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Exploring Students' Spatial Understanding Barriers in Deep Learning-Oriented Two-Variable Linear Inequality Learning in Grade X of SMA Negeri 06 Pontianak

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ABSTRACT: This article aims to describe students' spatial understanding barriers in solving Two-Variable Linear Inequality (PtLDV) problems through a deep learning-oriented perspective. The study was designed as descriptive qualitative research using a case study approach in Grade X of SMA Negeri 06 Pontianak. Data were planned to be collected through spatial understanding essay tests, semi-structured interviews, and documentation; meanwhile, the initial findings presented in this article were developed from preliminary observation and teacher interview data in the research design. The analysis focused on four dimensions: spatial visualization, representational transformation, spatial relation, and spatial orientation, and connected them with meaningful, mindful, and joyful learning. The findings indicate that students major difficulties appeared when they transformed contextual information into mathematical models, drew graphs, determined boundary lines and shading directions, connected algebraic intersection points with graphical representations, and explained the position of points in relation to the solution region. Students with relatively high spatial understanding tended to follow procedures but still needed reinforcement in visual reasoning. Students in the moderate category understood some procedures but were not consistent in connecting symbolic and visual representations. Students in the low category experienced barriers from reading visual information to interpreting final answers. Therefore, students' spatial understanding difficulties in PtLDV are not only procedural but also related to weak representational connections and limited awareness of the meaning of graphs. PtLDV instruction should emphasize visual exploration, spatial argumentation, and contextual problem solving to support deeper mathematical understanding.

KEYWORDS: spatial understanding, deep learning, two-variable linear inequality, mathematical representation, student difficulties, mathematics learning.
Field Classification: Mathematics Education; Algebra Learning; Qualitative Research.

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1. INTRODUCTION

Mathematics plays an important role in developing logical, analytical, critical, and representational thinking. At the senior high school level, these abilities become highly visible when students study algebra, particularly the topic of Two-Variable Linear Inequalities (PtLDV). PtLDV does not only require symbolic manipulation but also the ability to understand graphs, boundary lines, intersection points, and solution regions on the Cartesian plane. Therefore, spatial understanding is a crucial component of students success in learning PtLDV.

Spatial understanding refers to the ability to imagine, organize, and interpret relationships among objects or visual information in space or on a plane. In the context of PtLDV, spatial understanding is needed when students transform inequalities into graphs, choose the appropriate type of boundary line, determine shading directions, and test the position of points relative to the solution region. When this ability is not sufficiently developed, students tend to rely on algebraic procedures without understanding the visual meaning of the solution obtained.

This problem was evident in the preliminary observation conducted in Grade X of SMA Negeri 06 Pontianak. The teacher interview indicated that some students found numerical problems easier than graphical information. Students still had difficulty determining appropriate points, drawing lines, understanding relationships among lines, connecting intersection points with graphs, and interpreting answers in the context of problems. The difficulties became more visible when students were required to transform word problems into mathematical models and determine the correct shaded region.

These conditions show that students' errors in PtLDV cannot be interpreted merely as computational mistakes. Errors should be understood as signs of thinking barriers in visualization, relation, transformation, and spatial orientation. Thus, the analysis of students' difficulties should focus on students thinking processes rather than only on the correctness of final answers.

A deep learning perspective is relevant for interpreting these difficulties because it emphasizes meaningful, mindful, and joyful learning. Through this perspective, students are encouraged to understand reasons, connect multiple representations, and explain the meaning of concepts in new situations. This article aims to describe students' spatial understanding barriers in deep learning-oriented PtLDV learning and to formulate implications for mathematics instruction.

2. LITERATURE REVIEW

2.1 Spatial Understanding in PtLDV Learning

Spatial understanding is related to students' ability to imagine objects, understand positional relationships, transform representations, and determine the orientation of an object toward another object. In mathematics learning, this ability supports students when they deal with graphs, diagrams, coordinate planes, geometric figures, and other visual representations. Risalah et al. (2016) explained that spatial reasoning is a thinking process used to visualize objects and understand abstract meanings through objects or symbols.

In PtLDV, spatial understanding is involved when students determine boundary lines from algebraic forms, decide whether a line should be solid or dashed, test points to determine the solution region, and explain the meaning of the shaded region. The topic requires integration between symbolic and visual representations. Hartono et al. (2019) stated that algebra is important for helping students understand real-life problems, but the abstract nature of algebra often causes difficulty when students must connect symbols with real situations.

2.2 Deep Learning as an Analytical Framework

Deep learning in education is not merely an activity of remembering; it is a process of understanding concepts deeply, connecting knowledge with experience, and applying knowledge in new situations. Fullan et al. (2018) viewed deep learning as learning that promotes student engagement, meaningful understanding, collaboration, creativity, and problem-solving ability. In mathematics learning, this principle can be seen when students are aware of their mathematical reasons, can explain relationships among concepts, and feel positively challenged in solving problems.

In this study, deep learning was used as an analytical orientation through three main characteristics: meaningful, mindful, and joyful learning. Meaningful learning appears when students are able to connect contextual problems with PtLDV concepts and interpret solution regions. Mindful learning appears when students can explain reasons, thinking processes, relationships among lines, and the position of points in relation to the solution region. Joyful learning appears when students are actively involved in exploring graphs, shaded regions, and spatial relationships on the coordinate plane.

3. DATA AND METHODOLOGY

This research used a qualitative approach with a descriptive method and a case study design. The qualitative approach was chosen because the purpose of the research was to understand deeply the forms of students' spatial understanding difficulties, not to test causal relationships statistically. The case study design was used because the research focused on the case of Grade X students' difficulties at SMA Negeri 06 Pontianak in solving PtLDV problems.

The research setting was SMA Negeri 06 Pontianak, West Kalimantan. The data sources were directed toward Grade X students in the 2025/2026 academic year. The main subjects were selected purposively based on variations in spatial understanding levels, namely high, moderate, and low categories. Each category was represented by two students for in-depth interviews after the spatial understanding test. Therefore, the analysis considered not only scores but also reasons, processes, and difficulties reflected in students' answers.

The data collection techniques consisted of essay tests, semi-structured interviews, and documentation. The essay test was constructed based on indicators of spatial visualization, representational transformation, spatial relation, and spatial orientation. Interviews were used to investigate students reasons when reading graphs, drawing boundary lines, determining intersection points, interpreting shaded regions, and explaining graphical changes. Documentation was used to strengthen the data through students answer sheets and records of learning activities.

Data analysis was conducted through data reduction, data display, conclusion drawing, and triangulation. Data reduction was carried out by selecting students' answers and interview excerpts relevant to the research indicators. Data display was presented in narrative descriptions and finding tables. Triangulation was conducted by comparing test data, interview data, and documentation to obtain more consistent and credible findings.

Table 1. Focus of Deep Learning-Oriented Spatial Understanding Analysis

Aspect	Main Indicator	Observed Difficulty	Deep Learning Connection
Spatial visualization	Reading and predicting graphs	Students were inaccurate in predicting the location of the solution region before drawing the graph.	Mindful awareness of visual reasoning.
Representational transformation	Changing models into graphs	Students incorrectly determined points, boundary lines, or shading directions.	Meaningful connection between symbols and visuals.
Spatial relation	Explaining relationships between lines and regions	Students were unable to explain positional relationships among lines, intersection points, and solution regions.	Mindful reasoning through mathematical argumentation.
Spatial orientation	Determining point positions	Students were incorrect in identifying points inside or outside the solution region.	Joyful exploration through coordinate-plane activities.

4. RESULTS AND DISCUSSION

4.1 General Findings on Students Difficulties

The analysis of preliminary observation data and teacher interviews showed that students' difficulties in PtLDV appeared in layered forms. Students did not only make errors in algebraic operations but also experienced barriers when reading and constructing visual representations. The teacher stated that students tended to understand numerical questions faster than graphical questions. This indicates that visual representation had not yet become an accessible source of information for students.

In the aspect of spatial visualization, difficulties appeared when students had to predict the location of solution regions and draw graphs. Some students did not determine axis intercepts accurately, did not consistently draw boundary lines, and did not understand that inequality signs determine whether a line should be solid or dashed. As a result, the graphs they produced did not always represent the given mathematical model.

In the aspect of representational transformation, difficulties emerged when students had to convert word problems into PtLDV models. The teacher stated that students were often confused in determining variables, building relationships between two quantities, and writing appropriate inequalities. This barrier indicates that students had not fully understood the relationship among contextual situations, algebraic symbols, and visual forms on the coordinate plane.

In the aspect of spatial relation, some students could calculate intersection points using substitution or elimination, but they did not understand that those points represented the intersection of two lines on a graph. Students were also not consistent in explaining why certain lines bounded the solution region. In other words, relationships among mathematical objects had not been understood as a unified visual and conceptual structure.

In the aspect of spatial orientation, the most visible difficulties appeared when students determined shading directions and point positions relative to the solution region. Several students viewed graph changes merely as changes in images without being able to explain the cause. When dealing with gradient changes, students knew the term slope but could not yet imagine how coefficient changes influenced the shape or direction of a line.

Table 2. Synthesis of Difficulties Based on Spatial Understanding Aspects

Aspect	Difficulty Symptom	Example Indication in PtLDV	Learning Meaning
Visualization	Students were not yet able to read graphical information easily.	Incorrectly determining points on axes and the form of boundary lines.	Graph-reading practice is needed before computational procedures.
Transformation	Students found it difficult to transform word problems into mathematical models.	Variables and inequalities did not match the context.	The context-symbol-graph connection needs to be strengthened.
Relation	Students did not understand relationships among lines and intersection points.	Intersection points were calculated but not interpreted graphically.	Discussion of visual reasons and meanings is needed.
Orientation	Students made errors in determining shading directions and point positions.	Points that did not satisfy the inequality were still considered solutions.	Point testing and solution-region exploration are needed.

4.2 Difficulties Based on Spatial Understanding Categories

The analysis of high, moderate, and low categories showed different characteristics of difficulty. Students in the high category tended to understand the basic steps of drawing graphs and were able to complete some procedures. However, the visual reasons they provided were not always complete. They still needed guiding questions to explain why a particular region was chosen as the solution region.

Students in the moderate category generally understood some information in the problems but were not consistent in connecting algebraic forms with graphs. During the drawing stage, students could determine several points but still misplaced lines or shading regions. During the explanation stage, students often mentioned the final answer without describing the relationship among lines, points, and solution regions.

Students in the low category showed more fundamental barriers. Difficulties appeared from understanding problem information, determining variables, constructing models, to drawing graphs. In this category, students tended to guess shading directions or follow patterns without clear reasons. When asked to determine point positions, students had not used substitution tests accurately and had not connected the tests with point locations on the coordinate plane.

Table 3. Students' Difficulty Tendencies by Understanding Category

Category	Observed Strength	Dominant Difficulty	Instructional Follow-Up
High	Able to follow basic procedures and read some graph information.	Visual reasoning and solution-region interpretation were not complete.	Provide open-ended tasks that require students to justify shading decisions.
Moderate	Understood some symbolic information and several graphing steps.	Connections among symbols, points, lines, and solution regions were unstable.	Use scaffolding from value tables to graphs and then to point testing.
Low	Recognized some terms but did not use them accurately.	Difficulty constructing models, drawing lines, and determining point positions.	Use visual media, concrete examples, and gradual contextual exercises.

4.3 Discussion

The findings show that students' difficulties in PtLDV were interconnected across aspects. Errors in drawing graphs could originate from difficulty understanding word problems. Errors in determining shading directions could occur because students had not understood the relationship between inequality signs and regions satisfying the conditions. Errors in interpreting points could occur because students had not connected substitution tests with point positions on the coordinate plane.

These findings are consistent with the view that algebra learning requires coordination among symbolic, visual, and verbal representations. When one representation is not understood, students struggle to construct complete understanding. Therefore, PtLDV learning needs to provide opportunities for students to move from context to model, from model to graph, and from graph to interpretation. This process is also aligned with the principle of deep learning because students do not merely calculate; they become aware of the reasons and meanings behind each step.

Within a deep learning framework, meaningful learning can be developed through contextual problems such as parking arrangements, fruit sales, or production planning. Mindful learning can be developed by asking students to explain reasons for selecting boundary lines, shading directions, and test points. Joyful learning can be developed through graph exploration activities, group discussions, or the use of visual media so that students do not perceive PtLDV as a purely abstract procedure.

The practical implication of these findings is the need for teachers to emphasize visual language in instruction. Students need to become accustomed to reading graphs before drawing them, estimating solution regions before performing calculations, and testing points explicitly. Teachers may also use reflective questions such as: Why is this region shaded? What is the meaning of the boundary line? Which point satisfies the inequality? How does a change in coefficient affect the slope of the line? Such questions help students build spatial and conceptual awareness.

5. CONCLUSION

Based on the analysis, students' spatial understanding difficulties in PtLDV learning in Grade X of SMA Negeri 06 Pontianak appeared in four main aspects. First, in spatial visualization, students had difficulty reading graphs, predicting the form of solution regions, and drawing boundary lines. Second, in representational transformation, students experienced barriers when changing word problems into mathematical models and connecting them with graphs. Third, in spatial relation, students were not yet consistent in explaining relationships among lines, intersection points, and solution regions. Fourth, in spatial orientation, students still made errors in determining shading directions and the position of points relative to the solution region.

Students in the high category were relatively able to perform procedures but still needed reinforcement in visual explanations. Students in the moderate category understood some steps but had not consistently connected symbolic and graphical representations. Students in the low category experienced broad barriers from understanding problem information to interpreting answers. Therefore, students' difficulties in PtLDV are not only procedural errors but also indications of weak representational connections and insufficiently deep spatial understanding.

Deep learning-oriented PtLDV instruction should be designed so that students learn meaningfully, mindfully, and joyfully. Teachers can strengthen graph exploration, reasoning discussions, point testing, solution-region interpretation, and contextual problems. These strategies are expected to help students not only obtain correct answers but also understand the visual and conceptual meanings of two-variable linear inequalities.

6. LIMITATIONS AND RECOMMENDATIONS

This article was prepared as a development manuscript based on the research design and preliminary observation findings. When the final research data become available, the results section should be enriched with students' test scores, interview excerpts, examples of answer sheets, and a more detailed triangulation process. Future researchers are encouraged to present data based on subject codes, understanding categories, and spatial understanding indicators so that the conclusions become stronger and more empirically grounded.

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