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Students' Learning Obstacles in Relational Thinking on Arithmetic, Algebra, and Linear Equations in One Variable

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Abstract

Various studies on relational thinking have been conducted, but none have explicitly examined students' learning obstacles from the ontogenetic, epistemological, and didactical perspectives. This study aims to identify and describe students' learning obstacles in relational thinking within arithmetic, algebra, and linear equations in one variable. This study employs a qualitative approach guided by Miles and Huberman's framework, which involves data collection, data reduction, data display, and drawing and verifying conclusions. The study used tests and interviews to gather information. Data were collected in August 2023 from 32 students of 8th grade at SMPN 17 Tangerang Selatan. Analysis revealed that students encountered ontogenetic, didactical, and epistemological obstacles when solving mathematics problems requiring relational thinking. The ontogenetic obstacle manifested as a lack of confidence in their own mathematical abilities. The didactical obstacle arose from the use of instructional materials and learning designs that did not facilitate development of relational thinking ability. The epistemological obstacle was evident in students' failure to understand arithmetic and algebraic operation rules, inability to construct mathematical models from everyday situations, and misinterpretation of the equals sign ("=") as an operational command rather than a symbol of equality. Teachers therefore require additional learning resources to reinforce students' understanding of the concept of equality. Future research should focus on developing and evaluating instructional designs specifically aimed at enhancing students' relational thinking ability.

Keywords: Learning Obstacle; Linear Equations in One Variable; Relational Thinking Skills

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INTRODUCTION

Mathematics is one of the mandatory subjects studied from elementary school, junior high school, and senior high school, even up to university level (Risnawati et al., 2023;Wahyuningsih & Amidi, 2023). This is because mathematics has an important role in all aspects of life, especially in improving thinking power related to solving problems (Islami et al., 2022; Kızıltoprak & Köse, 2017; Nafiah, Amin & Rahaju, 2022). Thinking is an important potential that every person must posses. By thinking, someone can build strategies to solve problems in everyday life. Thinking ability must be mastered to face the 21st century's challenges (Agustina et al., 2022).

One type of thinking ability is relational thinking ability. In mathematics learning, relational thinking ability is practiced and developed as students study arithmetic and algebra. According to Tri et al. (2022) relational thinking ability is the most important part of algebraic reasoning. The role of relational thinking ability is to serve as a bridge between numbers, number operations, and algebraic reasoning (Tri et al., 2022).

Relational thinking involves understanding the equivalence and relationships between numbers (Kindrat & Osana, 2018). Beyond number relationships, Harbour et al. (2016) further explain that relational thinking involves the meaning of the equal sign, the basic use of properties of operations, and strategic decision-making. Relational thinking emphasizes viewing mathematical expressions and equations as wholes, rather than as computational processes (Tri et al., 2022; Carpenter et al., 2005). In relational thinking, mathematical expressions and equations are seen as wholes, not as processes carried out step by step (Carpenter et al., 2005).

Comparing mathematical expressions involving the equal sign (“=”) is part of relational thinking (Lenz, 2022; Pandapotan Nainggolan, 2022; Ardiansari et al., 2023; Tomé et al., 2019). The goal of relational thinking is to help students realize that both sides of an equation represent the same value, even without performing any calculations (Kızıltoprak & Köse, 2017). A student who states that $4 + 5 = 3 + 6$ or $2x + 2y = 2(x + y)$ is demonstrating their relational thinking ability (Kızıltoprak & Köse, 2017). The student understands that both sides of the equation are of equal value. When faced with a problem such as 154 + 200 = ….. + 190, a student might add the numbers on the left side and then subtract 190 from the result to find the answer. If the student arrives at the correct answer through this procedure, it shows an understanding that the equal sign represents the concept of equivalence. However, if a student answers the problem with 154 + 10 without using the previous steps, it indicates that the student has optimized their relational thinking ability. The student not only understands that the equal sign signifies equivalence, but also that it is not merely a command to compute from left to right.

In a broader context, relational thinking is defined as the process of building connections among mathematical elements and using them to find solutions to given problems (Lenz, 2022). Relational thinking helps students understand and solve everyday mathematical problems (Kurniawan & Rudhito, 2016; Nafiah, Amin & Rahaju, 2022; Ramadhan et al., 2021). In relational thinking, students construct connections between the given information, their prior knowledge, and their understanding of mathematical properties or structures to solve problems (Nafiah, Amin & Rahaju, 2022). According to Hejny et al (Zakaria et al, 2018), the characteristics of problem-solving procedures in relational thinking include forming a comprehensive representation of the problem, analyzing it to identify the core structure, determining the key elements or relationships within the problem, and then devising a solution strategy based on those elements or relationships. A person who engages in relational thinking will apply abstract rules to new situations (Wardani & Susanah, 2020). Based on this perspective, relational thinking involves not only the interpretation of the equal sign (“=”), but also the application of relational ability in solving everyday mathematical problems.

Based on the explanation of relational thinking, in general, relational thinking ability can be understood as the ability to build connections between given information and prior knowledge, as well as to view mathematical expressions and equations as wholes in order to solve mathematical problems. The scope of relational thinking can be divided into (1)understanding the meaning of the equal sign (“=”) as a concept of equivalence, and interpreting mathematical expressions and equations as integrated wholes, and (2)constructing connections between the given information and mathematical concepts, and formulating strategies to solve mathematical problems.

Relational thinking ability needs to be developed, especially in arithmetic and algebra topics. According to Kindrat & Osana (2018), the importance of relational thinking in mathematics lies in its support for the development of both arithmetic and algebraic reasoning. This process is rooted in how students can abstract mathematical concepts related to equivalence and relationships. Students' inability to optimize their relational thinking ability may result in difficulties in solving other mathematical problems, such as in the topic of linear equations in one variable. In learning linear equations in one variable, students are required to understand algebraic expressions and apply their relational thinking ability. This underlies the learning progression where students first study arithmetic, followed by algebra, and then move on to linear equations in one variable. With a strong foundation in relational thinking and a solid understanding of arithmetic and algebra, it is expected that students will find it easier to learn linear equations in one variable.

It is found that the ideal conditions that should occur are not supported by existing conditions. Instead, students still make mistakes in solving mathematics problems, related to both arithmetic and algebra. One of the research findings shows that students better understood the "=" symbol as a sign for carrying out operations rather than showing equality.

Students' mistakes are generally caused by a condition that is characterized by learning obstacle (Ramli & Prabawanto, 2020). A learning obstacle is a condition where a person cannot follow the learning process properly. This is characterized by the presence of certain obstacles in achieving learning outcomes (Rahmi & Yulianti, 2022). Brousseau (1997) classifies learning obstacles into three types, namely ontogenic, epistemological and didactic obstacles. Ontogenic obstacles is related to students' mental readiness and cognitive maturity in receiving knowledge, epistemological obstacles are barriers caused by students' limited understanding and mastery on something (concept, problem or other) and didactic obstacles are caused by didactic systems such as sequence factors, methods, the delivery of material and curriculum.

To minimize the learning obstacles occurring to students, teachers need to analyze the learning obstacles experienced by them. If a teacher is able to identify the learning difficulties experienced by students, this is going to be an excellent basis for improving the learning process. Therefore, the expected learning goals can be achieved.

The research results show that students underwent learning difficulties in solving problems that required relational thinking skills, especially in arithmetic and algebra materials. Sidik et al. (2021) in their research conclude that students experienced obstacles in learning about arithmetic operations, and problems of adding and subtracting integers. The obstacles found were ontogenic, didactic and epistemological obstacles. Syarah et al. (2023) in their research related to algebra material show that when working on algebra questions, students made mistakes in understanding the questions, recognizing variables, coefficients, constants or misunderstanding how algebra concepts were operated.

In general, research on relational thinking ability has been widely conducted both in Indonesia and internationally. Most studies on relational thinking are qualitative, aiming to describe students' relational thinking ability when solving mathematical problems. The existing trend in qualitative research tends to focus on describing how students demonstrate relational thinking in arithmetic or algebra topics by considering certain variables. These include cognitive styles such as impulsive and reflective (Satriawan et al., 2018; Wardani & Susanah, 2020), auditory learning styles (Agustini & Rahaju, 2022), quitter visual, camper visual, and climber visual types (Pradika et al., 2019), field-independent and field-dependent cognitive styles (Bahri et al., 2019), systematic and precise cognitive styles (Khoyimah, 2021), visual, auditory, and kinesthetic learning styles (Nafiah & Rahaju, 2022), as well as self-efficacy (Fauziyah & Ismail, 2022).

Although numerous studies have explored relational thinking in mathematics education, to date, there has been no research that explicitly investigates students' learning obstacles in solving mathematical problems related to arithmetic, algebra, and linear equations in one variable through an epistemological, didactical, and ontogenetic lens. Most existing studies tend to focus on describing students' relational thinking abilities based on cognitive or learning styles, without thoroughly uncovering the root causes or learning obstacles students encounter. In fact, understanding learning obstacles is essential to determine the extent to which students face epistemological, didactical, and ontogenetic barriers in grasping relational mathematical concepts.

Based on this research gap, this study aims to identify and explain the learning obstacles encountered by students in applying relational thinking in arithmetic, algebra, and linear equations in one variable, through an epistemological, didactical, and ontogenetic perspective. This study not only seeks to reveal students' epistemological knowledge gaps, but also to identify the didactical and ontogenetic factors that contribute to the emergence of misconceptions in relational thinking. The findings of this study are expected to contribute to the development of more effective mathematics learning designs, particularly in helping students build a deep and relational understanding of fundamental mathematical concepts.

METHOD

This study is a qualitative research that aims to identify and explain learning obstacles that occur in the teaching and learning process of arithmetic, algebra, and linear equations in one variable, particularly in relation to students' relational thinking ability. The research subjects consisted of 32 students of 8th grade at SMPN 17 Tangerang Selatan randomly selected from SMP N 17 South Tangerang. Data were collected through interviews and tests. The test instrument was previously validated by two lecturers who are experts in mathematics education. The test was administered to assess students' relational thinking ability. The test items used in this study are presented in Table 1.

Table 1. Relational Thinking Ability Test

No	Indicator	Question
1	Understanding the meaning of the "=" sign as a concept of equivalence and comprehending mathematical expressions and equations as a whole.	1. Solve the following problem: a. $3 + 14 = \dots\dots . + 11$ b. $127 + 118 = \dots\dots . . + 121$ c. $237 + 187 + 14 = \dots\dots . + 190 + 15$ d. $6 + 14 \times 2 = \dots ....$ e. $4 \times 18 \times 220 = 6 \times 12 \times \dots\dots$
2	Understanding the meaning of the "=" sign as a concept of equivalence and comprehending mathematical expressions and equations as a whole.	2. State whether the following equation is TRUE or FALSE a. $2xy = 2yx$ b. $3x + (y + 5) = (3x + y) + 5$ c. $3(4 - 5x) + 7y = 12 - 5x + 7y$
3	Building connections between the given information and mathematical concepts, as well as formulating strategies to solve mathematical problems.	3. Tommy and two friends of his want to buy a bag for a gift for their teacher. The cost IDR 230,000. They have saved IDR 125,000 until now. If each person contributes the same amount to purchase the bag, how much more money will each person have to prepare?

Next, semi-structured interviews were conducted with 9 students. The researcher grouped the students' responses according to the types of errors they made. The students interviewed were randomly selected from among those who experienced learning obstacles while completing the given tasks, representing each type of error.

In analyzing the data, the researcher followed the stages proposed by Miles & Huberman (Yunengsih & Syahrilfuddin, 2020), namely data collection, data reduction, data presentation, and drawing conclusions and verification. The process began by grouping and identifying similarities in the data related to students' errors and learning obstacles encountered while solving the given problems. Next, the data were reduced according to the research objectives and deepened through interviews with students who experienced learning obstacles. In the final stage, the data were presented qualitatively, describing the learning obstacles faced by the students. The categorization of research data into types of obstacles refers to Table 2.

Table 2. Types of Learning Obstacles

No	Types of Obstacles	Definition
1	Ontogenic	Obstacles related to students' mental readiness and cognitive maturity in receiving knowledge.
2	Epistemological	Obstacles caused by limitations in students' understanding and mastery of certain concepts, problems, or other matters.
3	Didactic obstacles	Obstacles resulting from didactic systems such as the sequence, methods, presentation of material, and curriculum.

RESULTS AND DISCUSSION

Students' success in correctly solving mathematical problems is one of the indicators of successful mathematics learning. Examining students' problem-solving results provides insights into their actual understanding of specific mathematical concepts. Students' understanding can be identified by analyzing their responses to mathematics problems. Furthermore, their answers can also be used to identify learning obstacles that may contribute to low levels of understanding.

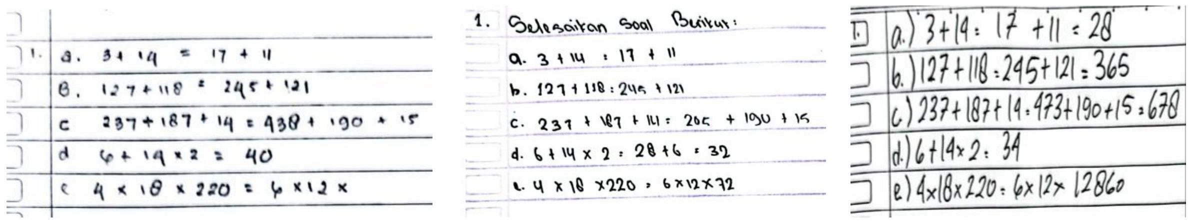
The instrument used in this study consisted of test items related to arithmetic, algebra, and linear equations in one variable. The questions used in this study are presented in Table 1. Items 1 and 2 are related to students' abilities in arithmetic and algebra. These items aim to assess students' relational thinking ability through indicators such as understanding the meaning of the equals sign (“=”) as a concept of equality, and interpreting mathematical expressions and equations as a whole. Item 3 focuses on the topic of linear equations in one variable, which also requires students to apply their relational thinking ability. Students' relational thinking ability are demonstrated by the process of establishing mathematical relationships from the information in the problem, creating mathematical models or expressions of algebraic equations and solving these equations. In solving item number 3, students will simultaneously demonstrate their relational thinking ability in understanding the meaning of the equals sign. Based on the test administered to 32 eighth-grade junior high school students, the results were obtained as foolows.

Table 3. Number of Learning Obstacle Findings

Item No	Number of Learning Obstacles
1	29
2	24
3	30

Table 3 shows that for all test items given, students experienced learning obstacles. These obstacles were encountered by almost all students. The identification of whether a learning obstacle was present or not was determined not solely based on the students’ final answers, but through an analysis grounded in indicators of relational thinking. Based on item number 1, students experienced learning obstacles when solving the given test item. Figure 1 presents an example of a student’s work on item number 1.

Item number 1 is an algebra problem that requires relational thinking ability to solve. In working on item number 1, the mistake made by the students was a failure to understand the meaning of the equals sign (“=”) as a symbol of equality. It can be observed that Students A and B answered item 1a by adding the numbers on the left-hand side. As a result, they wrote 17, whereas they should have filled in 6.



Student A **Student B** **Student C**

Figure 1. Sample Student Answer for Item Number 1

A similar error was made by Student C, who added the numbers on the left-hand side to obtain 17. Then proceeded by adding 17 to 11, to get 28, which is even more incorrect. Likewise, for items 1b and 1c, the student committed the same type of mistake. The student is indicated to lack relational thinking ability, where in relational thinking one must first employ the relational meaning of the equals sign (Molina & Castro, 2021; Fajar Kusuma et al., 2018). In answering these items, the student interprets the equals sign as an operational symbol rather than as a symbol of mathematical equality (Kusuma et al., 2018).

In item 1d, Student A clearly did not understand the properties of arithmetic operations. Consequently, he added 16 + 4 first and then multiplied the sum by 2. This indicates that the student's arithmetic skills remain underdeveloped. To explore why the student provided that answer, an interview was conducted. Part of the Researcher's (R) interview with Student A is as follows:

R : How did you answer item number 1a to get 17?
A : From 3 + 14.
R : What do you think the number 11 in item number 1a means?
A : The result of 3 + 14 is 17, and then it should be added to 11, but because there was no equals sign, I didn't do the 17 + 11 part.
R : For item number 1d, how did you arrive at 40?
A : I did the calculation from the front, Ma'am: 6 + 14 equals 20, then I multiplied that by 2, so the result is 40.

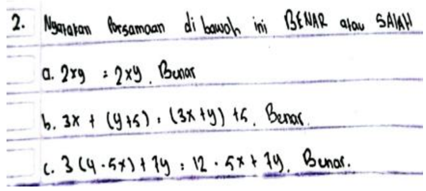
Part of the Researcher's (P) interview with Student C is as follows:

R : How did you answer item number 1a?
C : From 3 + 14 = 17, then I added 11 to get 28.
R : What do you think the equals sign ("=") means in item number 1a?
C : It tells me to calculate.
R : Why did you add "=" after the number 11?
C : So that it can be calculated.
R : Have you ever worked on problems like this before?
C : It's a bit different, Ma'am. In the math textbook, usually after the "=" comes … (the student writes an example like 2 + 3 + 4 = …).

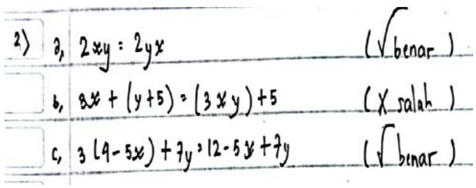
Understanding the concept of an equation and the meaning of the equals sign ("=") is crucial. In an equation, the equals sign should be interpreted as a symbol of equality, indicating that the expressions on both sides represent the same value (Kusuma et al., 2018; Usodo et al., 2020). However, many students who have learned arithmetic view the equals sign as a prompt to perform an operation rather than as a relational symbol that connects two expressions (Fuchs, 2015). This misconception can lead to an incorrect understanding of the equals sign.

From the findings of Item 1 responses and the student interviews, two types of obstacles were identified, epistemological and didactic. The epistemological obstacle is that students do not understand that the equals sign ("=") is a symbol of equality. Instead, they continually manipulate both sides of the equation in their solution process (Kusuma et al., 2018). Students treat the equals sign as an operator for computation or simply as a cue to write down an answer. In addition, many students have not mastered basic arithmetic operations, so they cannot correctly solve problems involving addition and multiplication. This is regrettable because mastery of these arithmetic skills should serve as the foundational prerequisite before learning algebra and linear equations in one variable. The didactic obstacle is indicated by students' unfamiliarity with the types of problems presented, suggesting that mathematics instruction has not regularly exposed them to a variety of problem formats.

The instrument used in this research is a test question of linear equation in one variable. The questions used in this research is "Tommy and two friends of his want to buy a bag for a gift for their teacher. The cost IDR 230,000. They have saved IDR 125,000 until now. If each person contributes the same amount to purchase the bag, how much more money will each person have to prepare?" The question is a problem about linear equations in one variable where students have to use their relational thinking skills. Students' relational thinking skills are demonstrated by the process of establishing mathematical relationships from the information in the problem, creating mathematical models or expressions of algebraic equations and solving these equations. In it, students are required to understand the symbol "=" in mathematical models as a form of equality. In other words, if it is related to relational thinking skills, students must identify problems and create formulas or algebraic equations from these problems, then solve them. Based on item number 2, students experienced a learning obstacle when solving the given test item. Figure 2 shows a student's work for item number 2.



Student D



Student E

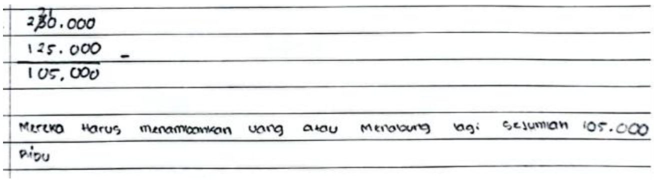
Student F

Figure 2. Sample Student Answer for Item Number 2

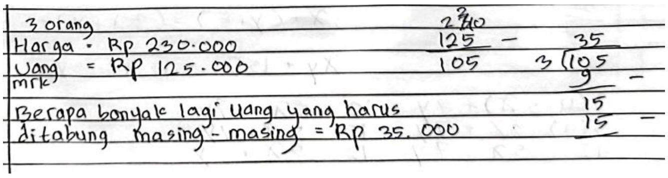
In working on item number 2, the error made by the students was a lack of understanding of the concept of equations as it relates to algebraic material. The students did not comprehend the operational rules for algebraic expressions, so they were unable to identify which equations were correct and which were incorrect. Student F answered "incorrect" for item 2a, reasoning that the right-hand side contained "yx," which is different from the left-hand side, where "xy" was written.

For Student E, the researcher revisited his answer sheet during the interview to determine why he had omitted the plus sign on the right-hand side. The student acknowledged that he had been careless and that he should have included the plus sign. However, he still answered "incorrect" for item 2b, explaining that he believed the parentheses should be evaluated first and that the result would change if the parentheses were moved. This indicates that the student does not yet understand or master the operational properties of algebra. Without this foundational understanding, the student is far from possessing the relational thinking ability needed to recognize equality in an equation involving variables. For item 2c, all students answered "correct," which likewise suggests a lack of understanding of the algebraic operations they were expected to have learned. This conclusion is reinforced by the interview . Student explained that he answered "correct" because he multiplied 3 by 4 to get 12. These findings reveal an epistemological obstacle that is a limitation in the students' understanding and mastery of algebraic operation properties. In terms of cognitive level, the students should already be operating at the level of algebraic thinking. Although algebra is not new material for them, they were nonetheless unable to solve these items correctly.

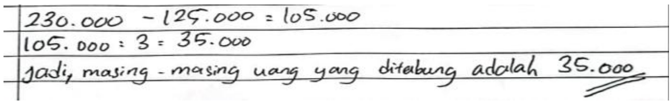
Based on item number 3, students experienced a learning obstacle when solving the given test item. Figure 3 shows a student's work for item number 3.



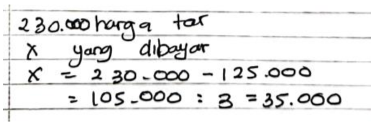
Student G



Student H



Student I



Student J

Figure 3. Sample Student Answer for Item Number 3

Student G did not understand item number 3 properly, so student answered 105,000. The student was also unable to create a mathematical model of the problem given, so student carried out a direct subtraction operation to solve the problem. Next, an interview was conducted to explore the process of obtaining these answers. Interviews were conducted with students H

R : How did you get the final result of 35,000?
H : Because the price of the bag is 230,000 and I have already collected 125,000, so I subtract 125,000 from 230,000. The result is 105,000, then divide it by 3 because there are 3 children who will save.
R : Yes, your answer is correct. So do you know how a mathematical model can represent the problem of question number 3?
H : I don't know.
R : Have you studied linear equations in one variable?
H : Yes, ma'am.
R : Did you not encounter this problem when studying linear equations in one variable?
H : Oh yes ma'am, I have. During practice there were questions like that.
R : Well, try to remember again, how to make a mathematical model.
H : I forgot ma'am, I can't.
R : Do you like mathematics subjects?
H : No ma'am.
R : Why?
H : All the math questions are difficult.

The researcher also conducted interviews with students I, the results of which were as follows.

R : How did you get the final result of 35,000?

I : There was already 125,000, then I used it to reduce the price of the bag 230,000, so the remaining is 105,000. Because it is covered by 3 people, I divide it by 3, so the result is 35,000. Each has to save 35,000.
R : Yes, you are correct. So, do you know how a mathematical model represent the problem?
I : Oh, x y like that, ma'am?
R : Yes, that's right, this is about linear equations in one variable. The problem can be made into mathematical model.
I : Oh, linear equations in one variable, ma'am. So what can I make of the example in variable form, ma'am?
R : Try it.
I : x is what each child must save again, then x = 230,000 – 125,000 (the researcher provides a clue to help students, because it should be 3x = 230,000 – 125,000).

Students H and J arrived at the correct final result of 35,000. Each still needs to save 35,000 to meet the savings required to purchase the bag. Although their final answers are correct, they did not utilize their relational thinking ability. Relational thinking is the process of constructing relationships among mathematical elements and using those relationships to find solutions to existing problems (Lenz, 2022). The students were able to arrive at the solution, but they did not employ relational thinking. They were unable to translate the story problem into mathematical symbols and solve it. In other words, they could not connect the contextual problem to mathematical notation in order to produce a more structured answer. This finding is supported by Wahyuni et al. (2023) which states that challenges encountered during mathematical problem solving include difficulties in understanding contextual problems and in building relationships among those problems for decision making.

Next, the student J starts solving the problem with a good start, namely by representing what he is looking for with "x". However, it was wrong because he made a mathematical model of x = 230.000 – 125.000. Because if "x" is the value you are trying to figure out then the correct equation is 3x = 230.000 – 125.000. Still, students also seemed unable to use mathematical procedures correctly. He performed the subtraction and continued with the division. Next, an interview was conducted with the student J to find out the reasons why he gave the answer like that. The results of the interview showed that the students believed they had carried out the operation correctly to solve the problem given. Until the researcher showed that the equation he made was not correct, even though the final result was correct.

R : In the third line you write that x = 230.000-125.000, then x = 105.000, then in the fourth line you write that x=105.000 : 3, then x = 35.000. Which one is true?
J : Oh yes ma'am, I mean the third line doesn't have an x, the x should just be written on the fourth line.
R : Can the third line still contain x? (researcher provides clues to help students).
J : Oh yes ma'am, you can. This means the equation should be 3x = 230.000 – 125.000.
R : In the fourth line you suddenly appear ":3", divided by 3. Is it okay like that?
J : Em, that's okay, ma'am, because the results are correct.

These findings indicate that, in solving mathematical problems, students still face learning obstacles. Based on their responses to item number 3, both ontogenetic and epistemological obstacles were identified. These obstacles reveal limitations in students' conceptual understanding and their lack of mental readiness to grasp more advanced ideas. For example, students like Student G still cannot fully comprehend the problem. Furthermore, students are unable to construct a mathematical model from the given problem. They also do not understand that "=" is a symbol indicating equality, as exemplified by Student J's response.

In addition, there is an obstacle stemming from students' lack of confidence in their own mathematical abilities, student perceive mathematics as difficult.

According to Brousseau (1997), there are three types of learning obstacles: ontogenic obstacles, didactical obstacles, and epistemological obstacles. An ontogenic obstacle is a learning barrier that occurs due to limitations related to the student's mental readiness to learn. A didactical obstacle is a barrier that arises from the methods or approaches used by a teacher, including the instructional media employed. An epistemological obstacle is a barrier that occurs because of limitations in the student's knowledge within a particular context. Table 4 shows the classification of learning obstacles experienced by students based on the findings.

Table 4. Classification of Learning Obstacles

Question No	Learning Obstacles	Classification
1	(a) Students do not understand the "=" sign as a form of equality but rather as an operational command.	Epistemological
	(b) Students do not understand the rules of operations in arithmetic.	Epistemological
	(c) Students are not familiar with the type of test questions given.	Didactical
2	(d) Students do not understand the rules of operations in algebra.	Epistemological
3	(e) Students are unable to fully understand the problem.	Epistemological
	(f) Students are unable to create a mathematical model from a word problem.	Epistemological
	(g) Students are unable to apply the concept of linear equations in one variable to contextual problems.	Epistemological
	(h) Students do not understand the operating rules in algebra. Students do not understand the meaning of the "=" as a symbol as of equality	Epistemological
	(i) Students lack confidence in their mathematical abilities.	Ontogenetic

Table 4 shows that students experience all three types of obstacles. Ontogenetic obstacles appear in point (i). It is evident that the students' difficulties are related to their mental unpreparedness for learning. Ontogenetic obstacles are divided into three categories: instrumental, conceptual, and psychological (Suryadi, 2019). An instrumental ontogenetic obstacle refers to a student's unpreparedness due to factors that prevent full engagement with the learning situation, as a result of not understanding the key technical aspects of the learning process. This type of difficulty was not observed.

Ontogenetic conceptual obstacles are characterized by students' unpreparedness related to their prior learning experiences (Suryadi, 2019). This means that the conceptual level embedded in the material does not align with the students' circumstances as determined by their previous learning experiences. This type of difficulty was not observed. These students are situated at a cognitive stage appropriate for the material presented. The items given have been studied in accordance with the development of their thinking abilities, so theoretically they should be able to solve the problems.

The final type of ontogenetic obstacle is ontogenetic psychological obstacles. Ontogenetic psychological obstacles are students' unpreparedness to learn due to psychological factors such as motivation, interest, behavior, and engagement with the material (Suryadi, 2019). This condition is evident in point i, where the student lacks confidence in their ability to learn and solve mathematical problems. The student perceives mathematics as difficult.

The second type of obstacle is didactical obstacles. Didactical obstacles arise from the methods or media used by the teacher during the learning process (Suryadi, 2019). In general, this obstacle is related to lesson design (Ardiansari et al., 2023). This obstacle was identified from student interviews in which students stated they were not familiar with the problems given. This indicates that the teacher did not design instruction to develop students' relational thinking ability. The teacher also did not modify practice problems aimed at training students' relational thinking skills. To follow up on this finding, the researcher interviewed the teacher. From that interview, it was revealed that seventh- and eighth-grade students at the junior high school level were already using the Merdeka Curriculum textbook. One of the practice problems presented in that book is as follows:

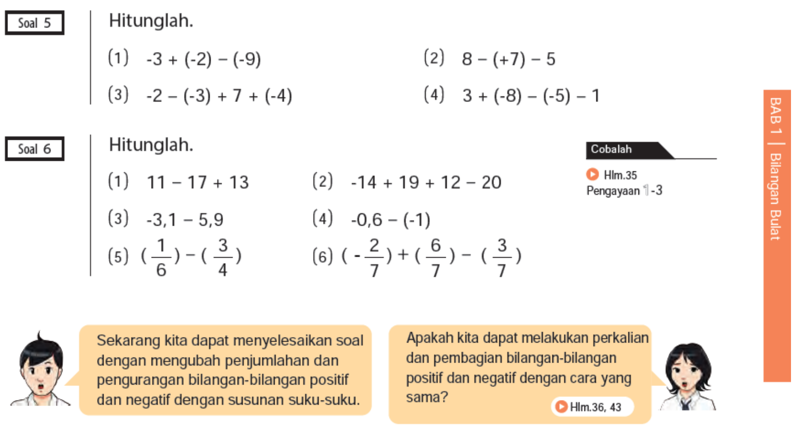


Figure 4. Problems in the Merdeka Curriculum Junior High School Book

The Merdeka Curriculum textbook being used has not been optimal in facilitating the development of students' relational thinking ability. This supports the students' statements that they were not familiar with the test items given by the researcher. The practice problems the students have worked on tend to be simple and do not encourage them to understand the equals sign ("=") as a symbol of equality. Students are more familiar with problems like "125 + 245 = ..." than with "125 + 245 = ...+ 200."

The final type of obstacle is the epistemological obstacle. An epistemological obstacle arises from limitations in students' knowledge of the material being studied or the specific context (Suryadi, 2019). This condition is evident in points (a), (b), (d), (e), (f), (g), and (h). Students do not understand operational rules in both arithmetic and algebra, cannot construct mathematical models from everyday problems, and interpret the equals sign ("=") as a command to perform operations rather than as a symbol of equality. A critical emphasis of the epistemological obstacle in this study is that students do not understand the equals sign as a form of equality but treat it as an operational instruction. For example, when presented with "3 + 14 = … + 11," students responded by writing "3 + 14 = 17 + 11 = 28". This indicates a limitation in their understanding and mastery of the equation concept signified by the "=" symbol. Even at the junior high level, students regard "=" as an operational command. This obstacle is further illustrated by students' response to item number 3, "x = 230,000 − 125,000 = 105,000 ÷ 3 = 35,000". This difficulty is not due to the test items being misaligned with students' cognitive development. Since they have already learned these topics previously, but rather because prior instructional processes did not sufficiently promote deep, conceptual understanding.

The researcher conducted an interview with the teacher to explore the students' relational thinking obstacles in arithmetic, algebra, and linear equations in one variable. Based on the teacher's responses, it was revealed that there are limitations in the use of mathematics learning resources. In mathematics instruction, the teacher uses the textbook recommended by the education office or government, which follows the Merdeka Curriculum. The practice problems in this book tend to emphasize students' computational skills only (see Figure 4). Instruction is not specifically designed to ensure that students understand the equals sign ("=") as a symbol of equality.

Based on constructivist theory (Piaget, 1971;Vygotsky, 1978), knowledge is actively built through continually developing cognitive schemas. If, during initial instruction, students receive only procedural explanations without conceptual connections, those schemas tend to be shallow and fragmented. For example, when students first learn algebraic operations, they may merely memorize the sequence of steps without understanding the relational meaning behind the "=" symbol. Consequently, even though the material has been taught, students cannot integrate fundamental concepts such as the property of equality and operational hierarchy into their reasoning when faced with novel problem variations. Thus, epistemological obstacles arise because students have not been able to assimilate concepts meaningfully or link them to a broader range of problem contexts.

Teachers require support through alternative learning resources rich in exploratory and conceptual activities, particularly for introducing and deepening students' understanding of the concept of equality. The lack of emphasis on the equals sign ("=") as a symbol of equality can potentially hinder the development of students' relational thinking ability. Therefore, instruction must be designed to facilitate conceptual understanding via approaches that encourage students to develop their relational thinking ability. Additionally, educational policies need to place greater emphasis on strengthening relational thinking in mathematics instruction, especially at the elementary and junior high school levels. Textbooks and instructional materials provided by the government or publishers should be evaluated and revised to ensure better alignment, so as to optimally support teachers in fostering students' relational understanding.

CONCLUSION

Based on the analysis, it can be concluded that students encounter learning obstacles when solving mathematics problems through relational thinking, comprising ontogenic, didactical, and epistemological obstacles. The ontogenic obstacle manifests as students' lack of confidence in their own mathematical abilities. The didactical obstacle is identified in the use of instructional materials and learning design that do not facilitate students' development of relational thinking ability. The epistemological obstacle is evident in students' failure to understand arithmetic and algebraic operation rules, inability to construct mathematical models from everyday problems, and misinterpretation of the equals sign ("=") as an operational command rather than as a symbol of equality.

RECOMMENDATION

Teachers require alternative learning resources that offer rich exploratory and conceptual activities to strengthen students' understanding of the concept of equality in arithmetic, algebra, and linear equations in one variable. Future research is recommended to conduct development or experimental studies aimed at designing and evaluating the effectiveness of instructional designs specifically intended to enhance students' relational thinking ability.

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