranked 69th out of 79 countries in mathematical literacy, with a score of 366, which falls below the average. This score also reflects a decline compared to the results from four years earlier, in 2018

(OECD, 2023a). The low score indicates that students face significant difficulties in solving PISA problems. This aligns with research findings that report students struggle with understanding the intent of the problem, translating the problem into mathematical expressions, planning and executing problem-solving strategies, and accurately concluding the solutions to the problems (Hasibuan & Hasanah, 2022). Another study also suggests that one of the reasons for the low PISA scores of Indonesian students in general is that they are not trained to solve questions with characteristics similar to those found in the PISA assessments (Mansur, 2018). Based on these findings, the author believes that it is important to identify various obstacles that arise and affect students' understanding of mathematical concepts (Fadlelmula, 2022).

One type of learning obstacle that may occur is the epistemological obstacle, which refers to a barrier caused by students' limited understanding of knowledge in a specific context, or when previous knowledge is not relevant to solving new problems (Brosseau, 2002). Epistemological obstacles do not only focus on the mistakes made by students, but also delve deeper into how previous concepts were acquired and developed (Siagian et al., 2022). The epistemological obstacles faced by students in solving PISA-based mathematical literacy problems are complex issues that involve limitations in understanding, connecting, and applying mathematical knowledge in real-world contexts. Kholid et al. (2022) found that the main difficulty students face is in the process of mathematization, which involves identifying mathematical variables and relevant structures from real-world problems and converting them into mathematical forms. This difficulty is caused by a lack of adequate training from teachers in teaching students how to effectively carry out the mathematization process. Students are often trained only to solve procedural problems without developing the ability to understand the context or construct mathematical models. This finding aligns with the research by Aydın & Özgeldi (2019), which identified that students' errors in solving PISA-based problems often result from a lack of integration between contextual, conceptual, and procedural knowledge. These three types of knowledge should work synergistically to help students understand problems, build mathematical models, and perform the necessary operations. However, students often fail in one or more of these stages, particularly when faced with problems requiring a deep understanding of real-world contexts.

Epistemological obstacles in solving PISA-based problems, such as difficulties in mathematization, are closely related to challenges students face in learning functions. Functions, which falls under the PISA content domain of Change and Relationship (OCDE, 2024) require both conceptual and procedural knowledge, often present obstacles like misconceptions and difficulties in interpreting representations, such as graphs. These issues highlight the need for students to develop a deeper understanding of mathematical concepts beyond procedural skills, emphasizing the integration of contextual, conceptual, and procedural knowledge in learning. Functions are an important topic in mathematics that focuses on the study of quantities, patterns, relationships, and the structures that are formed (NCTM, 2020). A strong understanding of functions is crucial for students to recognize and interpret relationships between variables, and it forms the foundation for success in studying advanced mathematics such as calculus, algebra, and other higher-level topics ((Burns-Childers & Vidakovic, 2018); (Bardini et al., 2014)). Several studies indicate learning obstacles in the topic of functions, including the study of epistemological obstacles among upper-secondary students in understanding the concepts of limits and functions. These obstacles include misconceptions of concepts, limitations in understanding representations, and the influence of prior learning that focuses on operational procedures rather than conceptual understanding (Sulastri et al., 2022). Other research also examines learning obstacles faced by high school students in the topic of quadratic functions, where students experience difficulties in understanding the concepts of quadratic functions and quadratic equations. Additionally, students struggle with interpreting information from the graphs of functions, which prevents them from solving quadratic function problems accurately (Ruli et al., 2018).

Based on previous research, there has been no exploration of epistemological obstacles related to the topic of functions among middle school students from the perspective of PISA-standard mathematical literacy. By examining these obstacles, educators can design more effective teaching strategies that align with students' needs, including adjustments to teaching methods, the use of appropriate resources, and enhanced training for teachers to support a more inclusive learning process, ultimately leading to an improvement in students' mathematical literacy skills. This forms the basis for the research titled "Epistemological Obstacles of Secondary School Students in Solving PISA-Standard Mathematical Literacy Problems Related to Functions."

▪ METHOD

Participans

The participants in this study were eighth-grade students from a junior high school in Bandung who had already studied the topic of functions. Using purposive sampling, four students as R01, R02, R03, and R04 were selected from a total of 32 students. These students met the research criteria and were analyzed in greater depth regarding their epistemological obstacles in solving pisa-standard mathematical literacy problems related to functions.

Research and Design

The research design used in this study follows a qualitative approach within the framework of Didactical Design Research (DDR). The DDR methodology involves three stages of analysis: (1) Didactic situation analysis before instruction, aimed at producing a hypothetical didactical design that includes both didactic and pedagogical analyses, (2) Metapedadidactic analysis, which examines the teacher's ability in terms of three components are flexibility, coherence, and unity in teaching, and (3) Retrospective analysis, which links the results of the hypothetical situation analysis with the metapedadidactic analysis (Suryadi, 2010). This study focuses on the stage of learning obstacles especifically epistemological obstacles, prior to analyzing the didactic situations encountered by the participants, with the goal of developing an effective didactical design to address these obstacles.

Instruments

The instruments used in this study included both test and non-test methods to ensure objective results. The test instrument was designed to identify the epistemological in solving pisa-standard mathematical literacy problems related to functions. Then, the non-test instrument used in this study was an interview. The non-test instrument aimed to explore in depth the reasoning and thought processes behind students' answers to the test questions. The interview focused on identifying the sources and nature of students' epistemological obstacles when solving mathematical literacy problems. Data from the interviews were used to complement and validate findings from the test results, providing a richer understanding of the challenges students faced.

The test instrument consisted of four questions presented in different contexts aligned with PISA, namely occupational, social, personal, and scientific contexts. The test questions were adapted from PISA test items modified to fit the Indonesian context and complemented with recommendations from mathematics teachers to align with the school curriculum while maintaining PISA test standards. The test instrument was validated by experts, consisting of one lecturer and one mathematics teacher. The validation was based on PISA's mathematical literacy indicators, which include formulating, employing, and interpreting, as detailed in Table 1 below (OECD, 2023b).

Table 1. The indicators of PISA mathematical literacy competency

Number	Process	Indicator
1	Formulating	Understanding problems by formulating statements and questions that align with the contextual situation to be transformed into a mathematical model.
		Determining variables and formulating assumptions to translate the context into a mathematical representation.
2	Employing	Using concepts, facts, and algebraic calculation procedures to solve problems.
		Analyzing information mathematically from diagrams and mathematical graphs.
		Applying mathematical tools in problem-solving.
3	Interpreting	Using mathematical reasoning to evaluate solutions and mathematical results in relation to the problem's context.

Data Analysis

The data analysis process based on the Miles and Heburman model, was carried out as follows: (1) data reduction was carried out by selecting relevant data related to students' epistemological obstacles in solving PISA-standard mathematical literacy problems on the topic of functions, (2) data presentation was done by showcasing examples of test answer sheets and interview results from one participant for each PISA problem context, and (3) analysis of the test answer sheets and interview results was conducted, which was then presented in the form of a descriptive narrative (Gusnardi & Muda, 2019). This allowed conclusions to be drawn regarding students' epistemological obstacles in solving PISA-standard mathematical literacy problems on the topic of functions.

▪ RESULT AND DISSCUSSION

Based on the test instrument that was distributed and the interview results with the participants, the following findings were obtained.

Question 1

In question number 1, a problem with a work-related context is presented. Respondents are asked to depict a function in a graph that corresponds to the problem and determine which of the two provided job options is the most profitable based on mathematical calculations. R01, R02, and R04 provided answers, albeit incomplete, while

R03 did not submit any answer. The answer sheet example by one respondent (R02) can be seen in figure 2 below.

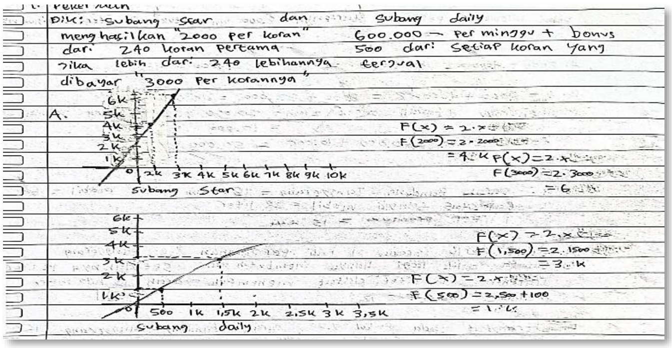

Figure 2 The answer sheet by R02

Based on the answer sheet of student R02, it is evident that the student attempted to understand and solve the problem systematically by writing down the given information, albeit incompletely. According to the PISA indicator for the formulating process, the student was unable to assign variables based on the information provided which is consisten with Kholid et al.'s (2022) study. As a result, R02 struggled to translate the function-related problem into a function equation (Jupri & Drijvers, 2016). In question 1, R02 was required to create formula before creating function graph. However, due to the habit of being given functions in equation form, the student followed a similar pattern by first converting the function into an equation before proceeding to create its graph. This case underscores the importance of encouraging students to develop flexible problem-solving strategies and to break away from the habit of simply working with formulation and memorizing. To gain deeper insights, the researcher conducted an interview with R02.

The results of the interview are as follows.

R02 : I first made the function f(x), then I created the graph. For example, if 2 newspapers are sold, they get Rp4,000. If 3 newspapers are sold, it’s Rp6,000. Then I connected the points.

P : Is the number of newspapers the horizontal part or the vertical part (pointing to the answer sheet)?

R02 : The horizontal part, ma'am.

P : Why did you write 2k, 4k, and so on?

R02 : I followed the vertical part, ma'am.

P : If we relate this to the concept of a function, which part would be the domain, codomain, and range? Is the graph always a straight line?

R02 : I don't know, ma'am. I'm confused about how to make the graph. I looked at my notes, and there was only one example with a story. I just followed the steps.

Previously, the researcher asked all students including R02 about the definition of a function. Student R02 defined a function as a relationship between sets A and B. This indicates that R02 had an incomplete initial understanding of the concept of a function (Bardini et al., 2014). Additionally, R02 struggled to determine the domain, codomain, and range of the given mathematical literacy problem. R02 plotted points for horizontal and vertical lines with identical values without considering the domain and codomain. Moreover, R02 connected the points with a straight line, disregarding the fact that the range should consist of natural numbers representing the monetary value of newspapers sold. Furthermore, R02 merely followed examples from their mathematics notebook, where graphs were always presented as straight lines without fully understanding the concept of a function or how to represent it graphically. This demonstrates a lack of deep understanding of how a line in a graph represents the relationship between variables, namely the domain and range (Thompson & Carlson, 2017). In line with Walde's (2017) study, the lack of understanding of the concept of functions and their representation caused the participant to also struggle with independently representing function problems in graphical form. The use of visual representations, such as graphs, in the learning process should help participants better understand mathematical relationships. However, this depends on the students' initial level of understanding (Cooper et al., 2018). Further, R02 wrote a continuation of the answer to part B of question 1 than can be seen in figure 3 below.

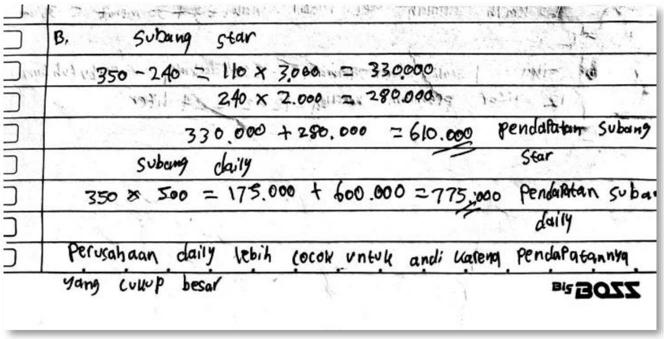
B, Subang Star
350 - 240 = 110 x 3.000 = 330.000
240 x 2.000 = 280.000
330.000 + 280.000 = 610.000 pendapatan Subang Star
Subang daily
350 x 500 = 175.000 + 600.000 = 775.000 pendapatan subang daily
Perusahaan daily lebih cocok untuk andi karena pendapatannya yang cukup besar

Figure 3 The continued answer sheet by R02

Here is the continued interview results with R02.

P : Are you sure about your answer for part B?

R02 : Yes, ma'am.

P : Try to explain how you did the calculation.

R02 :(explains the steps) This is wrong, ma'am. It should have been 240.000×2.000=480.000. I wasn't careful.

In question 1 part B, although R02 did not fully understand the concept of functions, they were able to use correct mathematical reasoning to solve contextual problems in different ways. This indicates that mathematical literacy, which involves understanding functions in real-life contexts, can be gained through processing specific and varied information. It is the teacher's responsibility to integrate students' knowledge with their real-life experiences. This approach ensures that students not only grasp mathematical concepts theoretically but also understand how this knowledge is connected to everyday problems. By linking mathematics to real-life contexts, students recognize that mathematics is not merely about formulas or abstract numbers, but also a tool for solving practical issues ((Kolar & Hodnik, 2021); (Fauzana et al., 2020)) .

Question 2

In question number 2, a problem with a social context involving transportation fares, specifically taxis, is presented. Respondents are asked to determine the form of the function and calculate the fare according to the given problem. Regarding the task of determining the function's form, all respondents provided their answers. The answer sheet example by one respondent (R04) can be seen in figure 4 below.

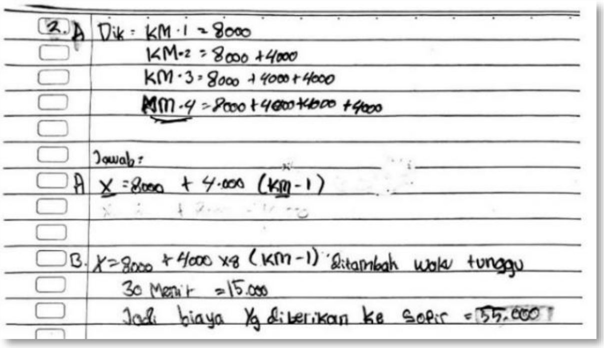
2.A Dik : KM·1 = 8000
KM·2 = 8000 + 4000
KM·3 = 8000 + 4000 + 4000
KM·4 = 8000 + 4000 + 4000 + 4000
Jawab :
A x = 8000 + 4.000 (km-1)
B. x = 8000 + 4000 x 8 (km-1) ditambah waktu tunggu
30 Menit = 15.000
Jadi biaya yg diberikan ke sopir = 55.000

Figure 4 The answer sheet by R04

Based on the answer sheet of student R04, it was observed that R04 only wrote down the given information incompletely. According to the PISA indicators for the formulating process, R04 was also unable to assign variables based on the presented information, consistent with the findings from student R02. As a result, R04 also struggled to determine the function's form in an algebraic equation. R04 created the function equation x=8.000+4.000(km-1) and mentioned that the x in question represents the function f(x). This aligns with research findings that indicate one of the difficulties students face in solving function problems is assuming the range as the variable x (Aziz & Kurniasih, 2019). The limited understanding of the basic concept of functions causes students to not understand that f(x) represents the range of the association between the domain and the range. To gain deeper insights, the researcher conducted an interview with R04. The results of the interview are as follows.

P : Alright. Would you like to explain me how you solved the problem?
R04 : So, ma'am, the initial fare is Rp8,000. The next fare is Rp4.000. For 2 km, it would be Rp8.000 + Rp4.000, making Rp12.000. For 3 km, it would be Rp8.000 + Rp4.000 + Rp4.000, making Rp16.000, and so on."
P : So, what is the form of the function?
R04 : x=8.000+4.000(km-1)
P : What is "x"?
R04 : The function of x, ma'am.

Previously, R04 explained that the problem presented was too lengthy, which caused the student to omit some of the given information and the specific question being asked in the mathematical literacy problem. This difficulty arose because R04 was not accustomed to solving systematic word problems. R04 also defined a function. R04 stated function as a relationship, "It is usually presented as sets A and B, formed by using arrow diagrams. Each element in A has a pair in B." Based on this explanation, R04 was able to provide a complete definition of a function. However, when solving mathematical literacy problems, the student struggled to determine the variables from the given information, resulting in the inability to correctly write the function equation. The student struggled to connect the real elements of the presented problems with mathematical concepts due to their incomplete prior knowledge or reliance on memorization. In addition to their difficulty in defining functions, their limited understanding of domain and range in word problems also became an obstacle in solving the problems. Moreover, the student lacked proficiency in algebraic concepts, particularly in determining variables from the given problems. The participants' limited comprehension of mathematical language, which is essential for grasping the basic concept of functions, impeded their ability to solve problems involving problem-solving and reasoning as required by PISA indicators (Al-Mutawah et al., 2019). This is in line with previous research, which indicates that prerequisite skills for understanding the concept of functions include concepts such as relations, domain, range, variables, and sets (Parhizgar et al., 2022).

Furthermore, to answer part B, R04 used mathematical reasoning and problem-solving skills, linking it with the equation created earlier. Through the interview stages, the student was actually able to explain how they solved the problem, although they mistakenly assigned the variables. The student had difficulty forming a function from a word problem because, during the function lessons, they were used to being given the function formula in the form of an equation f(x) to substitute a value of x. The results of the follow-up interview with R04 are as follows.

P : For Part B, why did you write 8.000+4000 ×8 (km-1)+waiting time 30 menit?
R04 : Because the passenger traveled 9 km, ma'am. So, they have to pay 8,000 at the start. They also need to pay for the waiting time, which is 30,000 per hour.
P : Is the writing correct?
R04 : I'm not sure, ma'am. Because usually, we're given the formula and then just plug in the values.

Question 3

In question number 3, a problem with a personal context is presented. Respondents are asked to solve the related problem and create a table and function of the table showing the relationship between the distance traveled and the fuel consumed during the journey. Additionally, respondents are required to calculate the relationship between time and distance traveled. The answer sheet example by one respondent (R01) can be seen in figure 5 below.

P : Now, for part B, what is being asked?
R01 : A table of the function that shows the relationship between the amount of fuel and the distance traveled, with the fuel capacity being 20 liters.
P : Why didn’t you answer it?
R01 : I’m confused, ma’am, about how to write it in table form and formula.
P : Previously, I asked you what a function is.
R01 : It’s the relationship between the domain and codomain, ma’am. The domain should have only one pair.

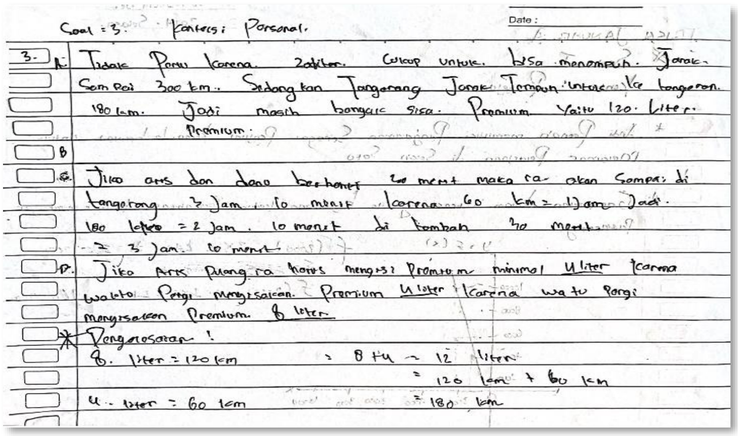

Figure 5. The answer sheet by R01

P : If we relate this to the concept of a function, is the distance or the amount of fuel the domain and range?
R01 : The fuel, mam.
P : Are you sure? What is the domain?
R01 : I'm not sure, ma'am. I'm confused when it comes to word problems, ma'am.

Based on the student's answer sheet above, it is evident that the student solved the problem directly without writing down the given information and the question being asked in the problem. Previously, R01 explained that the problem presented was too lengthy. Then, R01 stated the definition of a function as "the relationship between the domain and codomain. The domain should have only one pair." Based on this explanation, R01 was able to state the definition correctly. However, when solving the mathematical literacy problem, R01 struggled to represent the function problem in the form of a table and function equation, as R04 did. R01 did not consider a function as a set of pairs of values, it is difficult to understand the different ways of representing functions (Trujillo et al., 2023).

Based on the interview results, participants mentioned that they are typically given function problems in the form of a formula (equation) as an algebraic representation, rather than creating the mathematical model themselves based on the given definition. This aligns with other research, which suggests that teachers tend to provide formulas at the outset, rather than explaining how the definition of a function is represented in a function equation (Aziz & Kurniasih, 2019). This leads to students' understanding still being incomplete, as they do not perceive a function as a process of change involving mathematical objects that can be directly derived from real-world contexts and expressed in various forms, including function equations in algebraic form (Jukić Matić et al., 2022).

The participants' limited understanding of mathematical language, crucial for grasping fundamental concepts of functions, hindered their ability to effectively solve problems that require problem-solving and reasoning, as outlined by PISA indicators. This aligns with previous research, which highlights the importance of prerequisite skills such as relations, domain, range, variables, and sets in understanding the concept of functions ((Al-Mutawah et al., 2019); (Parhizgar et al., 2022)). R01 only used mathematical reasoning and problem-solving without realizing that the mathematical literacy problem involving functions could also be represented in various forms, which would allow the understanding of the function itself to be seen as a problem in daily life. The student used different reasoning approaches to solve contextual problems, even though they did not fully understand the concept of functions. It became apparent that, even when students had incorrectly formulated the function, they were able to substitute the domain into the function and perform the calculations correctly. This shows that a person's mathematical knowledge also depends on the context. When students engage in tasks from real-life contexts that require mathematical thinking, they acquire new knowledge by processing information in specific and varied ways. This process, which is part of mathematical literacy, not only helps students solve real-world problems but also strengthens their mathematical knowledge itself (Kolar & Hodnik, 2021).

Question 4

In question number 4, a problem with a scientific context is presented. Respondents are tasked with creating a cost estimation function based on the available information and solving the related problem using the function. Among the four respondents, only one respondent, R03, provided an answer, which was limited to stating the given information. The answer sheet example by one respondent (R03) can be seen in figure 6 below.

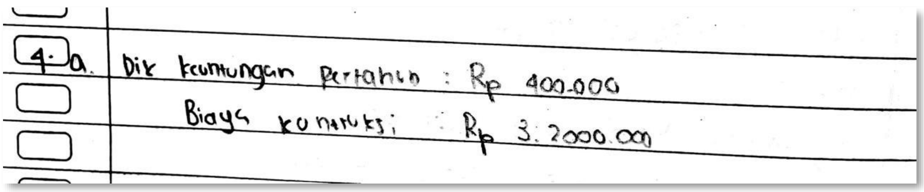

Figure 6. The answer sheet by R03

Based on the answer sheet provided, the student only wrote down the given information but was unable to determine the steps to solve the problem based on the information presented.

P : What does part A of the question ask?
R03 : Create a function for estimating the costs and profits generated by the company
P : In algebra, what is n called?
R03 : I don't understand algebra, ma'am.

Furthermore, R03 struggled to differentiate between the concepts of relations and functions. This indicates that the student has an incomplete initial understanding of functions. Question number 4, which involved a science context, asked the students to write a function for estimating expenses as the subtraction of annual profit n from the expenditure cost in constant form. R03 was unable to identify the role of n in the algebraic equation. .... his research is consistent with studies showing that...

Here is the continued interview results with R03.
P : May I see your notebook?
R03 : (Shows the notebook that contains some material on solving function problems in story form)
P : Try to seolve this. Let f(x)=2x+1, what is the value of f(5)?
R03 : Hmm.. 6 ma'am. 2x is changed by 5 value. So, f(x)=5+1.

R03 mentioned that when studying the topic of functions, they were not accustomed to using word problems, especially those related to science. When given a function in equation form, R03 could not correctly substitute values into the variables. This suggests that R03 also has limited prerequisite knowledge, particularly regarding algebraic forms and operations in algebra.

Based on the instrument test ad interview results, it indicates that students who struggle to understand basic algebra concepts often face significant obstacles in the mathematization process of forming function equations, particularly in transforming real-world problems into symbolic mathematical models (Jupri & Drijvers, 2016). From a teaching perspective, an approach emphasizing repetitive practice in translating verbal phrases into appropriate mathematical expressions is essential. This is also in line with the research comes from Fauzana et al. (2020) which shows that learning approaches such as Realistic Mathematics Education (RME) can enhance students' mathematical literacy skills. This is because RME focuses on integrating real-world contexts into learning, helping students connect mathematical concepts to everyday life and encouraging them to understand mathematics through experience rather than merely memorizing formulas.The study further notes that students’ difficulties in transforming real-world problems into mathematical models are often rooted in learning habits that focus on routine tasks rather than word problems that require deeper comprehension. Therefore, developing curricula and teaching materials enriched with contextual problems is crucial for strengthening students' mathematization abilities. Additionally, providing reflective strategies that enable students to independently evaluate their processes and solutions is equally important. These findings underscore the need for intensive teacher training to help students not only master algebraic concepts but also apply them flexibly across various content and contexts, such as function topics aligned with PISA standards.

Based on the results of the instruments that have been tested, the epistemological obstacles faced by middle school students in solving PISA-standard mathematical literacy problems on the topic of functions are as follows:

Table 2. Epistemological obstacle’s student solving PISA-standart mathematical literacy problem on the topic of functions

No	Epistemological Obstacles	Forms of Epistemological Obstacles
1	Understanding the concept of functions	• Incomplete understanding of the definition of a function. • Difficulty connecting the definition of a function to problem-solving. • Limited understanding of domain, codomain, and range, particularly in the context of word problems.
2	Representing functions as equations	• Struggles to create function equations from real-world problems. • Reliance on memorized examples without understanding the underlying concepts. • Limited understanding of variables, which hinders the ability to connect variables in problems
3	Representing functions as graphs	• Inability to draw graphs that accurately represent the relationship between domain, codomain, and range.

		• Assumption that all function graphs must be straight lines. • Lack of understanding that the type of domain (e.g., natural numbers) affects the graph's representation.
4	Representing functions as tables	• Failure to represent functions in tabular form, often providing answers in narrative form instead. • Unfamiliarity with converting real-world problems into tables.
5	Solving context-based problems	• Lack of familiarity with real-world problem-solving tasks. • Difficulty structuring a systematic approach to solving problems. • Challenges in linking real-world elements to mathematical concepts like domain, range, and variables

▪ CONCLUSION

This study reveals that reveal that secondary school students face significant epistemological obstacles when solving PISA-standard mathematical literacy problems related to functions. These obstacles include limited understanding of the concept of functions, difficulty representing functions in various forms such as equations, graphs, and tables, and challenges in solving context-based problems. The root causes of these obstacles are incomplete foundational knowledge, such as understanding domains, ranges, and variables, as well as insufficient exposure to contextual problem-solving. Students also tend to rely heavily on rote memorization rather than developing deeper conceptual understanding and reasoning skills. To overcome these challenges, educators should adopt contextual teaching approaches that strengthen students' foundational understanding of functions. Providing opportunities for students to represent functions in multiple formats, such as equations, graphs, and tables, can help bridge the gap between theoretical knowledge and practical application. Incorporating problem-based learning that aligns with PISA indicators and encouraging systematic problem-solving strategies are also essential for fostering mathematical reasoning and literacy. By implementing these strategies, educators can better prepare students to address real-world mathematical problems and improve their overall literacy skills, thereby contributing to global educational goals.

▪ REFERENCES

Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. International Journal of Education and Practice, 7(3), 258–273. https://doi.org/10.18488/journal.61.2019.73.258.273

Astuti, M., Ismail, F., Fatimah, S., Puspita, W., & Herlina. (2024). The relevance of the merdeka curriculum in improving the quality of islamic education In Indonesia. International Journal of Learning, Teaching and Educational Research, 23(6), 56–72. https://doi.org/10.26803/ijlter.23.6.3

Aydın, U., & Özgeldi, M. (2019). The PISA Tasks: Unveiling prospective elementary mathematics teachers' difficulties with contextual, conceptual, and procedural

knowledge. Scandinavian Journal of Educational Research, 63(1), 105–123. https://doi.org/10.1080/00313831.2017.1324906
Aziz, T. A., & Kurniasih, M. D. (2019). External representation flexibility of domain and range of function. Journal on Mathematics Education, 10(1), 143–155. https://doi.org/10.22342/jme.10.1.5257.143-156
Bardini, C., Pierce, R., Vincent, J., & King, D. (2014). Undergraduate mathematics students' understanding of the concept of function. Journal on Mathematics Education, 5(2), 85–107. https://doi.org/10.22342/jme.5.2.1495.85-107
Brosseau, G. (2002). Theory of didactical situations in mathematics. kluwer academic publisher.
Burns-Childers, A., & Vidakovic, D. (2018). Calculus students' understanding of the vertex of the quadratic function in relation to the concept of derivative. International Journal of Mathematical Education in Science and Technology, 49(5), 660–679. https://doi.org/10.1080/0020739X.2017.1409367
Cooper, J. L., Sidney, P. G., & Alibali, M. W. (2018). Who benefits from diagrams and illustrations in math problems? ability and attitudes matter. Applied Cognitive Psychology, 32(1), 24–38. https://doi.org/10.1002/acp.3371
Fadlelmula, F. K. (2022). Enablers and obstacles in teaching and learning of mathematics: A systematic review in LUMAT journal. Lumat, 10(2), 33–55. https://doi.org/10.31129/LUMAT.10.2.1627
Fauzana, R., Dahlan, J. A., & Jupri, A. (2020). The influence of realistic mathematics education (RME) approach in enhancing students' mathematical literacy skills. Journal of Physics: Conference Series, 1521(3), 0–5. https://doi.org/10.1088/1742-6596/1521/3/032052
Genc, M., & Erbas, A. K. (2019). Secondary mathematics teachers' conceptions of mathematical literacy. International Journal of Education in Mathematics, Science and Technology, 7(3), 222–237.
Gusnardi, & Muda, I. (2019). Educational institution performance measurement based on miles and huberman models using balanced scorecard approach. Quality - Access to Success, 20(170), 32–41.
Hasibuan, Y. A., & Hasanah, R. U. (2022). Analysis of the difficulties of junior high school students in solving pisa model mathematics problems. Jurnal Pendidikan Progresif, 12(2), 435–450. https://doi.org/10.23960/jpp.v12.i2.202204
Jukić Matić, L., Kehler-Poljak, G., & Rukavina, S. (2022). The influence of curriculum on the concept of function: an empirical study of pre-service teachers. European Journal of Science and Mathematics Education, 10(3), 380–395. https://doi.org/10.30935/SCIMATH/12042
Jungjohann, J., Gebhardt, M., & Scheer, D. (2022). Understanding and improving teachers' graph literacy for data-based decision-making via video intervention. Frontiers in Education, 7(September), 1–18. https://doi.org/10.3389/feduc.2022.919152
Jupri, A., & Drijvers, P. (2016). Student difficulties in mathematizing word problems in Algebra. Eurasia Journal of Mathematics, Science and Technology Education, 12(9), 2481–2502. https://doi.org/10.12973/eurasia.2016.1299a
Kholid, M. N., Rofi'ah, F., Ishartono, N., Waluyo, M., Maharani, S., Swastika, A., Faiziyah, N., & Sari, C. K. (2022). What are students' difficulties in implementing

mathematical literacy skills for solving PISA-Like problem? Journal of Higher Education Theory and Practice, 22(2), 181–200. https://doi.org/10.33423/jhetp.v22i2.5057
Kolar, V. M., & Hodnik, T. (2021). Mathematical literacy from the perspective of solving contextual problems. European Journal of Educational Research, 10(1), 467–483. https://doi.org/10.12973/EU-JER.10.1.467
Mansur, N. (2018). *Melatih literasi matematika siswa dengan soal PISA.* Prisma, Prosiding Seminar Nasional Matematika. 1, 140–144. https://journal.unnes.ac.id/sju/index.php/prisma/
NCTM. (2020). Standards for the preparation of secondary mathematics teachers. The National Council of Teachers of Mathematics, Inc., May, 1–84.
Nurgabyl, D., Satkulov, B., & Kagazbayeva, A. (2023). Formation and development of mathematical literacy in the context of evaluative - Study tasks of PISA. Journal on Mathematics Education, 14(4), 701–722. https://doi.org/10.22342/jme.v14i4.pp701-722
O'Shea, A., Breen, S., & Jaworski, B. (2016). The development of a function concept inventory. International Journal of Research in Undergraduate Mathematics Education, 2(3), 279–296. https://doi.org/10.1007/s40753-016-0030-5
OCDE. (2024). Pisa 2022. In Perfiles Educativos (Vol. 46, Issue 183). https://doi.org/10.22201/iisue.24486167e.2024.183.61714
OECD. (2023a). PISA 2022 results factsheets Indonesia. OECD (Organisation for Economic Co-Operation and Development) Publication, 1–9. https://www.oecd.org/en/publications/pisa-2022-results-volume-i-and-ii-country-notes_ed6fbcc5-en/indonesia_c2e1ae0e-en.html
OECD. (2023b). Program For International Student (PISA) 2022 Assessment and analytical framework. In OECD (Organisation for Economic Co-operation and Development) Publishing. https://www.oecd-ilibrary.org/education/pisa-2022-assessment-and-analytical-framework_dfe0bf9c-en
Parhizgar, Z., Dehbashi, A., Liljedahl, P., & Alamolhodaei, H. (2022). Exploring students' misconceptions of the function concept through problem-posing tasks and their views thereon. International Journal of Mathematical Education in Science and Technology, 53(12), 3261–3285. https://doi.org/10.1080/0020739X.2021.1937732
Retnawati, H., & Wulandari, N. F. (2018). The development of students' professional self-concept. Problems of Education in the 21st Century, 77(4), 816–824. https://doi.org/10.15405/epsbs.2018.09.95
Ruli, R. M., Priatna, N., Sufyani, P., & Endang, M. (2018). Analysis learning obstacle on quadratic function topic. International Journal of Information and Education Technology, 8(9), 681–684. https://doi.org/10.18178/ijiet.2018.8.9.1122
Siagian, M. D., Suryadi, D., Nurlaelah, E., & Prabawanto, S. (2022). Investigation of secondary students' epistemological obstacles in the inequality concept. Mathematics Teaching-Research Journal, 14(4), 106–128. https://doi.org/10.1007/978-3-642-17735-4
Sulastri, R., Suryadi, D., Prabawanto, S., & Cahya, E. (2022). Epistemological obstacles on limit and functions concepts-a phenomenological study in online learning. Mathematics Teaching-Research Journal, 14(5), 84–106.

Sumirattana, S., Makanong, A., & Thipkong, S. (2017). Using realistic mathematics education and the DAPIC problem-solving process to enhance secondary school students' mathematical literacy. Kasetsart Journal of Social Sciences, 38(3), 307–315. https://doi.org/10.1016/j.kjss.2016.06.001

Suryadi, D. (2010). Metapedadidaktik dan didactical design research (DDR). Sintesis Hasil Pemikiran Berdasarkan Lesson Study, 1–14.

Thompson, P. W., & Carlson, M. P. (2017). Variation, covariation, and functions: Foundational ways of mathematical thinking. Compendium for Research in Mathematics Education, January, 421–456.

Trujillo, M., Atarés, L., Canet, M. J., & Pérez-Pascual, M. A. (2023). Learning difficulties with the concept of function in maths: a literature review. Education Sciences, 13(5). https://doi.org/10.3390/educsci13050495

Umbara, U., & Suryadi, D. (2019). Re-interpretation of mathematical literacy based on the teacher's perspective. International Journal of Instruction, 12(4), 789–806. https://doi.org/10.29333/iji.2019.12450a

Walde, G. S. (2017). Difficulties of concept of function: The case of general secondary school students of Ethiopia. International Journal of Scientific & Engineering Research, 8(4), 1–10. https://doi.org/10.14299/ijser.2017.04.002