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INVESTIGATING EIGHTH-GRADE STUDENTS' CONCEPTUAL UNDERSTANDING OF CARTESIAN COORDINATES IN JUNIOR HIGH SCHOOL MATHEMATICS

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Abstract

Understanding mathematical concepts is a crucial aspect of learning mathematics, as it enables students to solve problems, reason logically, and apply knowledge in various contexts. This study aimed to analyze eighth-grade students' conceptual understanding of Cartesian coordinate material. The population of this research consisted of junior high school students in a school located in the Karawang district, with a sample of 30 students from class VIII. Data were collected using a mathematical comprehension test consisting of four questions, each designed to assess specific indicators of conceptual understanding, including identifying points, determining direction and distance, and analyzing the relative positions of lines. The results showed that students frequently made errors in several areas: many struggled to accurately identify points on the Cartesian plane, had difficulty determining direction and distance from a given point, and often misinterpreted the positions of lines relative to one another. These findings indicate that students' conceptual understanding of Cartesian coordinates remains limited, which may hinder their overall mathematical performance. Therefore, it is recommended that teachers implement more targeted instructional strategies, such as visual representations, guided practice, and interactive exercises, to enhance students' comprehension and strengthen their mathematical reasoning skills. The contribution of this study lies in providing empirical evidence on students' specific misconceptions related to Cartesian coordinates and offering pedagogical implications that can inform the development of more effective instructional approaches in mathematics classrooms.

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INTRODUCTION

Education Education plays a crucial role in determining the progress of a nation, and an advanced nation reflects the success of its educational system. The primary purpose of education is to enhance the intellectual capacity of a society. Education can be defined as a conscious learning process aimed at improving an individual's understanding, thinking skills, and abilities. According to Law No. 20 of 2003, education is a conscious and deliberate effort to create a learning environment and learning process through which students actively develop their potential to acquire spiritual strength, self-control, personality, intelligence, noble character, and the skills necessary for themselves, society, the nation, and the state. Education also serves as a platform for developing students' abilities and cultivating their potential. As students grow and develop their abilities, they are expected to acquire knowledge, creativity, good character, independence, and a sense of responsibility as members of society.

According to Sujana (2019), education is a continuous and never-ending process, aimed at producing sustainable quality and shaping individuals who are prepared for the future while being grounded in national cultural values and Pancasila. In line with this, mathematics education is one of the subjects taught from elementary school through higher education. Rahmah (2013) explains that mathematics is formed through human experiences in the empirical world. Mathematics is an essential field of study both in schools and in everyday life, and it consists of interconnected concepts across various topics.

Yunita and Imami (2022) state that mathematics and conceptual understanding are interrelated, as conceptual understanding is required to solve abstract mathematical problems. Furthermore, Alan and Afriansyah (2017) emphasize that in the process of learning mathematics, conceptual understanding plays a critical role. They argue that the material taught to students should not merely be memorized; instead, students should develop a deeper understanding of the concepts being taught. Therefore, it is necessary for students to possess a solid grasp of fundamental mathematical concepts to understand subsequent topics. Bani (2011) also asserts that mathematical understanding is one of the essential goals of mathematics instruction. Mathematics learning aimed at conceptual understanding is crucial for solving mathematical problems and for supporting other scientific disciplines (Putra et al., 2018). Students with strong mathematical understanding are better able to comprehend mathematical concepts. This aligns with Baroody's view (as cited in Dahlan, 2004), which states that understanding and reasoning can improve students' learning outcomes. When students are given problems involving real objects, pattern recognition, proof construction, and evaluation of mathematical situations, their understanding can be enhanced through doing mathematics (Purwasih, 2015).

Cartesian coordinates constitute an important topic because they serve as the foundation for analytic geometry, which is widely applied in various aspects of life (Suci et al., 2020). According to Triharnanto (2022), students often make errors when learning Cartesian coordinates, particularly in placing points or identifying coordinate values. Mistakes commonly occur when students confuse the placement of x- and y-values, leading to reversed or incorrect coordinate pairs. Similarly, Nurfalah and Zanthy (2020) report that students often experience confusion when constructing Cartesian coordinates, especially

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in determining which values represent the domain and the range for the x- and y-axes. This indicates that students still struggle with prerequisite knowledge related to Cartesian coordinates. Thus, it is crucial for students to acquire a strong conceptual understanding of Cartesian coordinates to support their learning of subsequent mathematical topics. This study was conducted to analyze students' mathematical understanding of Cartesian coordinate material based on the indicators of mathematical understanding ability. According to Dahlan (as cited in Yani et al., 2019), most experts evaluate mathematical understanding through the following indicators: (1) the ability to restate learned concepts; (2) the ability to classify objects based on whether they meet the defining characteristics of a concept; (3) the ability to apply concepts algorithmically; and (4) the ability to identify examples and non-examples of a concept.

METHOD

This study employed a qualitative descriptive method to provide an overview of students' mathematical comprehension of Cartesian coordinate material. The aim was to describe how eighth-grade students understand and apply mathematical concepts in solving problems related to Cartesian coordinates. The subjects of this study were 30 students from class VIII at a junior high school in Karawang. The research instruments included a mathematical comprehension test and an interview guide to collect both quantitative and qualitative data regarding students' understanding.

The study was conducted in three stages: planning, implementation, and observation. During the planning stage, the research instruments were carefully developed and validated by experts to ensure content accuracy and alignment with the learning objectives. The implementation stage involved administering a mathematical comprehension test focused on Cartesian coordinate material. The test was designed to assess specific indicators, including the ability to restate concepts, classify objects, apply algorithms, and provide examples and non-examples. In the observation stage, students' errors were analyzed to identify common difficulties in understanding Cartesian coordinates. Students were considered to have good comprehension if they were able to correctly solve the test items according to the established indicators. According to Putra et al. (2018), the test items must meet the predetermined comprehension criteria to ensure that the results accurately reflect students' conceptual understanding. Students' mathematical comprehension scores were analyzed using the following percentage formula:

$$\text{Score (\%)} = \frac{Student's\ score}{Ideal\ score} \times 100$$

Table 1. Criteria for Mathematical Comprehension Ability

Score (%)	Comprehension Level
90% - 100%	Very High
75% - 89%	High
55% - 74%	Medium
40% - 54%	Low
0% - 39%	Very Low

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As shown in Table 1, students' mathematical comprehension ability is categorized into five levels: very high, high, medium, low, and very low. Each student's responses on the mathematical comprehension test were assessed and grouped according to these criteria. Subsequently, an analysis was conducted to identify and examine the errors made by students in solving the test items. This approach allows the researcher to determine not only the overall comprehension level of each student but also the specific areas in which students face difficulties, providing valuable insights for instructional improvement.

RESULTS AND DISCUSSION

After analyzing the collected data, a comprehensive overview of students' mathematical comprehension related to Cartesian coordinates was obtained. The findings reflect the extent to which students demonstrated conceptual understanding across the indicators assessed, including their ability to restate concepts, classify mathematical objects, apply procedures, and identify examples and non-examples of the concepts learned. These results provide a detailed depiction of students' strengths and weaknesses, allowing for a clearer understanding of the specific areas in which misconceptions or difficulties persist. The overall distribution of students' scores on each test item is presented in the following table.:

Table 2. Achievement of Each Mathematical Comprehension Test Item

No.	Skill Measured	Average Score	Maximum Score	Achievement (%)
1	Students can determine the coordinates of a point in a contextual problem	14	20	70
2	Students can identify the position of a point according to its quadrant	9	20	45
3	Students can use, apply, and select procedures to determine the position of a point relative to another point	8	20	40
4	Students can apply concepts or problem-solving algorithms to determine the position of a point relative to another point	7.5	20	37

Based on the statistical calculations, the results of the mathematical comprehension test for eighth-grade students at a junior high school in Karawang with four test items can be described as follows: the average score for item 1 was 14 with an achievement of 70%; for item 2, the average score was 9 with 45% achievement; for item 3, the average score was 8 with 40% achievement; and for item 4, the average score was 7.5 with 37% achievement.

The categorization of the students' performance based on the mathematical comprehension test results is presented in Table 3. This classification provides a clearer picture of the students' comprehension levels and highlights areas where they face difficulties.

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Table 3. Categories of Mathematical Comprehension Ability

No	Interval (%)	Frequency	Percentage	Category
1	80 < N ≤ 100	0	0%	Very High
2	60 < N ≤ 80	0	0%	High
3	40 ≤ N ≤ 60	12	40%	Medium
4	20 < N ≤ 40	16	53%	Low
5	1 ≤ N ≤ 20	2	7%	Very Low

Based on the research findings, several types of difficulties were observed in students' completion of the mathematical comprehension test on Cartesian coordinates. Specifically, 30% of students struggled with applying concepts in Cartesian coordinates (item 1), 55% had difficulty explaining a concept based on its characteristics (item 2), 60% faced challenges in transforming information from one form to another (item 3), and 63% had problems relating one concept to another correctly (item 4).

As a result, students at the junior high school in Karawang were assessed as having low competence in solving mathematical problems across all indicators of mathematical comprehension. This is reflected in the test results: no students fell into the very high or high categories; 12 students (40%) were in the medium category; 16 students (53%) were in the low category; and 2 students (7%) were in the very low category. These results indicate that the majority of students require targeted instructional strategies to improve their conceptual understanding of Cartesian coordinates.

Next, using the students' test results, an additional analysis was conducted to identify the types of errors made by students when solving Cartesian coordinate equations and inequalities. Figures 1, 2, 3, and 4 illustrate students' solutions to the mathematical comprehension test items on Cartesian coordinates. This analysis aims to provide a detailed understanding of the specific difficulties students encounter, such as misplacing points, reversing the x- and y-coordinates, misinterpreting the relative position of lines, or applying incorrect procedures. By examining these errors, the researcher can identify patterns in students' misunderstandings and provide recommendations for targeted instructional strategies to improve conceptual understanding in Cartesian coordinate material.

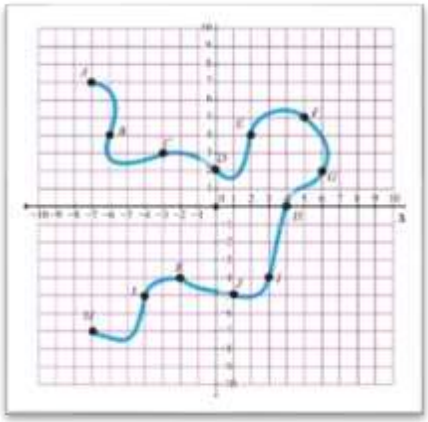

Figure 1. Test items 1 to 3

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Item 1 directs students to analyze a diagram depicting a river flowing through several points on a coordinate plane. After analyzing the diagram, students are asked to identify and list five coordinates of the points through which the river passes, based on the given illustration. The figure below presents the response of a representative student. This task assesses the students' ability to interpret a contextual situation, accurately locate points on a Cartesian plane, and restate the coordinates correctly. Errors in this task, such as incorrectly identifying points or reversing coordinates, provide insight into the students' difficulties in applying conceptual understanding of Cartesian coordinates in real-life contexts.

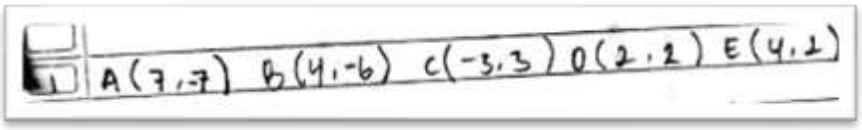

Figure 2. Student Response to Item 1

Based on Figure 2, it is evident that students encountered difficulties in determining the coordinates of points on the $X-$ and $Y-axes$. Many students demonstrated a lack of understanding of the fundamental concepts of Cartesian coordinates. For example, one student placed point A at $(7,-7)$, whereas the correct placement should have been $X = -7$ and Y = 7. Similarly, points B, C, D, and E were incorrectly plotted, indicating repeated errors in assigning the correct values to each axis.

Interviews with students revealed that their misunderstandings stemmed from a lack of conceptual comprehension. Many students admitted that they often relied on examples from the textbook without fully understanding the material. They followed the book mechanically, without internalizing the concepts of Cartesian coordinates. Students also reported that during the explanation of the material, they did not fully grasp the concepts, which contributed to errors when solving problems. This finding aligns with Putri et al. (2018), who stated that students' difficulties in learning mathematics often arise because they memorize concepts without constructing meaningful understanding, leading to frequent mistakes and challenges in problem-solving.

For Item 2, students were directed to identify points along the river flow located in Quadrants I, II, III, and IV. This question aimed to assess students' understanding of the quadrant concept in Cartesian coordinates. Figure 2 also presents the response of a representative student for this task, illustrating how errors persist in understanding quadrant placement and the spatial orientation of points on the coordinate plane.

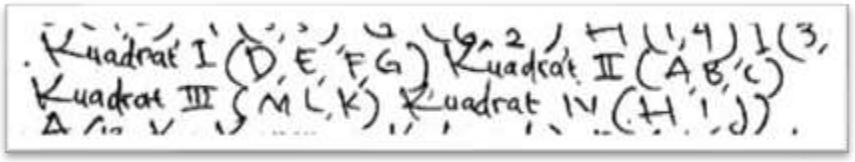

Figure 3. Student Response to Item 2

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Based on Figure 3, the skill being assessed was the students' ability to determine the position of a point according to its quadrant. On this indicator, students made errors in labeling quadrants and in locating points within each quadrant. Many students were unable to distinguish coordinates based on the characteristics of their respective quadrants. For example, some students wrote "kuadrat" instead of "quadrant," indicating a lack of understanding of the concept of quadrants in Cartesian coordinates and the placement of points within them.

Interviews with students revealed that many were unfamiliar with the term "quadrant" and only recognized the word "square" ("kuadrat"). Students also reported confusion when attempting problems that differed from the examples provided during instruction. This finding is consistent with Asih & Imami (2021), who noted that some students still struggle to restate a concept and classify objects based on mathematical principles. Similarly, Putri et al. (2018) emphasized that individuals with strong mathematical comprehension understand what they have learned, can apply concepts both within and beyond mathematical contexts, and can explain the steps taken in problem-solving.

Item 3 directed students to determine the coordinates of points A, B, C, and D relative to point G. This task assessed students' understanding of calculating distances from one point to another on the Cartesian plane. Figure 3 presents the response of a representative student, illustrating common errors in interpreting relative positions and measuring distances between points. These errors highlight gaps in students' conceptual understanding of spatial relationships in Cartesian coordinates.

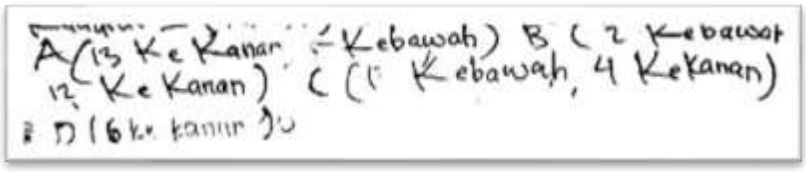

Figure 4. Student Response to Item 3

Based on Figure 4, the skill being assessed was students' ability to use, apply, and select procedures to determine the position of a point relative to another point. The main errors observed in Item 3 occurred when students attempted to apply concepts and determine the relative positions of points. Most students made mistakes in calculation rules and in selecting the correct operations needed to locate one point with respect to another. Interviews with students revealed that many were confused about the calculation procedures and lacked accuracy in performing the operations.

This finding aligns with Nurul (2015), who reported that errors often arise when students do not carefully read the questions and make careless mistakes in their calculations due to haste and inattention. Interviews with students revealed that many were confused about the calculation procedures and lacked accuracy in performing the operations. This finding aligns with Nurul (2015), who reported that errors often arise when students do not carefully read the questions and make careless mistakes in their calculations due to haste and inattention. Moreover, recent studies have emphasized the importance of cognitive factors in students' mathematical errors, suggesting that a lack of understanding of fundamental concepts can lead to persistent mistakes in calculations (Maharani et al., 2024). For instance, students who struggle with basic arithmetic operations often find

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themselves unable to apply more complex procedures correctly, resulting in a cycle of errors that can undermine their confidence and performance (Khoshaim, 2018).

Item 4 required students to determine the coordinates of points Q, R, S, and T relative to point P, given that P(4, −5), Q(3, 2), R(4, 7), S(−5, 4), and T(−3, −6). This item assessed students' ability to apply concepts and algorithms in solving problems involving relative positions on the Cartesian plane. The responses indicated that many students still struggled to accurately apply procedures and understand the relationships between points, demonstrating ongoing gaps in conceptual understanding of Cartesian coordinates.

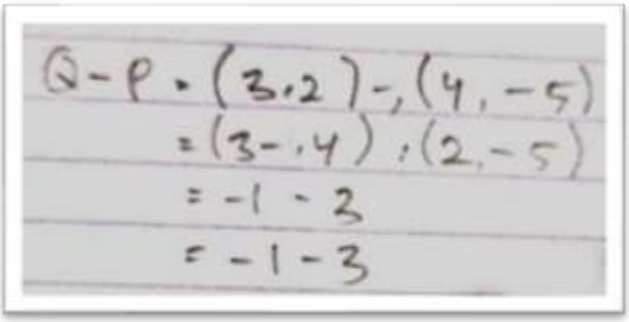

Figure 5. Student Response to Item 4

Based on Figure 5, the skill being assessed was students' ability to use, apply, and select procedures, as well as to implement algorithms in problem-solving to determine the position of points relative to other points. The main errors observed in Item 4 occurred when students attempted to apply concepts to locate points. Many students made mistakes in calculation rules and in selecting the correct operations to determine the position of one point relative to another.

This finding aligns with Utami & Wutsqa (2017), who reported that students' failures in problem-solving often occur when they are unable to establish connections between the material presented in the question and the ideas that need to be applied. These errors indicate that students still struggle with conceptual understanding and procedural application in Cartesian coordinates, highlighting the need for targeted instructional strategies to strengthen both conceptual and procedural competencies.

Recent studies indicate that students often struggle with understanding mathematical concepts and applying them correctly, leading to frequent errors in problem-solving tasks (Damayanti & Loviana, 2024). These challenges highlight the need for targeted instructional strategies to enhance students' critical thinking and accuracy in mathematics (Nufus et al., 2024). This is particularly important in light of findings that suggest a significant percentage of students demonstrate deficiencies in their mathematical reasoning and problem-solving skills. Addressing these issues through effective teaching methods can foster a deeper understanding of mathematical concepts and improve overall student performance (Setyo et al., 2023). Recent studies further corroborate these observations, indicating a widespread struggle among students to grasp and apply mathematical concepts effectively. This situation necessitates the implementation of targeted instructional strategies aimed at enhancing critical thinking and accuracy in mathematics

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CONCLUSION

Based on the results and discussion, it can be concluded that students' mathematical comprehension of Cartesian coordinate material falls into the low category. This is evidenced by the test results: no students achieved the very high or high categories, 12 students were in the medium category, 16 students were in the low category, and 2 students were in the very low category. The main errors identified in the mathematical comprehension test included: (1) a lack of understanding of Cartesian coordinate concepts, and (2) careless calculations and failure to follow correct procedures when solving problems. These findings indicate that students require further support to strengthen both conceptual understanding and procedural accuracy in Cartesian coordinate tasks.

Based on these findings, it is recommended that teachers present the material more clearly to ensure that students understand the underlying concepts. Additionally, the use of supplementary instructional media in mathematics learning is suggested to clarify concepts more effectively and to enhance students' motivation and engagement in learning mathematics.

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