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Analysis of High School Students' Reasoning and Understanding of Circle Properties

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Abstract

This study aims to analyze the ability of high school students to understand concepts and mathematical reasoning on the properties of circles. The study used a qualitative descriptive approach with a one-shot case study design, involving 20 students in class X of SMA Negeri 5 Cirebon who were selected through purposive sampling. Instruments in the form of post-tests are used to measure two cognitive aspects, namely concept understanding and mathematical reasoning. The results showed that the ability to understand concepts was higher than reasoning. As many as 80% of students were able to solve the circle area problem, and 90% were able to apply the juring area formula correctly, with an average comprehension score of 85. However, mathematical reasoning still varies, with an average score of 77.5; Only 75% of students can give rational reasons related to the shape of circles, and 80% are able to relate the concept of angles to daily life, and there are even students who get a score of 0. These findings show that conceptual mastery is not fully accompanied by reasoning skills, so it is necessary to apply problem-based learning strategies and the use of contextual interactive media to strengthen concept understanding while improving critical thinking skills and mathematical reasoning in a more meaningful way.

Keywords: Circle Geometry, Concept Understanding, Mathematical Reasoning, One-Shot Case Study

INTRODUCTION

Education is a fundamental aspect of human life that begins at birth, continues to develop over time, is universal, and is passed down continuously from one generation to the next (Hidayat et al., 2018). In education, continuous change is necessary to improve the quality of education (Rismawati et al., 2023). The education world still faces many issues in learning, especially in mathematics education (Kamarullah, 2017). Mathematics is one of the disciplines that plays an important role in developing logical, analytical, and systematic thinking skills (Sari Ningrum et al., 2023; Wahyuningtyas et al., 2023). Mathematics also plays a crucial role in the development of science and technology, serving as a tool in various fields and contributing to the advancement of mathematics itself, making it a compulsory subject at every level of education (Habibatul Izzah & Azizah, 2019). Mathematics education is required at every level of school, from elementary school (SD) to high school (SMA) (Murni Gultom & Tambunan, 2022). In high school education (SMA), geometry becomes one of the branches of mathematics that not only requires an understanding of concepts but also students' reasoning abilities in solving problems. Students are positioned as active subjects in learning, enabling them to build conceptual understanding and develop mathematical reasoning through independent problem-solving (Aminah et al., 2018). Following the principles of learning mathematics, students must be able to build conceptual knowledge in solving problems (Firmasari et al., 2022). Understanding concepts in geometry requires students to reason, explain, and apply these concepts logically through definitions, relationships, and representations, as well as to use them to solve problems (Rejohn, 2024). Students who have a strong conceptual understanding tend to be able to solve math problems effectively and connect the concepts used with relevant mathematical principles (Firmasari et al., 2024). In addition, mathematics is a discipline that emphasizes logical and systematic reasoning activities in understanding, analyzing, and solving problems (Aminah & Wahyuni, 2019). The reasoning ability of students in geometry material is the skill of using logical thinking to make conjectures, organize and evaluate evidence, and draw conclusions

based on concepts and geometric problems (Ariati & Juandi, 2022). Students' reasoning abilities in solving geometric problems heavily depend on their understanding of concepts, so reasoning and conceptual understanding become two highly interconnected aspects in geometry learning at school (Nasriadi & Mulyadi, 2022).

One of the topics in geometry that has a close relationship with real life and requires a deep understanding is the circle. A circle is one of the flat shapes that has special properties, such as diameter, radius, arc, chord, and center point, which distinguish it from other flat shapes (Nursila et al., 2023). However, in the implementation of learning, many students experience difficulties in understanding and connecting the properties of circles with the context of problem-solving (Luqman et al., 2024). This reflects the existence of challenges in reasoning and understanding concepts. The difficulties students have in understanding the concept of a circle indicate that their mastery of geometry material is not yet fully optimal, especially in the aspects of reasoning and understanding concepts (Ulfa et al., 2024). This is an important concern considering that the concepts within circles not only form the basis of geometry but are also applicable in everyday life. Learning that stimulates critical and reflective thinking is essential in building a strong understanding of concepts, as well as deep mathematical reasoning skills (Fuady, 2017). Unfortunately, learning that overly emphasizes memorizing formulas without exploring concepts and the context of problems has become one of the main factors causing students' low mastery of circle material (Sulaiman, 2018). This condition hampers students' ability to understand the interrelationship between the properties of circles and to reason the mathematical relationships underlying it. Therefore, it is important to conduct an in-depth study on the level of understanding of the concept and students' reasoning abilities regarding the properties of circles.

Some previous research findings suggest that students' reasoning and understanding abilities remain relatively low. Research conducted by (I. Wahyuni & Kharimah, 2017) It is revealed that students have not classically achieved completeness, with the achievement of each indicator of mathematical comprehension and reasoning skills reaching an average of 40%. In addition, research by (Yufentya et al., 2019) It is noted that high-ability students demonstrate strong concept understanding skills, as evidenced by their achievement rate of over 50%. In contrast, students with moderate and low abilities exhibit poor concept understanding skills, as indicated by results of less than 50% for each indicator. Another study conducted by (Z. Wahyuni et al., 2019) It is revealed that the overall mathematical reasoning ability of tenth-grade students falls into the moderate category with a score of 2.02. Based on its distribution, the mathematical reasoning ability of students in the high category consists of five students (18%), in the medium category are 15 students (53.5%), and in the low category are eight students (28.5%).

Unlike some previous studies that tend to focus the analysis on one aspect of students' abilities, this research combines the analysis of conceptual understanding and mathematical reasoning simultaneously, thus obtaining a more comprehensive picture of students' thinking profiles in the mathematics learning process. This is important considering that the aspects of understanding and reasoning are closely related and complement each other in the learning process, especially when facing problems that require higher-order thinking skills. High. Therefore, studying both aspects simultaneously becomes important to gain a comprehensive understanding of students' cognitive abilities. Furthermore, another novelty lies in the context of the material being analyzed, namely the properties of circles in the topic of geometry. The circle was chosen because it is one of the complex topics that often causes difficulties for students in connecting concepts and reasoning about its properties, especially when they are required to apply those concepts in the context of real-world problems or different visual and symbolic representations (Siburian et al., 2024).

Based on the description above, this research contributes to understanding the students' thinking profile on geometry material, especially the properties of circles, focusing mainly on

reasoning skills and understanding concepts. Through the analysis of these two aspects simultaneously, it is hoped that this research can provide a comprehensive understanding of students' cognitive abilities in learning geometry, especially in the material on the properties of circles. This is in line with the findings (Kowiyah et al., 2024) Conceptual understanding and mathematical reasoning are essential indicators in achieving high-level thinking competencies. Research by (Shujianto et al., 2024) Also corroborates that simultaneous analysis of concept understanding and reasoning can provide a more comprehensive picture of students' ability to solve geometry problems. Therefore, this study aims to analyze the reasoning abilities and mathematical concept understanding of high school students (SMA) on the topic of geometry, specifically the properties of circles.

RESEARCH METHODS

This research is a descriptive study with a qualitative approach, aimed at providing a detailed description of the processes and outcomes of learning based on non-numerical data. Qualitative descriptive analysis allows researchers to reveal the meanings contained in the data based on the perspectives and understandings of participants, without manipulating data or drawing general conclusions (Miles et al., 2018). Through a descriptive qualitative approach, this study examines students' test results on the topic of circles, categorizing them into two cognitive categories: concept understanding and mathematical reasoning.

The sampling technique used in this study is purposive sampling, which is a method of selecting samples deliberately based on specific criteria or considerations to ensure that the chosen subjects are relevant to the focus and objectives of the research (Patton, 2018). Purposive sampling is a method of selecting participants deliberately based on certain characteristics or qualities deemed relevant, and it is commonly used in qualitative research to obtain in-depth and specific information in order to optimize the effective use of research resources (Etikan et al., 2016). The research design used in this study is a one-shot case study, which is a pre-experimental design involving one group of subjects who are given a treatment and then immediately measured for the results (posttest), without a pre-test or control group (Cohen et al., 2018).

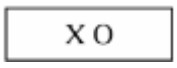

Figure 1. Experimental Design (I. Wahyuni & Kharimah, 2017)

Explanation:
X: the treatment given in the form of learning activities
O: measuring results through tests after treatment is given (posttest)

This research was conducted at State Senior High School 5 Cirebon, which was chosen as the study location because it is considered representative for analyzing the cognitive abilities of students in mathematics learning. The subjects of this study are 20 students from class X who were selected for analysis related to their understanding of concepts and mathematical reasoning abilities. Through this approach, it is hoped to obtain an in-depth understanding of the extent to which students can comprehend the material on circles and apply logical reasoning to solve the given problems.

RESULT AND DISCUSSION

Before analyzing mathematical reasoning abilities, the students first undergo a learning process designed using a problem-based learning approach. At this stage, the researcher acts as

the teacher who facilitates the learning activities according to the prepared design. After the problem-based learning is completed, students are given a test to measure their conceptual understanding and mathematical reasoning abilities.

Description of Data Test of Concept Understanding Ability

The data from the concept understanding ability tests obtained through the posttest activities are presented in Table 1 below.

Table 1. Data from Concept Understanding Ability Test Results

Indicator	Many Students Answered Correctly	Percentage of Students Who Answered Correctly
Apply the formula for the area of a circle by accurately substituting values and completing the calculations.	**16**	**80%**
Identifying and applying the formula for the area of a sector of a circle accurately in solving relevant mathematical problems.	**18**	**90%**

Based on the data presented in Table 1, 16 students (80%) were able to correctly solve the problem of applying the formula for the area of a circle by substituting the value and completing the calculation. This indicates that a majority of students can apply the formula for the area of a circle simply and accurately. This success indicates that students not only understand the formula but also apply it effectively in the context of the given problem. In addition, 18 students (90%) successfully identified and applied the formula for the area of a circular segment. This achievement indicates that the majority of students have a good conceptual understanding of the material on circular segments, as well as the ability to apply it accurately in solving relevant mathematical problems.

An achievement of 80% of students completing questions on the indicator of applying the formula for the area of a circle indicates that the majority of learners have mastered basic procedural skills in the geometry topic, particularly in the concept of the area of a circle. This mastery is not limited to merely remembering the formula, but also includes the ability to accurately substitute the radius values and perform the necessary numerical calculations. This success reflects a good connection between conceptual understanding and application skills in the context of the given problems. Thus, the learning process implemented can build a strong foundational knowledge of the concept of the area of a circle, as students do not just memorize (Siburian et al., 2024). Meanwhile, 90% of students demonstrated the ability to accurately identify and use the formula for the area of a circular sector. This high achievement indicates that most students have a good understanding of the relationship between the magnitude of the central angle and the area of the circle it represents. The material on circular sectors, which requires an understanding of the concept of proportion and its relation to the total area of the circle, has been successfully mastered by students in the form of adequate analytical skills. This indicates that, in addition to conceptual understanding, students are also able to build deep conceptual reasoning in solving mathematical problems related to parts of a circle. In line with, (Adi et al., 2018) that the importance of developing conceptual reasoning so that students do not only memorize formulas, but also understand the relationships within a circle analytically.

Description of Mathematical Reasoning Ability Test Data

The data from the concept understanding ability test, obtained through the posttest activities, are presented in Table 2 below.

Table 2. Data from Mathematical Reasoning Ability Test Results

Indicator	Many Students Answered Correctly	Percentage of Students Who Answered Correctly
Providing rational reasons for choosing a circular shape by considering functional and structural aspects.	**15**	**75%**
Relating the concept of angle measurement to its application in real life and relevant measurement activities.	**16**	**80%**

Table 2 indicates that the students' mathematical reasoning ability is classified as good. A total of 15 students (75%) successfully provided rational reasons for choosing the circular shape, considering both functional and structural aspects. This reflects the students' understanding of linking the concept of geometric shapes with their application in real life. Meanwhile, 16 students (80%) were able to link the concept of angle with daily life contexts and measurement activities. This achievement indicates that the majority of students have developed the reasoning ability to understand and apply the concept of angles in a contextual manner.

Mathematical reasoning ability is an important aspect of mathematics learning because it involves students' ability to provide logical reasoning, make generalizations, and connect concepts to real-world contexts (Asoraya & Ruli, 2023). In this context, the high proportion of students who can provide rational reasons for their choice of geometric shapes and relate the concept of angles to everyday life indicates a development in higher-order thinking skills, particularly in the domain of reasoning. The students' reasoning in choosing circular shapes based on function and structure indicates that they not only understand concepts abstractly but are also able to interpret and apply them in real situations (Novia Agustini et al., 2022). This is in line with the findings (Rizki et al., 2018), which emphasizes that contextual problem-based learning can enhance students' reasoning abilities in geometry. This ability reflects a deeper cognitive engagement, where students not only answer correctly but also can explain why a certain geometric shape is relevant to a specific condition. Furthermore, students' achievements in this reasoning aspect indicate the success of the learning process that not only focuses on procedural aspects but also emphasizes the development of critical and reflective thinking abilities.

After analyzing the post data, information regarding the maximum value, minimum value, average value, standard deviation, and variance of student scores was obtained, which is summarized in Table 3 below.

Table 3. Data from Mathematical Reasoning Ability Test Results

Statistical Data	Understanding Ability	Reasoning Ability
Number of students	20	20
Highest Value	100	100
Smallest Value	50	0
Average	85	77,5
Std. Deviation	23.508	34.316
Variance	552,631	1177,632

Based on Table 3, it was found that the average score of students' comprehension ability is 85, while the average score of reasoning ability is 77.5. The maximum score in both aspects is 100, but there is a difference in the minimum score, which is 50 for comprehension and 0 for reasoning. The standard deviation of comprehension ability is recorded at 23.508 with a variance of 552.631, while the standard deviation of reasoning ability is 34.316 with a variance of 1177.632. These results indicate that students' comprehension ability tends to be higher and more

evenly distributed compared to their reasoning ability, which shows a wider and more uneven distribution of scores.

Descriptive statistics reveal a notable disparity between students' mathematical understanding and reasoning abilities. The average understanding score of 85 indicates that students generally have a good grasp of mathematical concepts, especially in the topics they have studied. In contrast, the lower average reasoning score of 77.5 indicates that students' ability to develop logical arguments, explain reasons, and connect concepts to context is still relatively weaker compared to their understanding ability. This difference is even clearer when viewed in terms of the minimum values and standard deviations of each aspect. The minimum score for reasoning, being zero, indicates that there are students who showed no reasoning ability at all in answering questions, while the minimum score for understanding remains at 50. This shows that no student truly failed in the aspect of comprehension, while there are significant differences in the aspect of reasoning. The smaller standard deviation and variance in comprehension ability compared to reasoning ability reinforce the finding that the distribution of comprehension scores is more even (Ningsih et al., 2023). This means that most students show a relatively uniform level of understanding. In contrast, reasoning scores are more widely spread, indicating a gap among students in terms of logical and analytical thinking abilities. This is in line with findings that, although students can understand mathematical procedures well, they often struggle when asked to explain the reasons or make generalizations from the concepts being learned (Lestari et al., 2023). Thus, it can be concluded that reinforcement of mathematical reasoning aspects is still needed.

CONCLUSION

Based on the research results, it can be concluded that the ability of high school students to understand the material of the properties of circles shows a different tendency between concept understanding and mathematical reasoning. Regarding concept understanding, students are in the good category with an average score of 85. Most students (80%) could apply the circle area formula correctly, and 90% successfully used the wide range formula, indicating that basic procedural and conceptual skills have been adequately mastered. On the other hand, mathematical reasoning skills still varied, with an average score of 77.5, characterized by 75% of students who were able to provide rational reasons related to the shape of circles and 80% who were able to apply the concept of angles to the context of daily life. High variation in scores, even in the presence of students who obtained a score of 0, indicates a significant gap in the mastery of logical and analytical thinking skills.

These results show that mastery of procedural concepts is not fully accompanied by the ability to provide mathematical justifications and generalizations. Therefore, a learning approach emphasizes the development of reasoning, such as problem-based learning, reflective discussion, and contextual technology-based interactive media integration. The practical implication of this research is that teachers need to balance between mastery of concepts and reasoning through learning activities that encourage exploration, argumentation, and application of concepts in real situations. Thus, learning geometry, particularly circles, results in a strong conceptual understanding and more meaningful critical thinking and mathematical reasoning skills for students.

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