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Original Research

Analysis of Learning Obstacles in the Metapedadidactic Stage of the System of Linear Equations in Two Variables (SLETV)

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ABSTRACT

This study aims to identify and analyze various learning obstacles encountered by eighth-grade students in understanding the topic of systems of linear equations in two variables (SLETV), using the Didactical Design Research (DDR) approach at the metapedadidactic stage. Employing qualitative methods, data were collected through diagnostic pretests and posttests, classroom observations, and in-depth interviews. The findings reveal that students face three types of learning obstacles: ontogenic, didactic, and epistemological. Ontogenic obstacles are related to difficulties in understanding algebraic symbols and representing problems within real-life contexts, while didactic obstacles arise from teacher-centered instructional methods and insufficient supporting materials. Epistemological obstacles are evident in students' inability to apply conceptual knowledge when confronted with non-routine problems. Through DDR-based interventions—comprising prospective, metapedadidactic, and retrospective analyses—these learning barriers can be reduced, resulting in significantly improved student understanding, as reflected in enhanced learning outcome indicators. These findings highlight the importance of early detection of learning obstacles and the use of reflective practices during the metapedadidactic stage as a foundation for designing more adaptive mathematics teaching strategies that are aligned with students' needs.

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1. INTRODUCTION

Education plays a highly strategic role in everyday life, serving as the principal vehicle through which individuals continuously and systematically develop their potential, both cognitively and psychomotorically. Through education, learners are encouraged to broaden their abilities, motivation, spiritual strength, self-control, and the horizons required for personal advancement and social contribution. This is in accordance with Law Number 20 of 2003, Article 1, Paragraph 1, on the National Education System. In the context of rapid advancements in science, technology, and information, education becomes a crucial foundation for national development.

The quality improvement of national education is highly dependent on teachers, who serve as the spearhead of instructional implementation, as emphasized by Liu (2024), Naguit (2024), and Ralebese et al. (2025). Teachers' effectiveness and professionalism in managing the teaching and learning process, as well as their ability to utilize communicative instructional media, significantly contribute to educational quality (Riadi et al., 2022; Tamsah et al., 2021; Wiyono et al., 2022). Conversely, poor educational outcomes are often linked to suboptimal teacher performance. Therefore, teachers hold a pivotal role in enhancing educational quality to achieve national goals, namely,fostering an enlightened society and developing superior human resources.

One strategic initiative to improve educational quality is the implementation of the 2013 Curriculum, which places students at the center of the learning process (Abidin et al., 2023; Muhammad et al., 2022; Simanjuntak et al., 2022). This curriculum aims to prepare a generation that is creative, productive, and capable of making positive contributions to society. Within this framework, mathematics stands out as a critical subject due to its essential role in the development of science, technology, and critical thinking skills (Setiawan & Suwandi, 2022; Pahrudin et al., 2021). However, many students still perceive mathematics as a difficult subject, particularly due to the use of complex symbols and procedures, which remains a significant barrier in their learning process (Sfard, 2000).

According to the 2022 Program for International Student Assessment (PISA), Indonesian students ranked 68th, with an average mathematics literacy score of 379 (OECD, 2023), indicating ongoing challenges. Research has identified learning obstacles as a major factor inhibiting students from attaining expected competencies (Purbaningrum et al., 2023; Retnawati, 2022; Saha et al., 2024; Wijaya et al., 2023). These obstacles may arise from multiple aspects, such as students' developmental stages, teaching approaches employed, and students' ability to apply concepts in various contexts (Suryadi, 2013; Brousseau, 2002). Therefore, instructional strategies must be capable of addressing all these aspects in an integrated and comprehensive manner.

The topic of Systems of Linear Equations in Two Variables (SLETV) represents a fundamental material essential for establishing students' understanding of advanced concepts such as matrices, calculus, and mathematical modeling (Almubarak et al., 2023; Ario et al., 2025; Marhami et al., 2024). Nevertheless, previous studies indicate that students frequently encounter difficulties in modeling problems, using symbols, and solving exercises related to SLETV (Fatah & Sukoriyanto, 2024; Kusumah, 2024; Siahaan & Rosida, 2024). To address these challenges, this study adopts a Didactical Design Research (DDR) approach, focusing on metapedadidactic reflection as an effort to identify and overcome the learning obstacles experienced by students in SLETV topics. This study focuses on answering two questions: What learning difficulties do eighth-grade students face when studying SLETV? And to what extent can the use of DDR reduce these learning barriers?

Previous research has identified difficulties in SLETV (some recent studies, for example, Rizbudiani et al., 2021; Putri & Toyib, 2025; Utami et al., 2024). Several studies have also designed learning to improve learning outcomes on SLETV topics, e.g., Problem-Based Learning (PBL) (Barokah & Saputro, 2020) and web-based interactive mathematics learning media (Akbar et al., 2025). The results of previous studies have been very useful in exploring student difficulties and pedagogical approaches that can be used in the classroom. However, based on previous studies, research examining Didactical Design Research on SLETV topics is still very limited. This study offers a novel contribution through the application of a metapedadidactic approach in analyzing learning obstacles in SLETV among eighth-grade junior high school students. The term learning obstacle refers to various barriers encountered by students during the mathematics learning process, which are generally categorized into three types: ontogenic obstacles, related to individual students' developmental experiences; epistemological obstacles, concerning their understanding of concepts and subject matter; and didactic obstacles, encompassing the teaching approaches and strategies used. In this research context, the metapedadidactic approach characterized by teachers' critical reflection on didactic processes to improve instructional interventions is implemented in teaching SLETV in accordance with the 2013 Curriculum. Although some previous studies have addressed learning obstacles in general, there is a notable lack of synthesis that integrates the metapedadidactic perspective specifically within SLETV, thus providing a strong justification for the relevance of this research.

2. METHOD

This study employed a qualitative approach with a descriptive design as its principal method. Qualitative methodologies are frequently utilized in scientific research, particularly within the social sciences and education, as they aim to provide an in-depth understanding and complement findings derived from quantitative methods. In this context, the research was centered on knowledge construction through detailed exploration and discovery. The goal was to identify the various factors contributing to students' difficulties in learning mathematics and to examine effective strategies for overcoming these obstacles, with a specific focus on the teaching of systems of linear equations in two variables (SLETV) to eighth-grade students at a junior high school.

A Didactical Design Research (DDR) model was adopted as the guiding framework for this qualitative inquiry. DDR comprises a series of systematic phases designed to detect, analyze, and address learning obstacles among students, enabling more structured and contextual instructional improvements. The methodological details are as follows:

3.1. Research design

This study utilized a qualitative design based on Didactical Design Research (DDR) following the model established by Suryadi (2013). DDR was selected to facilitate the identification of learning obstacles and to guide the development of adaptive and responsive instructional designs tailored to findings from the field.

3.2. Research subjects and location

The subjects consisted of eighth-grade students from a selected junior high school. Subject selection was performed through purposive sampling, taking into account the diversity of students' characteristics, the readiness and willingness of the school to participate, and the experience of mathematics teachers in instructing SLETV topics. Purposive sampling, also known as judgmental or selective sampling, is a non-probability sampling method wherein researchers intentionally select individuals or groups deemed most relevant and capable of providing comprehensive insights in accordance with the research objectives. Thus, participants were chosen not randomly, but rather based on careful assessment and expertise to ensure a rich and thorough representation of the studied phenomena.

3.3. Research procedure

In this study, the DDR model followed a systematic process starting with an initial analysis of the didactical situation, where data were collected through classroom observations, review of instructional documents, and interviews with students and teachers. This phase helped identify learning obstacles, which were categorized into ontogenic, didactic, and epistemological factors. Based on these findings, the researchers developed lesson plans for SLETV that incorporated context-based problem-solving activities, visual scaffolding, group discussions, and formative assessments. These lesson plans were then reviewed and refined collaboratively with the teachers through lesson study before implementation. The didactical design was executed in the experimental classroom, with activities documented through video recordings, observational notes, and records of student responses, newly emerging difficulties, and teacher interventions. Finally, reflective discussions were held among researchers, teachers, and students to evaluate the effectiveness of the instructional design. Student outputs, such as worksheets and group tasks, were analyzed qualitatively using a learning obstacle rubric to assess the impact of the intervention.

3.4. Data collection techniques

The research utilizes multiple methods to collect data and gain a comprehensive understanding of the learning obstacles faced by students in the topic of Systems of Linear Equations in Two Variables (SLETV). Classroom observations are conducted to systematically document teacher-student interactions and the response patterns to instructional methods. In parallel, a review of relevant documentation, including lesson plans, worksheets, SLETV tasks, and other learning artifacts, is performed to assess how the material is being presented and engaged with. In-depth interviews with both students and teachers are conducted to explore their perceptions of the challenges encountered and the strategies implemented to address them. Additionally, a detailed analysis of student work is carried out, using a learning obstacle rubric to evaluate the students' approach to problem-solving, formulation, validation, and the implementation of their understanding in SLETV tasks. This multi-faceted approach allows for a deeper insight into the complexities of learning and teaching SLETV.

3.5. Data validity measures

To ensure data validity, a triangulation of techniques and sources was employed, combining observations, interviews, and document analyses. This approach allowed for a comprehensive understanding of the research topic by cross-referencing findings from different data sources. Additionally, peer debriefing and member checking were integral to the process, as the research findings were collaboratively discussed with participating teachers and other researchers. Preliminary results were also verified with participants, ensuring that the findings remained objective and accurately reflected their experiences and perspectives. This process helped to confirm the credibility and reliability of the research outcomes.

3.6. Data analysis technique

Data analysis in this study was conducted using a structured and systematic qualitative process. The initial step involved data reduction—the selection, focusing, simplification, fragmentation, and transformation of raw field notes into more manageable and structured information. This process was ongoing throughout the research to synthesize core findings, highlight key aspects, and identify emerging patterns and themes.

Following the reduction, categorization was performed, grouping learning difficulties into thematic clusters such as difficulties with concept comprehension, mathematical operations, and problem-solving procedures. This systematic categorization enabled clearer recognition of trends and issues.

The categorized data were then subject to in-depth interpretation regarding learning obstacles, aligning findings with established theories in mathematics education and examining contributing factors within the teaching and learning context, as well as student characteristics. The main objective was to comprehensively understand the underlying causes of the observed learning difficulties.

The final phase involved evaluating the effectiveness of the instructional design. The researchers compared student performance before and after the intervention, assessed improvements in conceptual understanding and mathematical problem-solving skills, and reflected on potential refinements to the learning design to ensure sustained relevance and applicability.

All analytical processes were reinforced by rigorous data validation through triangulation, thereby enhancing the reliability of the findings. The resulting insights provide a robust foundation for further development of mathematics instruction in junior high schools. Analysis revealed a range of learning obstacles faced by students, such as:

"I am still confused about when to add or subtract while solving a system of equations." "I have memorized formulas, but I find it difficult to determine the steps in word problems." For example, worksheet analysis indicated that 17 out of 30 students made errors with positive and negative operations, while 12 students were unable to classify important information in word problems.

Triangulation was conducted by verifying interview results with teacher observation notes and student assignment analyses. Data from various sources were compiled to check for consistency, thereby strengthening the field-based relevance of the identified learning obstacles.

3.7. Data Validity

Data validation in this study involved source and technique triangulation, wherein interview data were compared with observation and document study results. Member checks were also performed by requesting participants' confirmation of interim findings, and peer debriefings were used to safeguard objectivity and analytical consistency.

3.8. Practical and Theoretical Implications

The results of this research have important implications for mathematics teachers, highlighting the need for greater attention to students' varied learning obstacles and the design of adaptive, metapedadidactic instructional strategies. Theoretically, the study broadens perspectives on learning obstacles and enriches mathematics education theory, particularly regarding reflective approaches in curriculum innovation. Through this detailed and systematic methodology, the study seeks to deliver evidence-based, contextually relevant solutions to SLETV learning challenges among junior high school students in Indonesia.

3. RESULTS AND DISCUSSION

3.1. Results

This study examines the identification of students' learning obstacles in Systems of Linear Equations in Two Variables (SLETV) through classroom observations, analysis of student worksheets, and in-depth interviews. The findings revealed three main categories of learning obstacles. Ontogenic obstacles were evident as students struggled with grasping the concept of two variables and had difficulty abstracting contextual situations into appropriate SLETV representations. For example, many students faced challenges in identifying the correct variables when solving word problems. Didactic obstacles arose from a teacher-centered learning approach that provided limited real-life context and lacked opportunities for reflective discussion, resulting in student activities that focused on routine practice rather than fostering deep conceptual understanding. Finally, epistemological obstacles were identified as students performed well on routine problems but struggled with non-routine or open-ended questions, where they were required to apply mathematical concepts in real-life contexts. The summary of findings is presented in Table 1.

Table 1. Example of Learning Obstacle Based on Category

Category	Example of Obstacle
Ontogenic	Difficulty determining variables from word problems
Didactic	Instruction focused on example problems and repetitive practice
Epistemological	Failure to solve word problems or variations outside routine patterns

After the implementation of DDR-based learning design, there was a significant increase in indicators, as shown in Table 2.

Table 2. Indicator Improvement

Indicator	Pre-DDR	Post-DDR
Formulating SLETV from word problems	32%	78%
Explaining the reasoning behind the method choice	20%	60%
Use of tables/visual models	12%	65%
Solving HOTS SLETV problems	27%	74%
Actively responding in discussions	39%	80%

Table 2 shows the percentage change in students' ability to overcome learning obstacles at the Metapedadidactic stage in the two-variable linear equation system (SLETV) before and after DDR (Design, Development, and Reflection). On the indicator of formulating SLETV from word problems, students' ability to formulate two-variable linear equations (SLETV) from word problems showed a significant increase, from 32% in pre-DDR to 78% in post-DDR. This shows that DDR successfully helped students understand how to convert verbal problems into mathematical models. The next indicator, explaining the reasoning behind the method choice, showed an increase in students' ability to explain the reasons behind their method selection, rising from 20% in the pre-DDR to 60% in the post-DDR. This indicates that the DDR process also improved students' ability to understand and convey the reasons for their choice of problem-solving methods. There was also an increase in the use of tables/visual models indicator, where the use of tables and visual models increased from 12% in the pre-DDR to 65% in the post-DDR. This increase indicates that DDR facilitates students' understanding in using visual aids to solve SLETV problems. The next indicator is solving HOTS SLETV problems, with students' ability to solve SLETV problems that require higher-order thinking skills (HOTS) increasing from 27% in the pre-DDR to 74% in the post-DDR. This shows that DDR is effective in improving more complex problem-solving skills. Finally, for the indicator of actively responding in discussions, students' ability to actively participate in discussions increased significantly, from 39% in pre-DDR to 80% in post-DDR. This shows that DDR successfully encourages students to be more active in interacting and sharing ideas during the learning process. Overall, this table indicates that the implementation of DDR has a significant positive impact on students' abilities in various aspects of SLETV learning, especially in problem formulation, method selection, use of visual aids, HOTS problem solving, and participation in discussions.

3.2. Discussion

The findings of this study offer valuable insights for mathematics educators by uncovering the diverse learning obstacles encountered by students, enabling the development of more adaptive and responsive teaching strategies informed by a metapedadidactic approach. Theoretically, this research contributes to the broader understanding of student learning barriers, enriching the body of knowledge in mathematics education by emphasizing reflective teaching practices, particularly within curricula that require innovation and strategic adaptation. This is in line with the work of Astaño & Broma (2026), Lerkchaiyaphum & Lerkchaiyaphum (2025), and Sfard (2000), who discussed the need for mathematics instruction to address the challenges posed by abstract concepts and procedural learning.

The study identified three primary categories of learning obstacles in the topic of Systems of Linear Equations in Two Variables (SLETV): ontogenic, didactic, and epistemological. Ontogenic obstacles are linked to students' cognitive readiness and their mental preparation for abstract mathematical thinking. These barriers manifest in difficulty when students try to recognize variables and connect real-world contexts to formal mathematical representations. This finding supports the work of Brousseau (2002), who noted that students often struggle with abstract reasoning, especially in topics such as algebra, due to developmental factors that hinder their ability to generalize mathematical principles. Wilujeng et al., (2025) also pointed out similar cognitive challenges, particularly in recognizing the connections between abstract symbols and real-world applications in SLETV.

Didactic obstacles, as identified in this study, arise from teacher-centered, procedural instructional methods that limit the use of authentic contexts and offer few opportunities for collaborative discussion. This restricts students' development of deep conceptual understanding and their ability to transfer knowledge to new situations. This finding is consistent with Rowe (2006) who emphasized that ineffective instructional methods, particularly those that rely heavily on lectures and rote learning, contribute significantly to learning difficulties. Dwiguningtyas et al., (2025) further supported this notion by arguing that the lack of real-life context integration and student-centered teaching strategies limits students' engagement and their ability to apply mathematical knowledge effectively.

Epistemological obstacles emerged as students struggled with the application and transfer of SLETV concepts to non-routine or more complex problems. Many students relied heavily on memorized procedures without deeply understanding the underlying concepts. This aligns with the work of Sfard (2000), who argued that students often perform well in procedural tasks but face difficulties when confronted with problems that require critical and creative thinking. The reliance on rote learning, without a conceptual foundation, limits students' ability to solve unfamiliar or context-based problems, a challenge echoed by Lujan & DiCarlo (2006) and Suryadi (2013), who emphasized the need for instruction that goes beyond memorization to foster true understanding.

The implementation of a Didactical Design Research (DDR)-based instructional approach, which integrated contextual problem-solving, visual scaffolding, interactive discussions, and reflective activities, proved effective in improving student competencies, especially in terms of conceptual validation and application. This aligns with the findings of Mierluş-Mazilu & Yilmaz (2023), whose research demonstrated that integrating real-life scenarios and visual scaffolding into mathematics instruction helps students overcome abstraction difficulties and strengthen their conceptual understanding in SLETV. Similarly, Csapó & Molnár (2019) highlighted the importance of diagnostic assessment in identifying learning challenges and tailoring instructional designs to meet individual student needs. These findings reaffirm the value of contextualized, interactive teaching methods in addressing the challenges faced by students in mathematics learning.

Despite these improvements, ontogenic obstacles related to students' cognitive readiness remain unresolved. This points to the need for more personalized and sustained learning approaches that cater to individual cognitive development. Periodic diagnostic assessments, as suggested by Brousseau (2002), and the development of innovative teaching methods are essential strategies for bridging this gap. Moreover, this aligns with the work of Vygotsky (1978), who advocated for scaffolding that addresses students' developmental stages and progressively challenges them to advance their cognitive abilities.

In conclusion, the findings of this study not only align with prior research but also underscore the importance of adaptive, reflective, and contextualized teaching strategies in overcoming the multifaceted learning obstacles encountered in SLETV topics. These results support the recommendations of Brousseau (2002) and Suryadi (2013), who emphasized the need for continuous reflective innovation in mathematics instructional design and collaboration between teachers and students. By drawing on these theories and incorporating the findings from this study, educators can enhance the quality of mathematics learning, particularly within the SLETV curriculum, and better equip students with the skills to apply mathematical concepts in real-world contexts.

4. CONCLUSION

This study successfully identified three primary categories of learning obstacles experienced by eighth-grade junior high school students in mastering the topic of Systems of Linear Equations in Two Variables (SLETV): ontogenic obstacles related to limitations in cognitive readiness and mental preparedness, didactic obstacles arising from suboptimal instructional strategies, and epistemological obstacles associated with students' difficulties in effectively understanding and applying mathematical concepts. The Didactical Design Research (DDR)-based instructional design, which integrates real-life contexts, visual scaffolding, interactive discussions, and reflective activities, demonstrated effectiveness in enhancing students' understanding, particularly in conceptual validation and practical application. Nonetheless, ontogenic obstacles still require special attention through more personalized and sustained learning approaches. Additionally, many students continue to face challenges in mastering numerical operations and applying SLETV concepts in word problems. The metapedadidactic intervention proved capable of improving students' learning outcomes and mathematical comprehension, although deeper adjustments in problem-solving methods remain necessary to optimize instructional results.

To improve the quality of SLETV instruction, it is recommended that teachers routinely conduct diagnostic assessments to identify and monitor specific learning obstacles before and during the instructional process. The development of instructional designs should place greater emphasis on using contexts relevant to real life and implementing scaffolding methods progressively to help students build mathematical concepts gradually and systematically. Furthermore, active collaboration between teachers and students through reflective learning should be strengthened to support conceptual understanding and knowledge transfer skills. Future research should more intensively explore strategies to overcome ontogenic obstacles and evaluate the effectiveness of DDR implementation across other mathematics topics. Mathematics teachers are also encouraged to regularly engage in metapedadidactic reflection to recognize and address emerging learning obstacles in SLETV content. Moreover, school administrators and educational policymakers are urged to consider these findings in curriculum improvements and in the development of professional training programs for teachers.

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There is no conflict of interest in this study.

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ETHICAL STATEMENT

The research process has complied with ethical standards. All research subjects have agreed to participate in the research activities. The identities of all research subjects have been kept confidential.

AI USE STATEMENT

The ideas in this article are entirely original to the research team. No AI was used in writing the manuscript.

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