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STUDENT ERROR IN CIRCUMFERENTIAL AND CIRCULAR AREA MATERIALS: ANALYSIS BASED ON THE NOLTING CLASSIFICATION

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ABSTRACT

This study aims to analyze students' errors in solving problems around the perimeter and area of the circle based on the error category according to Nolting. These errors include conceptual, procedural, and calculation errors. The method used in this study is qualitative descriptive. The subjects of the study were 30 grade VIII students from a junior high school in Tasikmalaya. Research instruments included a written test designed to identify the type of error according to Nolting as well as a semi-structured interview to dig deeper into the causes of the error. The results showed that 28.5% of students experienced conceptual errors, 53.5% of students experienced procedural errors and 14.2% of students experienced calculation errors. Most students experience conceptual errors because they make mistakes in using the circumference and circle area formulas. Students also tend to make mistakes in distinguishing diameters and radius, as well as calculation errors on decimal numbers in multiplication and division operations. The discussion underlined that procedural errors are mostly caused by students' lack of conceptual understanding of the circle formula, while calculation errors often arise due to a lack of precision. The implementation of this research can be used by mathematics teachers to design more effective teaching strategies in overcoming students' systematic errors, such as emphasizing the understanding of basic concepts before introducing more complex problems, as well as increasing exercises that involve the application of formulas in a variety of ways.

Penelitian ini bertujuan untuk menganalisis kesalahan siswa dalam menyelesaikan masalah terkait keliling dan luas lingkaran berdasarkan kategori kesalahan menurut Nolting. Kesalahan tersebut meliputi kesalahan konseptual, prosedural, dan perhitungan. Metode yang digunakan dalam penelitian ini adalah deskriptif kualitatif. Subjek penelitian terdiri dari 30 siswa kelas VIII di sebuah sekolah menengah pertama di Tasikmalaya. Instrumen penelitian meliputi tes tertulis yang dirancang untuk mengidentifikasi jenis kesalahan menurut Nolting, serta wawancara semi-terstruktur untuk menggali lebih dalam penyebab kesalahan. Hasil penelitian menunjukkan bahwa 28,5% siswa mengalami kesalahan konseptual, 53,5% siswa mengalami kesalahan prosedural, dan 14,2% siswa mengalami kesalahan perhitungan. Sebagian besar siswa mengalami kesalahan konseptual karena melakukan kesalahan dalam menggunakan rumus keliling dan luas lingkaran. Siswa juga cenderung melakukan kesalahan dalam membedakan diameter dan jari-jari, serta kesalahan perhitungan pada bilangan desimal dalam operasi perkalian dan pembagian.

Pembahasan menekankan bahwa kesalahan prosedural sebagian besar disebabkan oleh kurangnya pemahaman konseptual siswa terhadap rumus lingkaran, sedangkan kesalahan perhitungan sering kali muncul akibat kurangnya ketelitian. Implementasi penelitian ini dapat dimanfaatkan oleh guru matematika untuk merancang strategi pengajaran yang lebih efektif dalam mengatasi kesalahan sistematis siswa, seperti menekankan pemahaman konsep dasar sebelum memperkenalkan masalah yang lebih kompleks, serta meningkatkan latihan yang melibatkan penerapan rumus dalam berbagai cara.

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1. INTRODUCTION

A deep conceptual understanding of basic geometry materials is an important foundation in the development of more complex mathematical abilities (Safari & Nurhida, 2024). However, there are still problems faced by students in completing geometry materials. The problem that is the focus of this research is the high error of students in solving problems related to circumference and circle area. The test result data obtained from the observation of grade VIII in one of the junior high schools in Tasikmalaya also showed that only 35% of students were able to solve the questions correctly. As many as 40% of students were unable to identify the basic elements of a circle such as radius or diameter, while another 25% made mistakes in the calculation process, such as the inconsistent use of π. This error reflects the weak conceptual and procedural understanding of students. This fact indicates that students' understanding of the basic concept of circles, which, if not handled properly, has the potential to hinder students' mastery of geometry materials. This is in line with Handayani (2019), that understanding mathematical concepts is very necessary for students to achieve the goal of learning mathematics. Without mastering basic concepts such as this circle material, students will make mistakes in understanding other geometric concepts, such as surface area and volume of space. Benefit (2024) also emphasizes that a shallow understanding of basic concepts is one of the main causes of students' failure to solve geometry problems.

The importance of this research lies in the fact that the circumference and area of a circle is a topic that has many practical applications, both in everyday life and in the field of science and technology. This requires a deeper understanding of the concept. However, currently there are still many students who are still wrong in understanding the concept of circumference and circle area. Aritonang & Pujiastuti (2023) revealed that errors in understanding geometry concepts are often caused by students' weak understanding of spatial concepts, visualization, and abstract thinking. In addition, if these errors are not analyzed and corrected, students will continue to experience errors in applying the concept in the future. In line with Kusuma et al. (2023) that mistakes made by students can be caused by several factors, including: (a) students' tendency to rush so that they ignore details, such as the units listed in the question, (b) students' lack of thoroughness in reading and understanding the content of the question thoroughly, (c) students' errors in recognizing the information available in the question, (d) misconceptions or lack of understanding of the requirements requested in the problem, and (e) the student's negligence in recording important information provided during the problem-solving process.

Previous research has discussed a lot about student mistakes in circle learning (Anwar & Hidayani, 2020; Ulhaq & Yuspriyanti, 2022; Simamora et al., 2022). Anwar & Hidayani (2020) in their research shows that students often make mistakes in using definitions or theorems, using improper algorithms, engineering errors, data errors, not writing down the final answer, and giving random answers. This is due to the lack of understanding of the concept of circle formulas due to memorization methods, weak mastery of algebra concepts, confusion in dealing with variations in problem shapes, inability to understand problems comprehensively, lack of precision, low motivation to learn mathematics, and students' tendency to rush to solve problems. Ulhaq & Yuspriyanti (2022) revealed the results of their research that students' mistakes in solving problems include various aspects, including misconceptions about the basic concepts underlying problem solving, inability to understand or interpret the content of the problem correctly, and mistakes in performing the mathematical operations needed to obtain solutions. These errors show that students not only experience obstacles in understanding concepts, but also face errors in critical reading skills and the correct application of procedural steps. Meanwhile, according to Simamora et al. (2022), the results of his research show that at the level of understanding of multistructural mathematical concepts, the most dominant types of student errors in learning circles are id (improper identification), ip (incorrect information isolation), um (error in understanding the relationship between elements), and shp (errors in symbol manipulation). This indicates that students experience obstacles both in understanding information conceptually and in integrating mathematical elements into problem solving. However, these studies still have limitations. Most only identify errors in general terms without using a structured and in-depth analysis framework. In addition, the analysis of the causes of errors is often not accompanied by in-depth interviews that can dig into the root of the problem from the student's perspective. In this context, research that adopts Nolting's theory becomes very relevant. Nolting's theory offers a framework for classifying student errors that consists of three main categories: conceptual errors, procedural errors, and calculation errors. This approach allows for a more systematic analysis to identify the various factors that cause student error in circular learning.

Research gaps are also evident from most studies that have been conducted that have focused only on identifying errors in general without using a more structured and in-depth framework of error analysis. For example, research conducted by Anwar & Hidayani (2020), that the research lacks a deep understanding of the causal factors behind student errors, such as lack of conceptual understanding, limited procedural skills, or the influence of learning strategies applied by teachers. In the research of Ulhaq & Yuspriyanti (2022), the analysis has not highlighted concrete strategies that can be applied to help students understand the correct concepts and procedures even though there are examples of student answers. In addition, the research of Simamora et al. (2022) only focuses on student errors without providing a detailed description of the relationship between these errors and the learning methods used or the background of students' initial abilities. As such, the study has the potential to be expanded through a more in-depth analysis and a more comprehensive approach to the factors that affect student error.

There have not been many studies that specifically use Nolting's theory in the analysis of geometric errors, especially on circular matter. Previous research has often focused only on the general types of errors without using a systematic analytical framework, thus providing in-depth insight into how and why these errors occur. Based on Nolting's theory (2012), there is a framework that classifies student errors into three main categories: conceptual errors, procedural errors, and calculation errors. Conceptual errors occur when students fail to understand the basic relationships between elements in a circle, such as radius and diameter. Procedural errors occur when students misapply formulas or calculation steps, for example when they make mistakes in arranging mathematical sequences of operations. Calculation errors are related to inaccuracies in performing numerical calculations, especially in the use of decimal numbers or multiplication by π.

The originality of this research lies in the use of Nolting's theory to analyze the types of mistakes made by students in the circumferential and circular area. Meanwhile, previous studies such as those conducted by Anwar & Hidayani (2020), Ulhaq & Yuspriyanti (2022) and Simamora et al. (2022) have focused more on procedural and conceptual errors in mathematics in general. Meanwhile, this study deepens the analysis on specific errors related to the calculation of circles. Using in-depth interviews as an additional method, the study not only identifies the mistakes made by students, but also explores the deep causes behind the errors, both in terms of conceptual understanding and procedural errors.

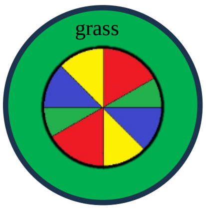
A major gap from previous studies was the lack of a comprehensive analysis of the errors that occur in circular matter. For example, a study by (Evianti et al. 2019; Umami & Asdarina, 2024), showed that students' errors mostly occurred due to an inability to understand the relationship between diameter and radius, but this study did not include an analysis of how students understood the mathematical operations related to π and decimal numbers in circumferential and area calculations. In addition, research by Hisyam et al. (2023) in it identifies students' spatial errors, but does not delve further into how students overcome these errors through appropriate learning strategies. This research will fill in the gaps by using Nolting-based analysis and exploring students' mistakes through in-depth interviews, so that it can provide a more comprehensive picture of the mistakes students make and how those mistakes can be overcome through the improvement of teaching strategies.

This research is expected to provide new insights in understanding the types of student mistakes as well as learning strategies that can be applied to improve understanding of basic geometry concepts, especially circle materials. The novelty of this research lies in the use of Nolting's theory-based analysis and in-depth interviews, which provide a comprehensive picture of the causes of student errors and strategic solutions to overcome them.

2. METHOD

This study uses a qualitative descriptive approach to analyze the mistakes of grade VIII students at a junior high school in Tasikmalaya city in solving the circumference and circle area problems, with a focus on conceptual and procedural understanding. This approach was chosen because it allows for an in-depth exploration of student errors, in accordance with the aim of describing the types of errors based on Nolting's theory as well as the causal factors. This research is designed in three main stages: (1) The preparatory stage which includes the development and validation of instruments in the form of diagnostic tests and observation sheets, with content validation by mathematics education experts; (2) Implementation stage, including the implementation of a diagnostic test with 2 essay questions designed to reveal conceptual, procedural, and computational errors, semi-structured interviews to explore students' understanding and the causes of errors, and classroom observation using observation sheets to record patterns of student interaction and responses; (3) The data analysis stage, involving data reduction through the classification of student errors based on Nolting theory, the presentation of data in the form of a descriptive narrative, and drawing conclusions based on the pattern of errors found, with data triangulation for validation of results. The research participants consisted of 30 students who were selected by *purposive sampling* based on the results of the initial diagnostic test, with varying mathematical backgrounds. Research instruments include diagnostic tests validated by experts, interview guides relevant to Nolting's theory, and observation sheets to document students' problem-solving strategies, with data collection techniques carried out in writing, in-depth interviews, and direct observation. The data obtained is systematically analyzed to provide learning recommendations that can improve students' understanding of the concept of circles. The questions used by the researcher are presented in the following Table 1.

Table 1. Question Instruments

<table>
<tr><th>No.</th><th>Question</th></tr>
<tr><td>1</td><td>Dina is a city explorer who loves to walk. Today, Dina decided to walk around a circular garden. If he plans to walk around the park for 3 full laps, what is the total distance he will travel if he knows that the radius of the park is 140 meters?</td></tr>
<tr><td>2</td><td>Pay attention to the design of the flower garden on the side!
Information:
- The yellow area is planted with flower A
- Green area planted with B flowers
- The red area is planted with C flowers
- The blue area is planted with D flowers


It is known that the radius of the large circle is 14 m, while the radius of the small circle is 7 m. the angle planted with flowers A and D is the same, while the size of the corner planted with flower C is twice as large as flower B.
Price list for creating a garden:
<table><tr><td>Garden Creation Details</td><td>Price</td></tr><tr><td>Painting around the garden</td><td>Rp. 20,000,00/meter</td></tr><tr><td>Planting grass</td><td>IDR 25,000.00/m2</td></tr><tr><td>Flower Planting A</td><td>Rp. 100,000.00/m2</td></tr></table></td></tr>
</table>

Flower planting B	Rp. 120,000.00/m2
Flower planting C	IDR 30,000.00/m2
Flower planting D	IDR 75,000.00/m2

a) How much does painting cost for a garden tour?
b) How much does planting cost for garden lawn area?
c) What is the planting cost for flower area A?
d) How much does it cost to plant for a B flower area?

Meanwhile, the indicator of the type of error used by the researcher is presented in the following Table 2.

Table 2. Types of Errors and Their Indicators

No.	Types of Errors	Indicators
1	Calculation Error	Students make mistakes in rewriting the components of the question given before completing the question, the operation marks, and the results of the answers.
2	Conceptual Errors	Students are wrong in mastering the concept of circumference and circle area.
3	Procedural Errors	Students know the formula but are still wrong in solving the problem.

3. RESULTS AND DISCUSSION

3.1. Result

Learning geometry on circumference and circle area materials is often a challenge for students. This material not only requires a deep understanding of the concept of circles, but also precision in applying the circumference and area formulas precisely. In practice, students often face errors caused by a lack of understanding of basic concepts, calculation errors, or an inability to interpret problems. Analysis of student errors is important to carry out in order to identify the types of errors that often occur, both conceptual and procedural. By analyzing student errors based on Nolting's theoretical framework, researchers can understand the factors that influence these errors, so that they can be the basis for designing more effective learning interventions. Data in the form of student work, interviews, and observations will be used to identify error patterns and provide recommendations for improvement in circular and circular learning.

The results showed that students experienced three main types of errors: calculative, conceptual, and procedural. Data was obtained through analysis of student work, interviews, and observations of 30 grade VIII students. The following is the data on the percentage of student errors found:

Table 3. Student Error Percentage Results

No.	Types of Student Errors	Subject	Percentage
1.	Calculation Error	S2, S5, S6, S10, S14, S15, S19, S24	28,5 %
2.	Conceptual Errors	S1, S2, S6, S7, S8, S12, S13, S16, S17, S18, S19, S20, S21, S25, S28	53,5 %
3.	Procedural Errors	S4, S19, S21, S23	14,2 %

The findings of this study provide in-depth insights into the mistakes that students often make in the circumferential and circular area, as well as the factors that contribute to these errors.

1. Calculation Error

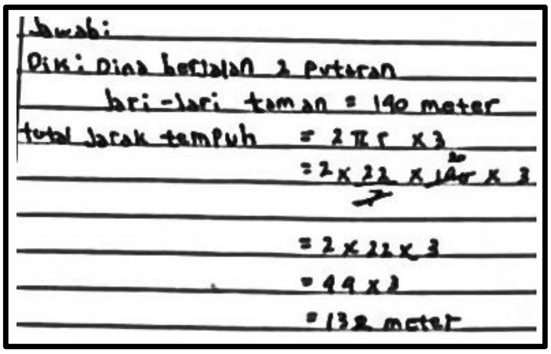


Figure 1. Results of Students' Answers to Question Number 1

Based on the students' answers in Figure 1, it was found that there was a calculation error in the step of solving the problem related to the circumference of the circle. Students use the circular formula with substitution of grades and . However, the student did not complete the division = 20 correctly, so this result was not further operated on the next step. This error is included in the category of calculation errors according to Nolting, because students are not thorough in carrying out the calculation stages even though they understand the concepts and formulas correctly. As a result, students obtained an incorrect circumference result, which was 132 meters for one lap, which had an impact on the total mileage error. The results of the interviews conducted by the researcher (P) and subject 2 (S2) are as follows.$K = 2\pi r \pi = \frac{22}{7} r = 140 \frac{140}{7}$

Dialogue 1

P : *"Okay, see your answer first, yes. You use the formula around the circle, well, then the* π *value* $K = 2\pi r$ *uses and substitution. But it's still not right. Do you know where it is wrong?"*$\frac{22}{7} r = 140$

S2 : *"Hmm... I don't know, sir. But I use the formula right, right?"*

P : *"Yes, the formula is correct. But let's see the steps. Here you write, but the result is not counted. What should be the result, try?"*$140 \div 7$

S2 : *"Oh yes, yes. Oh, I forgot, sir. It should, right?"*$140 \div 7 = 20$

P : *"That's right! So, the next step after that, the circumference will be 2×22×20, not 2×22. Try to calculate again!"*

S2 : *"Okay, sir. If that's 2×22=44, then 44×20=880. So the circumference is 880, huh?"*

P : *"Well, that's right. So it's around for one lap. What if it goes three rounds?"*

S2 : *"It's only three times, right, sir? So 880×3=2640"*

P : *"Sip! So the total distance is 2640 meters. Do you know why it could be wrong earlier?"*

S2 : *"It seems because I am not careful when working on the distribution, sir"*

P : *"Yes, that's it. From now on, try to be more careful!"*

S2 : *"Yes, sir. I will be more thorough. Thank you, sir"*

2. Conceptual Errors

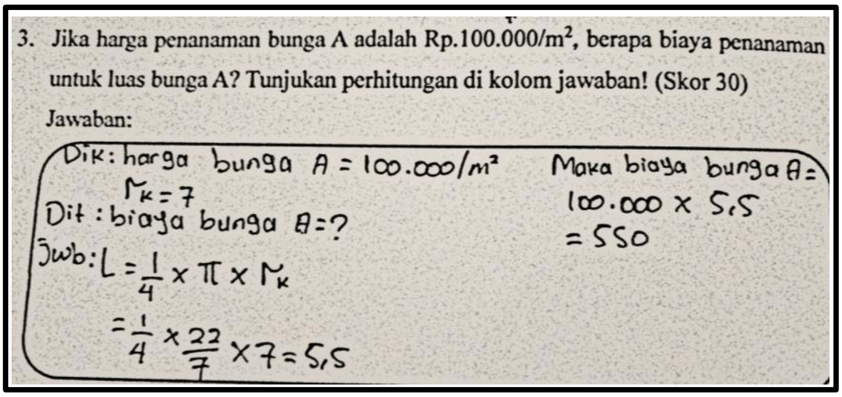


Figure 2. Results of Students' Answers to Question Number 2 (c)

Based on the students' answers in Figure 2, errors were found in applying the concept of circle area. Students use formulas, which should be . In the calculation, the student simply multiplies by, without squaring the radius, which is an important step in calculating the area of the circle. This error falls into the category of conceptual errors according to Nolting, because students have not properly understood the basic concept of circle area. As a result of this error, the results of the calculation of the circle area become inappropriate, thus affecting the calculation of the cost of planting flowers. The results of the interviews conducted by the researcher (P) and subject 7 (S7) are as follows.$L = \pi r L = \pi r^2 \pi r(r)$

Dialogue 2

P : *"Okay, sir, look at your answer first, yes. You have tried to calculate the area of the circle for the cost of planting flowers A. But the results are still not right. Do you know where the fault lies?"*

S7 : *"Hmm, I don't know, sir. I have used the formula for the area of the circle, which is "*$L = \pi r$

P : *"Oh yes? Let's look at the material again in the notebook that you have explained earlier"*

S7 : *"Oh yes, sir. I forgot that the r is squared. So I was wrong from the beginning, sir?"*

P : *"That's right. If the radius of the circle is r=7, let's recalculate the area with the correct formula"*

S7 : *"Okay, sir. If you use , it means . The result is 49, sir. Mean. So the area is 154 square meters, sir?*$L = \pi r^2 L = \frac{22}{7} \times 7^2 7^2 \frac{22}{7} \times 49$

P : *"That's right. Well, if the planting price is IDR 100,000 per square meter, what does it mean is the total cost?"*

S7 : *"It means that it is multiplied, sir, 154 × 100,000 = 15,400,000"*

P : *"That's right. So the total cost is Rp15,400,000. Now you understand why your answer was wrong?"*

S7 : *"Yes, sir. It turned out that I used the wrong formula. The fingers should be squared first"*

P : *"Okay, next time, don't make a mistake again, the concept of the formula"*

S7 : *"Okay, sir"*

3. Procedural Errors

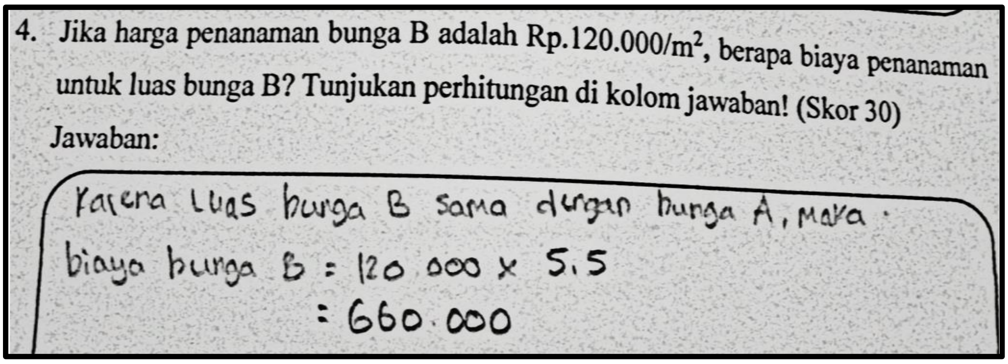

4. Jika harga penanaman bunga B adalah Rp.120.000/m², berapa biaya penanaman untuk luas bunga B? Tunjukan perhitungan di kolom jawaban! (Skor 30)
Jawaban:
Karena luas bunga B sama dengan bunga A, maka :
biaya bunga B = 120 000 × 5,5
= 660.000

Figure 3. Results of Students' Answers to Question Number 2 (d)

Based on the students' answers in Figure 3, procedural errors were found in solving problems related to the cost of planting flowers B. Students stated that the area of flowers B was equal to the area of flowers A, and directly used the result of the area of flowers A to calculate the cost of interest B. Even though the area A was equal to the area D. Although the calculation of the cost was correct, procedurally it was still incorrect. This procedural error shows that students are not careful in observing the problem. According to Nolting, these errors fall into the category of procedural errors because students do not follow the completion steps correctly despite understanding the basic concepts and being able to perform arithmetic calculations. The results of the interviews conducted by the researcher (P) and subject 4 (S4) are as follows.$120.000 \times 5{,}5 = 660.000$

Dialogue 3

P : "Okay, father, look at your answer first, yes. You have determined the area of the circle for the cost of planting B flowers. But it's still not right. Do you know where the fault lies?"

S4 : "Hmmm... I don't know, sir"

P : "Your answer is not right in the area, where do you determine the result of 5.5 m2?"

S4 : "The area is in accordance with the previous answer, sir, because area A and area B are the same, so I put it into this question as an area that is already known, to later calculate the cost needed."

P : "Okay, now you pay attention to the question, what is known there?"

S4 : "Oh yes sir, the same corner turned out to be a flower field A and D, not B."

P : "Well, that's right, does this mean that if this is the right answer?"

S4 : "Wrong, sir, does it mean that you still calculate the area of flower B first, then calculate the planting cost for flower B?"

P : "Yep, that's right. From now on, I will be more thorough in understanding the problem!"

S4 : "Okay sir, thank you"

3.2. Discussion

The calculation errors found indicate that students need to improve their basic arithmetic skills. Safari & Faradila (2024) states that the ability to calculate correctly is the key to solving more complex mathematical problems. Riyanto & Ishartono (2022) stated that strong mastery of arithmetic is fundamental to students' success in mathematics. Training students in performing basic operations such as addition, subtraction, multiplication, and division in relevant contexts will go a long way in reducing calculation errors. Dewanti & Muna (2023) also emphasized that the ability to perform arithmetic operations with accuracy and efficiency is essential for the further development of mathematical skills. Providing constructive feedback on any mistakes students make can also help them learn from their experience and improve their counting skills.

Identified conceptual errors indicate that students have made mistakes in understanding the relationship between the radius, diameter, and π values. This misunderstanding can result from several factors, including a lack of reinforcement of basic concepts in teaching. Learning that focuses only on mastering formulas without understanding the meaning behind them can lead to continuous errors. Luqman *et al.* (2024) emphasizes the importance of teaching that focuses on understanding concepts and relationships between concepts, and emphasizes that students should be invited to explore mathematics in a meaningful way. Kartika & Mutmainah (2019) stated that the use of visual representation in teaching can improve students' understanding of mathematical concepts. Jala (2021) also shows that context-based learning can help students develop a deeper understanding of mathematical concepts.

Procedural errors indicate that students can know formulas but are unable to apply them correctly. This indicates the need for sufficient practice in solving problems and an in-depth understanding of the steps in the application of formulas. Abdul Wahid et al., (2021) stated that good feedback and in-depth exploration of procedures can help students improve their skills in mathematics. Suhady et al., (2019) also argue that students' involvement in relevant and interesting problem-solving can increase their motivation to learn. Jefrizal et al., (2021) emphasized that the mathematical problem-solving process includes four stages: understanding the problem, planning the solution, executing the plan, and evaluating the solution. Therefore, teachers need to provide more practice of varied questions and emphasize the importance of following the steps carefully in the calculation process.

Based on the analysis of students' errors in three problems related to circumference and circle area, this study recommends the development of a learning approach that focuses on understanding the basic concepts of geometry, especially the relationship between radius, diameter, and π constants. This can be done by utilizing visual aids and interactive discussions. Fitri & Prahmana (2020) revealed that the context used as a visual aid plays an important role in the learning process to support students' understanding of learning about circles. Pasaribu & Syahputra (2022) emphasized that interactive discussions with student-centered learning are very necessary. So, students are not only proficient in completing math problems in class, but can also find concepts or take steps to solve problems in concrete global life related to mathematical concepts interactively.

In addition, it is necessary to provide a variety of exercises, including questions that emphasize the identification and correction of common errors, to strengthen the application of concepts in real contexts. Constructive feedback also needs to be given specifically so that students understand their mistakes and how to correct them. In line with Nainggolan & Listiani (2024) that effective feedback can help students in identifying and correcting mistakes, as well as motivate them to learn from mistakes. Basic arithmetic exercises in the context of geometry need to be improved to minimize calculation errors. Furthermore, collaborative learning through group discussions can be integrated to strengthen conceptual understanding and encourage students to support each other. This is in line with Situmorang (2024), that through group discussions, students become more productive, where they support each other and exchange ideas to achieve a better understanding. Thus, further research can be directed towards the implementation of these learning strategies to reduce students' procedural and conceptual errors, as well as evaluate the effectiveness of these approaches in improving student learning outcomes.

4. CONCLUSION

Based on the results of the research on the analysis of student errors on the circumference and area of the circle using the Nolting framework, it was found that conceptual, procedural, and calculation errors still dominated the students' difficulties. As many as 28.5% of students experienced conceptual errors due to not understanding the relationship between the radius, diameter, and the circumference and area formulas. Meanwhile, 53.5% of students made procedural errors due to inaccuracy in implementing problem-solving steps despite knowing the correct formula. In addition, 14.2% of students experienced calculation errors due to lack of precision in performing arithmetic operations, especially in decimal numbers and multiplication with π constants. The results of this study emphasize the importance of a learning approach that prioritizes conceptual understanding, the use of visual media such as GeoGebra, varied practice questions, and the provision of specific and constructive feedback. Thus, more effective teaching strategies are expected to reduce students' mistakes and improve their understanding of mathematical concepts in more depth.

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