

## **Analysis of Epistemological Barriers in Students' Problem-Solving of Basic Algebra in Junior High School through the Didactical Design Research (DDR) Approach**

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### **Abstract:**

Algebra is a fundamental topic in junior secondary mathematics, yet many students experience difficulties, particularly in solving algebra word problems. This study aims to analyze the epistemological obstacles encountered by eighth-grade students in solving basic algebra word problems using the Didactical Design Research (DDR) framework. A descriptive qualitative approach was employed with two eighth-grade students of SMP Muhammadiyah Merauke representing high and low cognitive ability levels. Data were collected through a written algebra word problem based on Polya's problem-solving stages and face-to-face recorded interviews. The findings indicate that students experience epistemological obstacles in interpreting problem contexts, understanding variables as general quantities, and reflecting on the correctness of algebraic models. These obstacles occur in both high- and low-ability students, suggesting that procedural skills are not always supported by meaningful conceptual understanding.

**Keywords:** epistemological obstacles, algebra word problems, problem solving, Didactical Design Research

### **Introduction**

Algebra is an essential subject in mathematics education at the junior high school level, as it serves as a foundation for developing symbolic thinking skills and mathematical modeling. According to Jusniani et al. (2024), understanding algebraic concepts, particularly those related to the meaning of variables and algebraic expressions, greatly affects students' ability to solve mathematical problems at subsequent educational levels. Therefore, algebra instruction at the junior high school level should not only emphasize procedural manipulation of symbols but also focus on understanding the meaning of symbols as representations of quantitative relationships. This conceptual understanding is greatly influenced by how students build cognitive schemas through the stages of action, process, object, and schema, as



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explained in the APOS approach to the development of the concept of area in flat shapes (Palobo et al., 2023a).

However, various studies indicate that algebra remains a challenging subject for junior high school students, especially when presented in the form of word problems. According to Jupri & Drijvers (2016), the main difficulty students face in solving algebra word problems lies in the process of mathematizing a contextual situation into an appropriate algebraic model. Students often struggle to relate the information provided in the word problem to symbolic representations, which results in the mathematical model created not accurately reflecting the actual problem.

Based on the researcher's experience during the School Field Practice (PLP) in grade VIII at a junior high school, it was found that students' difficulties in solving algebra word problems were not only reflected in incorrect answers but also in their thinking processes when interpreting variables. Many students used variable symbols without understanding their meaning as representations of general quantities. As a result, students tended to form algebraic expressions mechanically without considering their connection to the context of the problem. This field finding aligns with the research of Jusniani et al. (2024), which states that students often struggle to understand the meaning of algebraic symbols, even after formally studying the subject.

Algebra word problems require problem-solving skills involving multiple stages of thinking. According to Midawati (2022), problem-solving includes stages such as understanding the problem, planning a strategy, executing the strategy, and reviewing the results. In line with this framework, Midawati (2022) asserts that students' difficulties in mathematical problem-solving often arise at the initial stages, particularly in understanding the key information and forming an appropriate mathematical model. Difficulties at this early stage can lead to errors in subsequent stages, even if students have relatively good procedural abilities.

Students' mistakes in algebra are not solely due to procedural weaknesses but stem from limitations in conceptual understanding and the way students think about symbols and mathematical contexts. Therefore, the analysis of students' difficulties should be directed towards identifying the sources of these challenges more deeply, rather than merely focusing on the final answer.

One relevant approach for examining the sources of these difficulties is Didactical Design Research (DDR). Within the DDR framework, students' learning difficulties are understood as part of the didactic situation that forms through the interaction between students, the material, and the instructional design. The analysis in the initial stage of DDR focuses on identifying learning obstacles students face before designing further learning interventions. This approach allows researchers to understand students' difficulties as consequences of the learning experiences they have already encountered.

To create a conducive learning environment for students, a didactic approach is needed that encourages students to relate mathematical concepts to real-life contexts

(Ilma et al., 2022), fostering meaningful learning that enables students to understand mathematical topics based on fundamental understanding drawn from their everyday lives. The problems presented do not have predetermined solutions, rules, templates, or algorithms (Säfström et al., 2023).

In this context, epistemological barrier analysis becomes crucial. According to Marlinda et al. (2024), epistemological barriers arise when the knowledge students possess can only be applied in specific contexts and cannot be flexibly transferred to different situations, even though students have received prior learning. In algebra learning, epistemological barriers can be seen in students' inability to interpret variables, construct algebraic models from word problems, and re-interpret algebraic results in context. Epistemological barriers are also identified in studies of linear algebra with one variable, where students struggle to understand variables as representations of general quantities (Ruli et al., 2025).

Based on the description above, this study focuses on analyzing the epistemological barriers faced by grade VIII junior high school students in solving basic algebra word problems using the Didactical Design Research (DDR) framework, specifically at the initial analysis of the didactic situation. This study does not aim to test the effectiveness of specific teaching methods or media but rather to diagnose the epistemological barriers that arise from student responses. By identifying these barriers, the study is expected to contribute to understanding students' conceptual difficulties at the initial stage of algebra learning and serve as a foundation for developing more meaningful learning approaches.

## Research Methods

This study uses a descriptive qualitative approach with the Didactical Design Research (DDR) framework. The qualitative approach was chosen because the study aims to deeply understand students' thinking processes and the conceptual difficulties that arise in solving algebra problems. According to Marlinda et al. (2024), the study of epistemological barriers requires qualitative analysis because these barriers are related to the limitations in how students interpret and use mathematical knowledge in different contexts.

In the DDR framework, this study is limited to the initial stage of the didactic situation analysis, which is the diagnostic phase of students' learning obstacles before the design of the learning intervention is carried out. This limitation aligns with previous studies on epistemological barriers, which placed the identification of students' difficulties as the primary goal without applying a specific learning treatment. According to Dewanti & Komala (2023), analyzing epistemological barriers at the early stages of learning is important to understand the limitations of students' knowledge before designing a learning intervention.

This approach is also relevant because epistemological barriers are understood as obstacles that stem from the structure of the students' own knowledge. According

to Dewanti & Komala (2023), epistemological barriers do not arise by chance but are related to how students understand concepts, procedures, and operational techniques in mathematics.

This research was conducted at SMP Muhammadiyah Merauke. The subjects of the study consisted of two eighth-grade students who were selected purposively, each representing the categories of high and low cognitive ability.

The selection of subjects with contrasting abilities aims to obtain a picture of the variation in epistemological barriers experienced by the students. According to Yohani & Irvandi (n.d.), epistemological barriers can arise in students with various levels of cognitive ability, so analyzing students with different abilities is essential to obtain a picture of the variations in epistemological barriers experienced. In addition to cognitive ability, learning styles and gender may also influence students' mathematical thinking processes, as found in studies on students' understanding of geometry (Palobo et al., 2023b).

Furthermore, according to Poppy Dian Utami & Eva Dwi Minarti (2023), students' errors and difficulties in mathematics are not always related to low ability but often stem from limitations in conceptual understanding. Therefore, analyzing students with different ability levels becomes relevant in this study.

The research instruments consist of a written test in the form of word problems and semi-structured interviews.

**Table 1.** Essay problem

Topic	Question
Boxes Containing Balls	<p>Each box contains the same number of balls. Dita has 3 boxes and 4 balls outside the boxes. Rafi has 2 boxes and 7 balls outside the boxes.</p> <ol style="list-style-type: none"> <li>a. Write down all the information you can identify from the story above!</li> <li>b. Suppose the number of balls in one box is <math>x</math>. Write the algebraic expression for the total number of balls owned by Dita and Rafi. Explain how you determined it.</li> <li>c. Who has more balls? Represent this using algebraic expressions and explain your reasoning!</li> <li>d. Assume one box contains 5 balls. Calculate the total number of balls owned by Dita and Rafi. Does your calculation match the algebraic expressions you created? Explain your reasoning!</li> </ol>

The written test consists of a single algebra word problem with one variable, which does not form a system of equations. The problem is designed using a real-life context, specifically a scenario involving a box containing balls with an equal number and a comparison of the number of balls owned by two characters. Students are asked to identify important information, construct an algebraic model using variables as representations of general quantities, compare algebraic forms, and verify the accuracy of the model by substituting specific values.

The construction of the problem is explicitly based on the problem-solving stages according to Polya, namely understanding the problem, planning a strategy, executing the strategy, and checking the results. The use of Polya's steps aims to trace the students' thinking process at each stage of problem-solving. This approach aligns with the findings of Midawati (2022), which states that students' difficulties in solving mathematical problems often arise from the initial stage of understanding the problem and constructing a mathematical model.

The choice of word problems as the primary instrument is based on the consideration that, according to Jupri & Drijvers (2016), algebra word problems require the ability to mathematize a contextual situation into a symbolic model, which is often a primary source of difficulty for students. Furthermore, according to Hidayah & Beddu (2025), the context of word problems can more clearly reveal the gap between the students' conceptual understanding and procedural knowledge.

The interview instrument used is a semi-structured interview conducted face-to-face and recorded. The interview is not conducted in writing. The interview questions are designed based on students' responses to the written test and aim to explore students' interpretation of variables, reasons for constructing algebraic models, the parts of the problem they found difficult, and their habits in reviewing their work. This approach is in line with the research on epistemological barriers by Dewanti & Komala (2023), which emphasizes the importance of verbal data from students in understanding the sources of learning difficulties.

This study produces learning products/teaching materials in the form of a circle learning module assisted by augmented reality, and uses a 4D model approach. The results of this learning device are said to be good if they meet the criteria of being valid, practical and having potential effects. The subjects of this study involved all students 8th Grade C of SMP Negeri 4 Lubuklinggau, totaling 32 students and 1 mathematics subject teacher.

Students' answers are analyzed using an analytic scoring rubric with a scale of 0–3 for each stage of problem-solving according to Polya. This rubric is used to map the students' understanding profiles at each stage of problem-solving and serves as the basis for selecting interview subjects.

**Table 2:** Assessment Rubric

Score	Criteria Description
3 (High)	Demonstrates full conceptual understanding: identifies all relevant information, uses variables correctly, performs accurate operations, and interprets results according to the context.
2 (Moderate)	Demonstrates partial understanding: understands the context, but contains minor errors in modeling, calculation, or symbol interpretation.

Score	Criteria Description
1 (Low)	Answer is partially correct but incomplete or fails to explain the conceptual meaning; tends to be procedural.
0 (No understanding)	Shows no conceptual understanding: answer is blank, random, or completely incorrect.

The use of an analytic rubric aims to more specifically identify the stages of problem-solving that exhibit conceptual, procedural, or operational difficulties. According to Yohani & Irvandi (n.d.), categorizing students' difficulties based on conceptual, procedural, and operational indicators can help researchers understand the characteristics of epistemological barriers more systematically.

Data analysis is conducted in three main stages. The first stage involves analyzing students' written answers to identify error patterns and difficulties at each stage of problem-solving. The second stage is the identification of epistemological barriers based on the emerging patterns of difficulties. The third stage is the confirmation of the analysis results through interview data.

The determination of the types of epistemological barriers is done using a hybrid model. Barriers are not rigidly defined from the outset but are derived through analysis of student data and then interpreted with reference to the literature. The interpretation of epistemological barriers is linked to the difficulty of mathematizing word problems, according to Jupri & Drijvers (2016), as well as the characteristics of conceptual, procedural, and operational barriers as outlined by Yohani & Irvandi (n.d.). Data triangulation is performed by comparing the results of written answers and interview outcomes to ensure the consistency of the epistemological barrier findings.

## Results and Discussions

### *Students with High Cognitive skills*

At the stage of understanding the problem, the student with high cognitive ability wrote down the main information from the word problem. The student stated that each box contains balls, and the number of balls in each box is the same. This information was written in a short sentence, showing that the student understood the general context of the problem. However, the information written was not fully structured, and the quantitative relationship, such as the connection between the number of boxes and the total balls that may be implied in the problem, was not detailed.

At the stage of planning the strategy, the student used a variable to represent the unknown quantity in the problem. The variable was used to represent the number of balls in one box. The student began to form an algebraic expression based on the information previously understood. The algebraic expression written shows that the

student attempted to connect the context of the story with symbolic representation. However, the algebraic model written was limited to basic forms and lacked a written explanation regarding the choice of variables or the relationships between the quantities involved.

c. dita..  $3 \cdot x + 4 : 3 \cdot 10 + 4 : 34$   
 $x =$  kita umpamakan 10  
 karena kalo Rafi  $2 \cdot 10 + 7 : 27$

**Figure 1.** Student Work with High Cognitive Ability Point C

At the stage of executing the strategy, the student continued solving the problem using the algebraic model that had been constructed. The student attempted to compare or interpret the algebraic expression according to the question in the problem. The steps written show that the student followed the solution process sequentially. However, the descriptions of the steps were brief and lacked a deep written explanation regarding the meaning of each algebraic operation performed.

At the stage of checking the results, the student performed substitution of the values given in the problem into the algebraic model that had been constructed. The substitution was done to obtain a numerical result. The student wrote the result of the substitution as part of the final answer. The step of checking was carried out, although the student did not provide additional explanation regarding the consistency of the substitution results with the context of the problem.

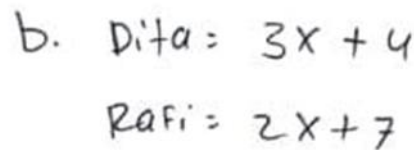
*Students with low Cognitive Skills*

At the stage of understanding the problem, the student with low cognitive ability wrote down the information from the problem briefly and with limitations. The information written only included part of the story without explaining the relationships between the elements in the problem. The answer given did not clearly organize the information, so the context of the problem was not fully reflected in the student's written response.

a. Dita = 3 kotak yang belum diketahui jumlah isinya  
 dan 4 bola di luar kotak  
 Rafi = 2 kotak yang belum diketahui jumlah isinya  
 dan 7 bola diluar kotak

**Figure 2.** Student Work with Low Cognitive Ability Point A

At the stage of planning the strategy, the student wrote an algebraic expression involving variables. However, the algebraic expression constructed did not fully align with the information in the problem. The variable was used without an explanation of its meaning or its relationship to the quantities in the story. The algebraic model



The image shows two handwritten algebraic expressions. The first is 'b. Dita = 3x + 4' and the second is 'Rafi = 2x + 7'. The handwriting is in black ink on a white background.

written did not reflect a clear relationship between the variables and the situation in the problem.

**Figure 3.** Student Work with Low Cognitive Ability Point B

At the stage of executing the strategy, the student continued the solution process based on the algebraic expression that had been written earlier. Algebraic operations were performed, but the steps written were not accompanied by an explanation regarding the reasons or meanings of the processes being carried out. The answers at this stage show that the student followed the solution procedure, although the connection between the steps taken and the context of the problem was not explicitly apparent.

At the stage of checking the results, the student performed substitution of values into the algebraic model that had been created. The result of the substitution was written as the final answer. However, the student did not write an explanation regarding the purpose of the substitution or its relationship to the context of the problem. The step of checking was carried out as part of the solution process, although no written reflection was provided on the consistency of the results with the situation in the problem.

Based on the analysis of written answers and interview results, it was found that epistemological barriers in solving basic algebra word problems appeared consistently across all stages of problem-solving according to Polya, particularly in the interpretation of the context, the use of variables, and the reflection on the results obtained. These barriers were not only experienced by students with low cognitive ability but were also observed in students with high cognitive ability, albeit with different characteristics.

At the stages of understanding the problem and planning the strategy, both subjects experienced difficulty mathematizing the contextual situation into a meaningful algebraic model. The interview results showed that students understood the story in general but had difficulty explaining the quantitative relationships between the information presented in the problem. Variables were used as symbols to

continue the calculation, but were not explicitly interpreted as representations of general quantities. These findings indicate the presence of conceptual epistemological barriers, as stated by Marlinda et al. (2024), that epistemological barriers arise when students' knowledge is limited to specific contexts or procedures and has not been integrated conceptually.

These findings are consistent with the research of Jupri & Drijvers (2016), which states that the main difficulty students face in algebra word problems lies in the process of mathematizing a contextual situation, especially in connecting the context of the story with symbolic representation. Additionally, Jusniani et al. (2024) found that students often use symbols and variables formally without understanding their meaning, causing the algebraic models created not to fully reflect the intended problem.

At the stages of executing the strategy and checking the results, students tended to follow the algebraic procedures mechanically. The interview revealed that students performed substitution because they were "asked by the problem," rather than as an effort to reflectively check the accuracy of the model. This condition indicates the presence of procedural epistemological barriers, where students are capable of performing algebraic operations but do not understand the purpose or meaning of the steps they are taking. These findings support the classification of epistemological barriers by Yohani & Irvandi (n.d.), which distinguishes between conceptual and procedural barriers in mathematical problem-solving.

Difficulties arising at the initial stages of problem-solving impacted subsequent stages, even though students had relatively adequate procedural abilities. This aligns with the findings of Midawati (2022), who states that errors in understanding the problem and constructing a mathematical model can lead to subsequent errors in the solution process. Therefore, epistemological barriers in this study are not isolated to a single stage but form a series of interrelated difficulties.

From the perspective of Didactical Design Research (DDR), these findings reflect the initial didactic situation students face in algebra learning. The epistemological barriers that emerge indicate that prior learning experiences have not fully supported the development of meaningful algebraic understanding, particularly in connecting symbols, variables, and the context of word problems. This strengthens the view of Dewanti & Komala (2023) that identifying epistemological barriers at the initial stage of learning is a crucial foundation for designing more effective and contextual learning. Epistemological barriers in algebraic operations have also been studied by Robby Ismail Fasya (2024), who states that these barriers include difficulties in understanding and applying concepts in problem-solving contexts. The application of learning models such as discovery learning has been shown to significantly improve students' problem-solving abilities in basic algebra (Palobo, 2021).

## Conclusions and Suggestions

Based on the analysis of written answers and interviews with eighth-grade students in solving basic algebra word problems, it can be concluded that students experience epistemological barriers at all stages of problem-solving according to Polya, especially in interpreting the context of the problem, understanding variables as representations of general quantities, and reflecting on the accuracy of the algebraic models constructed. These epistemological barriers were not only experienced by students with low cognitive ability but were also found in students with high cognitive ability, although with different levels and characteristics. This finding suggests that procedural ability does not always reflect a complete conceptual understanding, causing students to solve algebra word problems mechanically without a strong connection between symbols, context, and mathematical meaning.

In the framework of Didactical Design Research (DDR), which is limited to the initial analysis of the didactic situation, the results of this study reveal that students' epistemological barriers are a consequence of their algebra learning experiences, which have not fully emphasized the conceptual meaning and contextual relationships. Therefore, identifying epistemological barriers is an important initial step before designing further learning interventions. The findings of this study are expected to serve as a foundation for teachers and researchers in developing more meaningful algebra instruction, particularly by emphasizing the understanding of variables, algebraic modeling from contextual situations, and reflection on the problem-solving process and results.

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