INTEGRATION OF DIGITAL FORMATIVE ASSESSMENT IN DIDACTIC DESIGN TO REDUCE STUDENTS' LEARNING OBSTACLES IN THE MATERIAL OF TWO-VARIABLE LINEAR INEQUALITY SYSTEM

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Abstract

This research set out to characterise the learning obstacles experienced by students and to build a didactical design for the topic of Two-Variable Linear Inequality Systems (SPtLDV) combined with Digital Formative Assessment (DFA). It was prompted by observations that students commonly struggled with modelling contextual problems, locating boundary lines, sketching graphs, and pinpointing solution and intersection regions within SPtLDV. A qualitative Didactical Design Research (DDR) design guided the study, unfolding across three phases: analysis of the didactical situation, metapedadidactic analysis, and retrospective analysis. Grade X.5 students took part in the stage of identifying learning obstacles, while Grade X.3 students were involved in implementing the didactical design, both groups drawn from a state senior high school in Tegal City. Data collection combined diagnostic tests, interviews, classroom observation, and DFA tools comprising Google Form, Canva AI, and QR-code-based digital reflection. The findings indicate that epistemological obstacles predominated, marked by procedural understanding unaccompanied by conceptual grasp, alongside ontogenic obstacles evident in students' difficulty linking verbal, symbolic, and visual representations. These insights informed the design of a three-stage Hypothetical Learning Trajectory (HLT) together with Didactical and Pedagogical Anticipation (ADP) integrated with DFA. Across three teaching sessions, the implementation revealed close alignment between anticipated and actual student responses, accompanied by gains in students' ability to build mathematical models, sketch graphs, determine solution regions, and interpret their solutions. The study concludes that a didactical design grounded in identified learning obstacles and reinforced through DFA meaningfully supports students in developing a deeper understanding of SPtLDV.

Keywords: *didactical design; Digital Formative Assessment; learning barrier; Didactical Design Research;*

1 INTRODUCTION

Mathematics learning takes place in stages from elementary to tertiary level because of its contribution to fostering logical, systematic, analytical, and critical reasoning skills (Suhendar et al., 2023). However, this subject is often considered difficult and triggers anxiety in some students, so not a few are reluctant to be actively involved in the learning process. Ideally, mathematics learning does not only practice mastery of procedures, but also fosters the high-level thinking skills needed to answer global challenges (Laia et al., 2021), as well as forming rigor, discipline, and analytical and collaborative skills in students (Nurfadhillah et al., 2021).

One of the topics that has repeatedly been reported to be difficult for students is the Two-Variable Linear Inequality System (SPtLDV). The mistakes that arise are generally related to the calculation process and understanding of the story problem (Anditiasari et al., 2020), including at the stage of modeling the problem and determining the area of resolving inequality (Anggraini et al., 2022; Siregar et al., 2024). An initial study conducted by researchers through observation and interviews with mathematics teachers at a public high school in Tegal City reinforced this pattern: students had difficulty determining coordinate points, drawing boundary lines, utilizing test points, determining arsir areas, compiling mathematical models, and interpreting solutions on graphs. Most students are able to follow the exemplified completion steps, but experience a stalemate when faced with a variety of different questions or are asked to explain the mathematical reasons behind each step they take.

A number of studies show that SPtLDV is a material that is prone to misconceptions, ranging from mistakes in applying formulas to mistakes in translating problems into graphic form (Nurhayati et al., 2023). This condition indicates that students' understanding tends to still rely on procedures and has not been supported by adequate mastery of concepts. Previous studies have also noted learning obstacles with similar patterns in related materials, such as difficulties in converting contextual problems into mathematical models and interpreting the solution area (Jannah et al., 2025; Hasanah et al., 2024). However, these studies generally only reach the stage of identifying learning barriers, and not many have designed learning designs systematically by combining didactic design with digital-based formative evaluation as a step to minimize learning obstacles.

Didactic design is understood as a learning design that is prepared so that students can understand the material in its entirety while overcoming the learning barriers that have been identified (Hariyani et al., 2022; Khaerudin et al., 2023). On the other hand, advances in digital learning technology open up opportunities for the implementation of formative evaluations that are more diverse, interactive, and sustainable, while expanding the range of assessments to the affective and psychomotor domains integrated with digital literacy (Humaira et al., 2024). The combination of didactic design and Digital Formative Assessment (DFA) is believed to be able to provide continuous feedback, so that teachers can more quickly recognize learning obstacles and prepare didactic-pedagogical anticipations that are right on target.

Referring to the description above, this study was prepared with four objectives, namely (1) explaining the characteristics of students' learning obstacles in SPtLDV material, (2) preparing a hypothetical didactic design combined with Digital Formative Assessment, (3) explaining the process of implementing the didactic design, and (4) examining the results of retrospective analysis of its implementation in minimizing students' learning obstacles. Through this research, it is hoped that there will be practical contributions in the form of alternative SPtLDV learning designs that are responsive to student learning barriers while utilizing digital assessment technology in a meaningful way.

2 METHODOLOGY

This research was designed with a qualitative approach using Didactical Design Research (DDR) design. The qualitative approach was chosen because the focus of the research lies in deepening the learning process, the dynamics of interaction between teachers and students, and students' interpretation of the learning obstacles experienced, rather than on number-based data processing (Sugiyono, 2016). The DDR design was chosen because it provides space for researchers not only to explain learning obstacles, but also to design, implement, and evaluate learning designs in a reflective and continuous manner (Suryadi, 2010).

Based on the stages of DDR analysis according to Suryadi (in Hardani et al., 2020), this research was carried out in three stages. The first stage is in the form of a didactic situation analysis before learning takes place, including preliminary studies, providing diagnostic tests, and interviews to identify the types, causes, and patterns of learning obstacles in students. The second stage is metapedagogical analysis, namely the preparation of the Hypothetical Learning Trajectory (HLT) along with the didactic design of the hypothesis equipped with Didactic and

Pedagogical Anticipation (ADP), as well as integrating Digital Formative Assessment into the prepared learning tools. The third stage is in the form of retrospective analysis, which is to compare the prediction of student responses with the responses that actually appear during implementation, to assess the extent to which didactic design is effective in minimizing learning obstacles.

The research took place in one of the State High Schools in Tegal City by involving two groups of subjects. The first group is students in class X.5 who have previously studied SPtLDV, involved in the identification stage of learning obstacles through diagnostic tests and interviews. The second group, namely students in class X.3, acted as a classroom where hypothetical didactic design was applied. Primary data is sourced from diagnostic test results, initial test results via Google Form, group Student Worksheets (LKPD), individual evaluation results using Canva AI, digital reflection results through QR code scanning, and observation and interview notes. The secondary data was taken from school documents, learning tools, and literature relevant to SPtLDV, learning obstacles, DDR, and DFA.

Data collection was carried out through diagnostic tests, semi-structured interviews, direct observation of the course of learning, the use of Digital Formative Assessment instruments (Google Form, Canva AI, and QR code-based reflection), and documentation. Data were analyzed qualitatively through data reduction, grouping learning obstacles into epistemological, ontogenic, and didactic categories, prospective analysis to formulate student response predictions, metapedagogical analysis throughout implementation, and retrospective analysis to draw conclusions regarding the effectiveness of the developed didactic design. The findings are presented in a qualitative descriptive manner in the form of narratives, charts, and snippets of student work and interviews

3 RESULTS AND DISCUSSION

3.1 Characteristics of Student Learning Obstacles in SPtLDV Materials

Diagnostic tests and interviews conducted on students in grade X.5 showed that mastery of the basic concepts of SPtLDV, for example, distinguishing equations from inequality and converting simple contextual statements into symbols of inequality was in the category of being quite good. However, students' abilities decreased quite drastically in indicators that required reasoning and explanation of concepts, especially in determining boundary lines, settlement areas, slice areas, and interpreting solutions. Students' answers generally show a pattern of following the procedure that has been exemplified without the ability to explain the mathematical reasons behind it, for example the reason why the inequality sign is changed to the same sign as when determining the boundary line, or the reason for a test point to determine the selection of the arsiran area.

These findings confirm that epistemological obstacles dominate, namely the limitation of conceptual understanding that makes it difficult for students when faced with unfamiliar forms of questions or representations. In addition, ontogenic obstacles were also identified that appeared to be the students' ability to relate verbal, symbolic, and visual representations in an integrated manner, as well as didactic obstacles that were linked to previous learning experiences, especially in the way of conveying the concept of boundary lines and settlement areas. These three types of learning obstacles are in line with the results of a study by Nurhayati et al. (2023) on the vulnerability of misconceptions in SPtLDV, as well as the reports of Jannah et al. (2025) and Hasanah et al. (2024) on conceptual barriers to inequality materials and linear programs.

3.2 Didactic Design Construction Integrated Hypothesis Digital Formative Assessment

Departing from the characteristics of learning obstacles that have been identified, a Hypothetical Learning Trajectory (HLT) was prepared in the form of a framework for student learning trajectories consisting of three stages. The first stage is directed at strengthening the understanding of the basic concept of two-variable linear inequalities, including the recognition of the form of inequality, the recognition of the sign of inequality, and the testing of whether a point meets a particular inequality. The second stage focuses on the ability to draw inequality graphs, including determining the cutoff point of the coordinate axis, drawing lines according to the type of inequality mark, and determining the settlement area with the help of test points. The third stage combines all the capabilities of the previous stage to complete the inequality system in its entirety, including the depiction of several inequality at once in one coordinate field, the determination of the wedge area as a system solution, the determination of the corner point, and the solution of contextual problems.

In each didactic situation in HLT, student response prediction is included as well as Didactic and Pedagogical Anticipation (ADP) in the form of guiding questions, group discussion activities through LKPD, presentation of discussion results, and reinforcement of concepts by teachers. Furthermore, this didactic design is combined with Digital Formative Assessment through three instruments, namely Google Form which serves as an initial assessment to map student understanding before learning begins, Canva AI which is used as a means of individual evaluation at the end of each meeting, and QR code-based digital reflection to capture learning experiences and obstacles that students still feel. The three instruments are designed so that teachers obtain continuous feedback throughout the learning process, in line with the view that digital formative evaluation expands the scope of assessment to cognitive, affective, and psychomotor aspects in an integrated manner (Humaira et al., 2024).

3.3 Implementation of Integrated Didactic Design Digital Formative Assessment

The hypothetical didactic design was applied to students in grade X.3 during three continuous meetings, with each meeting consisting of an introductory activity, a core activity, and a closing activity. At the first meeting, some students still showed obstacles in recognizing information on contextual problems and turning them into mathematical models, as predicted in the didactic design. Thanks to ADP in the form of guiding questions and group discussions, students are gradually able to construct mathematical models with a better level of accuracy than during diagnostic tests.

At the second meeting, the observed obstacles were related to determining the boundary line, distinguishing full lines and dotted lines, and determining the arsiran area, and these obstacles were still dominated by epistemological factors in associating algebraic forms with graphical representations. The use of ADP helps students understand these stages more meaningfully, which is evident from the increased involvement of students in giving reasons for their chosen shade areas. At the third meeting, more obstacles arose in determining the slice area and the corner point of the settlement area, in line with the demand to integrate all the concepts that had been studied previously. Through guiding questions and reinforcement of concepts from the teacher, the majority of students managed to rebuild their understanding, although a small number still needed additional precision in determining the corner points.

Overall, the majority of response predictions in hypothetical didactic designs were proven to correspond to the actual responses of students in the classroom, indicating that the design had been carefully prepared based on the results of the identification of learning obstacles at the previous stage. The Digital Formative Assessment instrument also contributes through the provision of student understanding data on an ongoing basis, so that teachers are able to adjust learning strategies more responsively.

3.4 Results of Retrospective Analysis

Retrospective analysis shows that Didactic and Pedagogical Anticipation that has been designed in the form of guiding questions, group discussions, presentations, and reinforcement of concepts is mostly effective in helping students overcome learning barriers that arise during the implementation process. Nevertheless, teachers still need to provide additional reinforcement in several parts, especially in determining the area of the slice, determining the corner point, and interpreting solutions based on graphs. These findings are reflective inputs for the refinement of didactic design in the next stage of implementation.

Comparisons between pre- and post-implementation conditions show a decreasing tendency of epistemological and ontogenic barriers. Students' ability to compile mathematical models, draw graphs, determine the area of completion, and interpret solutions has improved compared to the results of diagnostic tests in the early stages. Digital Formative Assessment, which is realized through Google Form, Canva AI, and QR code-based reflections, has proven to play a role not only as a means of evaluation, but also as a source of information for teachers in making didactic decisions that are responsive to the development of student understanding. These findings strengthen the argument that combining didactic design with digital formative assessment is a relevant strategy to minimize students' learning obstacles in materials that demand the interconnectedness of algebraic representations and graphs, as is the case with SPtLDV.

4 CONCLUSION

This study shows that students' learning obstacles in the Two-Variable Linear Inequality System (SPtLDV) material are dominated by epistemological barriers, namely procedural understandings without being based on conceptual mastery, accompanied by ontogenic obstacles in relating verbal, symbolic, and visual representations. Departing from these characteristics, a three-stage Hypothetical Learning Trajectory and hypothetical didactic design were developed equipped with Didactic and Pedagogical Anticipation and combined with Digital Formative Assessment through Google Form, Canva AI, and QR code-based digital reflection. The application of didactic design at three meetings showed a high degree of agreement between students' predictions and actual responses, accompanied by improved students' ability to model problems, draw graphs, determine areas of solution, and interpret solutions. The results of the retrospective analysis confirmed that the didactic design prepared based on learning obstacles and strengthened by Digital Formative Assessment minimized helping students build a more meaningful understanding of SPtLDV, so that it can be used as an alternative to student-centered mathematics learning strategies. The next research is suggested to expand the scope of materials, subjects, and variations of the Digital Formative Assessment platform in order to obtain a more comprehensive generalization of results.

THANKS

This research makes a theoretical contribution by enriching the understanding of the characteristics of learning obstacles in SPtLDV material and how to overcome them through a structured didactic design. Methodologically, this study offers an integration pattern between Didactical Design Research and Digital Formative Assessment that can be adapted to other mathematical materials with multiple representation characteristics (algebra and graphs). Practically, these findings can be a reference for teachers in designing SPtLDV learning that is responsive to student learning barriers while utilizing digital assessment instruments to obtain continuous feedback.

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