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Praxeological Analysis of Epistemological Learning Obstacles in Junior High School Algebra

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Abstract. *Students' conceptual understanding and mathematical reasoning in algebra remain relatively low, making the analysis of epistemological learning obstacles an important issue in mathematics education. Although learning obstacles have been widely studied, research examining epistemological learning obstacles in algebra from the perspective of praxeology theory is still limited. This study aimed to analyze junior high school students' epistemological learning obstacles in algebra by examining the relationship between their problem-solving processes and the praxeological components of task, technique, technology, and theory. A qualitative descriptive approach was employed involving three seventh-grade students representing high, medium, and low mathematical ability, along with one mathematics teacher as a supporting informant. Data were collected through written tests, semi-structured interviews, observations, and documentation, and analyzed using the Miles and Huberman model with source and technique triangulation. The findings revealed that students experienced epistemological learning obstacles in understanding algebraic variables, identifying like terms, simplifying algebraic expressions, translating contextual problems into mathematical models, selecting appropriate solution strategies, and providing logical justification. The characteristics of these obstacles differed across ability levels, with higher-ability students demonstrating a more complete praxeological structure than medium- and low-ability students. These findings highlight the usefulness of praxeology theory in identifying students' epistemological learning obstacles and supporting more effective algebra instruction.*

Keywords: *epistemological learning obstacle, algebra, praxeology theory, qualitative research, mathematics education.*

INTRODUCTION

Mathematics education has experienced substantial changes in recent years due to the growing emphasis on developing higher-order thinking, conceptual understanding, and problem-solving skills required in the twenty-first century OECD (2023). As expectations for mathematics learning continue to increase, identifying the epistemological learning obstacles that limit students' conceptual understanding has become essential for enhancing their mathematical problem-solving abilities. Conceptual understanding is regarded as a key aspect of mathematics learning because it allows students to connect mathematical concepts

meaningfully, develop logical reasoning, and apply their knowledge in various contextual situations. Therefore, increasing attention has been given to examining students' learning obstacles, particularly in algebra, since it provides the basis for understanding more advanced mathematical concepts (Lestari & Suryadi, 2020; Asmara & Suryadi, 2024)

Despite these improvements, students' achievement in mathematics remains unsatisfactory. Results from the Programme for International Student Assessment (PISA) 2022 showed that Indonesia achieved an average mathematics score of 366, which was substantially lower than the OECD average of 472, reflecting continuing challenges in mathematical reasoning and conceptual problem solving (OECD, 2023). A similar pattern was identified in the 2023 Minimum Competency Assessment (AKM), where many junior high school students demonstrated difficulties in solving contextual mathematical tasks and expressing them in appropriate mathematical models (Kemendikbudristek, 2023). These results indicate that students' learning difficulties are not limited to computational mistakes but are also associated with insufficient conceptual understanding.

Algebra is among the mathematical topics that often present conceptual challenges for students. Previous research has shown that students commonly struggle to interpret algebraic variables, recognize like terms, simplify algebraic expressions, and represent verbal problems using mathematical models (Anggoro & Nurmalasari, 2022; Lestari & Suryadi, 2020; Supratman, 2018). These difficulties suggest that students' mistakes are not solely caused by procedural errors but also reflect limitations in their conceptual understanding, which are identified as epistemological learning obstacles. Initial observations at SMP Negeri 3 Ogan Komering Ulu further indicated that many seventh-grade students had difficulty simplifying algebraic expressions and converting contextual problems into appropriate algebraic models, highlighting the importance of conducting a more in-depth investigation.

Epistemological learning obstacles can be examined through students' reflective thinking, particularly their ability to evaluate and reconsider their initial mathematical solutions. Reflective thinking enables students to review their

problem-solving processes, identify errors, and reconstruct their reasoning when inconsistencies are found (Setiyani et al., 2024). Without sufficient reflection, misconceptions may remain unrecognized and persist because previously acquired knowledge can continue to influence students' reasoning even when it becomes inadequate in new mathematical contexts (Brousseau, 2002). Therefore, analyzing students' incorrect responses alone is insufficient to fully understand their learning obstacles. It is also necessary to investigate the underlying conceptions and knowledge structures that shape students' mathematical reasoning (Brousseau, 2002; Chevallard, 2006).

To gain a deeper understanding of these knowledge structures, this study employs the Anthropological Theory of the Didactic (ATD), particularly the concept of praxeology, as an analytical framework consisting of four interrelated components: task, technique, technology, and theory (Chevallard, 2006). These components represent the practical aspects of mathematical activity (praxis) and the theoretical explanations that justify the techniques used (logos). In contrast to conventional error analysis, which mainly focuses on identifying students' mistakes, praxeological analysis provides a framework for examining mathematical tasks, the techniques used to solve them, and the conceptual justifications underlying those techniques (Fardian et al., 2025). Accordingly, this framework provides a more comprehensive explanation of how students develop mathematical knowledge while solving algebraic problems.

Although learning obstacles in mathematics education have been widely investigated, several gaps remain. International studies have shown that students' misconceptions about the equal sign can hinder their understanding of algebraic concepts (Knuth et al., 2006; Löwenhielm, 2024). In Indonesia, Hidayah et al. (2021) examined learning obstacles in algebra, while Fardian et al. (2025) applied praxeology theory to analyze mathematics textbooks. However, these studies have not addressed the same combination of students' epistemological learning obstacles and praxeological analysis of their mathematical reasoning. Therefore, this study investigates students' epistemological learning obstacles in algebra through the

praxeological framework, focusing on the relationships among tasks, techniques, technology, and theory.

To fill this research gap, the present study investigates junior high school students' epistemological learning obstacles in algebra by examining the praxeological components of task, technique, technology, and theory. Employing a qualitative descriptive approach, the study aims to identify the characteristics of these learning obstacles and explore the factors that contribute to their occurrence during algebraic problem solving. The findings are expected to enrich the field of mathematics education by providing empirical evidence of students' conceptual difficulties and highlighting the value of praxeology theory as an analytical framework. In addition, the results are expected to support mathematics teachers in developing more effective instructional strategies while strengthening the connection between learning obstacle theory and classroom practice.

RESEARCH METHOD

This study adopted a qualitative descriptive design to investigate junior high school students' epistemological learning obstacles in algebra from the perspective of praxeology theory. The research was carried out at SMP Negeri 3 Ogan Komering Ulu, Indonesia, during the second semester of the 2025/2026 academic year. Participants were selected through purposive sampling based on the results of a reflective thinking ability test. The participants consisted of three seventh-grade students representing high, medium, and low levels of reflective thinking, together with one mathematics teacher who acted as a supporting informant. Students were included in the study if they had completed the algebra unit, agreed to participate throughout the research, and were able to provide information relevant to the research objectives. To maintain research ethics, the identities of all participants were kept confidential and anonymous throughout the study.

The instruments used in this study included a written algebra test, a semi-structured interview guide, observation sheets, and documentation. Before data collection, all research instruments were reviewed and validated by experts in mathematics education through expert judgment. The written test was designed to

identify students' epistemological learning obstacles, whereas the semi-structured interviews were conducted to gain deeper insights into the reasoning behind their solution strategies. Observation and documentation were used to complement and confirm the data obtained from the written tests and interviews. To enhance the trustworthiness of the findings, source triangulation and technique triangulation were employed.

The collected data were analyzed using the Miles and Huberman interactive model, which involves three stages: data reduction, data display, and conclusion drawing (Miles et al., 2019). The results were then interpreted through the praxeological framework, encompassing the four components of task, technique, technology, and theory, to examine the characteristics and factors underlying students' epistemological learning obstacles in algebra. Information obtained from written tests, interviews, observations, and documentation was continuously compared and integrated to produce a comprehensive interpretation and strengthen the trustworthiness of the findings (Bingham, 2023).

RESULT AND DISCUSSION

The findings revealed that students across high, moderate, and low levels of reflective thinking ability experienced epistemological obstacles in learning algebra. However, the characteristics of these obstacles differed according to their levels of reflective thinking ability. Students with high reflective thinking ability, represented by S2, experienced difficulties in generalizing contextual information into algebraic symbols. Students with moderate reflective thinking ability, represented by S4, encountered difficulties in connecting algebraic concepts consistently and applying appropriate procedures. Meanwhile, students with low reflective thinking ability, represented by S12, demonstrated fundamental misconceptions regarding variables and algebraic relationships.

The present findings are consistent with earlier studies reporting that epistemological learning obstacles frequently occur in junior high school mathematics learning (Lestari & Suryadi, 2020; Asmara & Suryadi, 2024). Previous research has also highlighted the importance of conceptual understanding in

influencing both the nature and the extent of learning obstacles that students experience during mathematical problem solving (Tamba & Saragih, 2020; Fardian et al., 2025).

Table 1. Characteristics of Epistemological Obstacles Based on Reflective Thinking

Ability Participant	Reflective Thinking Ability	Main Epistemological Obstacle
S2	High	Difficulty generalizing algebraic concepts
S4	Moderate	Difficulty connecting mathematical concepts
S12	Low	Misconceptions about variables and algebraic relationships

As presented in Table 1, epistemological obstacles were identified among all participants, regardless of their level of reflective thinking ability. This finding suggests that reflective thinking ability influences the characteristics of epistemological obstacles rather than their occurrence. Similar findings were reported by Tonra et al. (2025) and Warsitarumanti et al. (2024), who found that students with relatively high cognitive or reasoning abilities may still experience epistemological obstacles, particularly when encountering unfamiliar mathematical representations. The findings further indicate that the characteristics of students' epistemological obstacles are influenced more by the depth of their conceptual understanding than by their academic achievement alone. Although students with higher reflective thinking ability demonstrated more advanced reasoning processes, they still experienced difficulties when applying algebraic concepts to unfamiliar situations.

These findings are consistent with Brousseau's theory of epistemological obstacles, which proposes that learning difficulties emerge when previously acquired knowledge is restricted to familiar contexts and cannot be transferred effectively to new mathematical situations. In the present study, this was reflected in students' difficulties in generalizing algebraic representations beyond routine problem contexts. Similar results were reported by Asmara and Suryadi (2024), who observed that students frequently experienced difficulties in representing algebraic concepts in formal mathematical forms. This finding reinforces the view

that epistemological obstacles are closely related to students' conceptual construction during algebra learning.

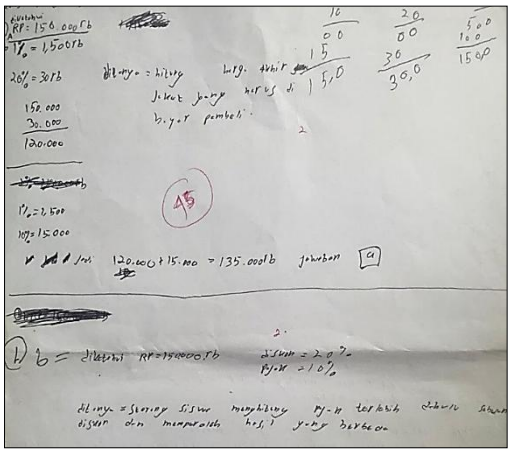

Figure 1. Student S2's Written Response

The written response of S2 showed that the student was able to identify the relevant information and complete numerical calculations involving percentages. In the first part of the problem, S2 successfully calculated the discount and tax when the initial price was presented as a specific numerical value. However, difficulties emerged when the student was asked to represent the initial price using a variable and express the situation algebraically. The interview provided further evidence of this difficulty.

> S2**:** "I am confused about using the letter x. When the problem uses Rp150,000, I know what to do: subtract and then add. But when it is replaced by x, I am confused about how to calculate the percentage."

S2 also explained that the variable represented the initial price but expressed uncertainty about performing operations when the value was not given numerically. This response indicates that S2 recognized the contextual meaning of the variable but had not fully understood its function as a general representation of an unknown quantity. The student could perform familiar numerical procedures but struggled to extend those procedures to symbolic expressions. From the praxeological perspective, the difficulty can be described through the following components:

- Task (T): S2 identified the relevant information, including the initial price, discount, and tax, but had difficulty translating their relationships into an algebraic model.
- Technique (τ): The student relied on numerical calculation procedures and could not appropriately extend them to expressions involving variables.
- Technology (Θ): S2 was unable to provide a sufficient mathematical justification for performing percentage operations involving a variable.
- Theory (θ): The student had not fully developed an understanding of variables as general representations of quantities in algebraic relationships.

These findings indicate that S2 experienced an epistemological obstacle primarily related to conceptual generalization. Although the student demonstrated relatively good numerical procedural skills, this knowledge could not yet be transferred effectively to symbolic algebraic situations.

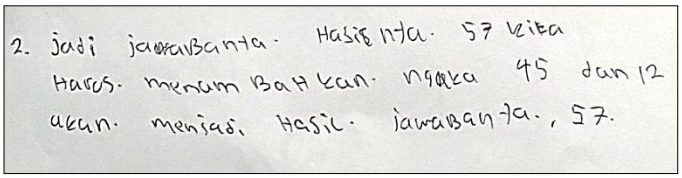

Figure 2. Student S4's Written Response

The written response and analysis of S4 indicated that the student could recognize some of the information provided in the problem and had an initial understanding of the algebraic concepts involved. Nevertheless, S4 experienced difficulties in connecting mathematical concepts consistently, resulting in an inappropriate mathematical model and inaccurate solution procedures. The analysis showed that the obstacle was not primarily caused by an inability to perform numerical operations. Instead, it was associated with the incomplete integration of algebraic concepts when the student attempted to solve a problem involving several related mathematical ideas.

From the praxeological perspective, the characteristics of S4's responses were identified as follows:

- Task (T): S4 could identify some of the known information and the requirements of the problem but had difficulty establishing the correct mathematical relationships.
- Technique (τ): The procedures selected by the student were not consistently applied, resulting in an inaccurate solution.
- Technology (Θ): The student had difficulty explaining the mathematical reasons underlying the procedures used.
- Theory (θ): Basic algebraic concepts had been partially understood but were not sufficiently integrated to support flexible application in different problem situations.

The findings suggest that S4 experienced conceptual epistemological obstacles accompanied by procedural difficulties. The student had acquired some relevant mathematical knowledge but had not yet developed sufficient connections among the concepts to solve the problem accurately. The interview with S21, another participant in the moderate category, provided additional evidence of similar difficulties:

> **S21:** "I know the information in the problem, but I am confused about determining the next step so that the answer is correct."
>
> **S21:** "I follow the example that was taught, but I am not sure whether the steps are appropriate."

These statements belong to S21 and are presented only as supporting evidence for the pattern identified in the moderate category, not as direct statements from S4. They indicate that students in this category could recognize relevant information but still experienced difficulties selecting and justifying appropriate procedures.

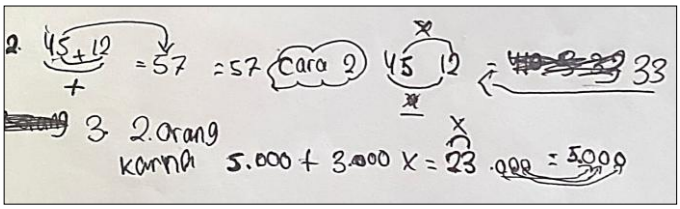

Figure 2. Student S12's Written Response

The written responses of S12 revealed more fundamental difficulties in understanding algebraic problems. In problems involving contextual information,

S12 tended to perform direct numerical calculations using the numbers appearing in the problem without first constructing the mathematical relationships involved.

For example, in question number 2, S12 added 45 and 12 because the problem contained the word *sum*. The interview confirmed this reasoning.

Researcher: “Why did you add 45 and 12 in question number 2?”

S12: “Because the problem contains the word sum, so I added them.”

Researcher: “What does the number 57 represent?”

S12: “The result of the numbers.”

Furthermore, when asked about the meaning of letters in an algebraic problem, S12 responded:

S12: “I do not really know.”

S12 also explained that the student felt confused when solving problems involving letters because it was unclear how to calculate them. These responses indicate that S12 relied on keywords and numerical information rather than interpreting the mathematical relationships in the problem. The student had not developed an adequate understanding of variables as representations of quantities or of equations as relationships between quantities.

The praxeological analysis of S12 can be described as follows:

- Task (T): S12 had difficulty identifying the mathematical relationships required by the problem and constructing an appropriate algebraic model.
- Technique (τ): The student relied on direct numerical operations instead of using algebraic modeling procedures.
- Technology (Θ): The student justified the selected operation based on the appearance of keywords rather than mathematical relationships.
- Theory (θ): The student had not adequately understood the concept of variables and equations as representations of relationships between quantities.

Therefore, S12 experienced conceptual and procedural epistemological obstacles. These difficulties were reflected not only in the incorrect final answers but also in the student's interpretation of variables, selection of solution techniques, and inability to evaluate the procedures used.

The findings from the three participants demonstrate that epistemological obstacles affected different components of students' praxeological structures. Although the specific manifestations differed, difficulties in conceptual understanding influenced students' selection of techniques and their ability to justify mathematical procedures.

Table 3. Comparison of Students' Responses Based on Chevallard's Praxeological Components

Praxeological component	S2 (High)	S4 (Moderate)	S12 (Low)
Task (T)	Identified relevant information but struggled to construct a symbolic model.	Recognized some information but struggled to establish mathematical relationships.	Had difficulty identifying the mathematical relationships required by the problem.
Technique (τ)	Relied on numerical procedures and struggled to extend them to variables.	Applied procedures inconsistently.	Used direct numerical operations without constructing an algebraic model.
Technology (Θ)	Could not adequately justify operations involving variables and percentages.	Had difficulty explaining the reasons for the procedures used.	Justified operations based on keywords in the problem.
Theory (θ)	Understanding of variables as general representations remained incomplete.	Algebraic concepts were partially understood but insufficiently connected.	Understanding of variables and equations as relationships between quantities remained limited.

As shown in Table 3, the theory component was closely related to the difficulties observed in the other praxeological components. In S2, incomplete understanding of variables limited the ability to extend numerical techniques to symbolic expressions. In S4, insufficient connections among algebraic concepts affected the consistency of the selected procedures and the explanations supporting them. In S12, limited understanding of variables and mathematical relationships influenced the interpretation of the task, the selection of techniques, and the justification of the procedures used.

These findings illustrate the interrelated nature of the four praxeological components. Difficulties in understanding mathematical concepts may influence not only what students do when solving a problem but also how they select and justify their solution techniques.

The findings indicate that students at all three levels of reflective thinking ability experienced epistemological obstacles in algebra, although their characteristics differed. S2 (high) struggled to generalize numerical procedures into symbolic forms, S4 (moderate) had difficulty connecting algebraic concepts, while S12 (low) showed fundamental difficulties in understanding variables and mathematical relationships. These findings support Brousseau's (2002) view that previously acquired knowledge may become an obstacle when applied to new contexts, as students' reliance on familiar numerical procedures can hinder the development of algebraic reasoning.

S2's difficulties highlight the importance of understanding mathematical relationships when transitioning from arithmetic to algebra. Knuth et al. (2006) demonstrated that understanding the equal sign is related to students' ability to solve equations, while Sumpter and Löwenhielm (2024) emphasized the importance of relational understanding among Grade 7 students. These findings suggest that algebraic reasoning requires more than computational skills; it also requires understanding the relationships underlying mathematical expressions.

S4's difficulties in connecting concepts and applying procedures consistently, along with S12's tendency to rely on numerical information and keywords rather than interpret algebraic relationships, indicate that students' obstacles involve both procedural and conceptual understanding. These findings are consistent with Lestari and Suryadi (2020) and Asmara and Suryadi (2024), who identified students' difficulties in understanding and performing algebraic operations.

From the praxeological perspective, the findings demonstrate the interconnectedness of task, technique, technology, and theory. Students' limited conceptual understanding affected their choice of techniques and their ability to justify mathematical procedures. This is consistent with Chevallard's (2006) Anthropological Theory of the Didactic, which connects practical components

(*praxis*) with theoretical components (*logos*), and with Fardian et al. (2025), who applied praxeological analysis to mathematical tasks, techniques, and theoretical justifications.

The findings also suggest that reflective thinking ability is related to how students recognize and evaluate mathematical strategies, although it does not necessarily eliminate epistemological obstacles when conceptual understanding remains incomplete. Therefore, algebra instruction should gradually connect numerical, contextual, and symbolic representations while encouraging students to explain, justify, and evaluate their mathematical procedures to strengthen conceptual understanding and reflective thinking.

CONCLUSION

This study shows that junior high school students continue to encounter epistemological learning obstacles in algebra, particularly in understanding variables, identifying like terms, simplifying algebraic expressions, translating contextual problems into mathematical models, selecting appropriate solution strategies, and providing logical justification for their answers. The findings also indicate that the characteristics of these obstacles vary according to students' levels of reflective thinking ability. Students with higher reflective thinking ability demonstrated more complete praxeological structures and applied more appropriate problem-solving strategies, whereas those with moderate and lower reflective thinking ability experienced greater conceptual, procedural, and representational difficulties. Moreover, the praxeological analysis revealed that these epistemological learning obstacles were reflected across the four interconnected components of task, technique, technology, and theory, offering a more comprehensive explanation of the knowledge structures underlying students' difficulties in learning algebra.

This study contributes to the existing literature by integrating the theory of epistemological learning obstacles with the praxeological framework, providing a more comprehensive perspective on students' mathematical thinking in algebra learning. The findings also offer practical implications for mathematics teachers by

emphasizing the importance of instructional strategies that promote conceptual understanding, reflective thinking, and problem-solving skills. However, further research is needed to investigate epistemological learning obstacles in greater depth by involving more participants across different levels of reflective thinking ability and exploring other mathematical topics. Future studies could also examine the development and implementation of praxeology-based didactical designs to address the identified obstacles.

Despite its contributions, this study has several limitations. It involved only three participants from a single junior high school and focused solely on algebra, which may restrict the transferability of the findings to other contexts. Future research is therefore encouraged to include a larger and more diverse sample, examine different mathematical topics and educational levels, and design instructional interventions grounded in praxeology theory to further examine and extend the findings of the present study.

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