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ANALYSIS OF STUDENTS' ERRORS IN SOLVING CIRCLE GEOMETRY PROBLEMS

Imelda Gulia Cristi Malonta, Gita Kristin Adventyska Ropo, Yunda Victorina Tobondo*, Sertin Allolayuk, Elisabet Djunaidy

Universitas Kristen Tentena, Poso, Indonesia
*Corresponding author, email: yundatobondo@gmail.com

Abstract

This study aimed to identify the types of errors made by Grade 11 students when solving circle-geometry problems and to explore factors associated with those errors using Newman's Error Analysis Procedure. Descriptive qualitative design was employed. Six students at SMA GKST 1 Tentena, Poso Regency, Central Sulawesi, were purposively selected to represent high, moderate, and low mathematical ability. Data was collected through a written test consisting of three open-ended problems on inscribed angles, circle circumference, and the equation of a circle, followed by task-based interviews and documentation. The data were analyzed through data condensation, data display, and conclusion drawing and verification, with students' responses classified into Newman's five error categories. Across 18 student-problem responses, process-skill errors occurred most frequently (9 cases; 50.0%), followed by comprehension errors (6; 33.3%), transformation errors (6; 33.3%), encoding errors (5; 27.8%), and reading errors (1; 5.6%). Because one response could contain more than one error category, percentages are calculated separately for each category using 18 responses as the denominator and are not intended to sum to 100%. The findings point to a need for instruction that combines conceptual explanation, explicit mathematical representation, procedural checking, and complete written conclusions.

Keywords: *Circle Geometry; Error Analysis; Mathematical Problem Solving; Newman's Procedure*

Abstrak

Penelitian ini bertujuan mengidentifikasi jenis kesalahan siswa kelas XI dalam menyelesaikan soal geometri materi lingkaran serta menelaah faktor yang berkaitan dengan kesalahan tersebut menggunakan prosedur analisis kesalahan Newman. Penelitian menggunakan pendekatan kualitatif dengan desain deskriptif. Enam siswa SMA GKST 1 Tentena, Kabupaten Poso, Sulawesi Tengah, dipilih secara purposif untuk mewakili kemampuan matematika tinggi, sedang, dan rendah. Data dikumpulkan melalui tes tertulis yang terdiri atas tiga soal uraian tentang sudut keliling, keliling lingkaran, dan persamaan lingkaran, dilanjutkan dengan wawancara berbasis tugas serta dokumentasi. Data dianalisis melalui kondensasi data, penyajian data, serta penarikan dan verifikasi kesimpulan. Jawaban siswa diklasifikasikan ke dalam lima kategori kesalahan Newman. Dari 18 respons siswa terhadap soal, kesalahan keterampilan proses paling sering ditemukan (9 kasus; 50,0%), diikuti kesalahan memahami (6; 33,3%), transformasi (6; 33,3%), penulisan jawaban (5; 27,8%), dan membaca (1; 5,6%). Satu respons dapat memuat lebih dari satu kategori kesalahan sehingga persentase setiap kategori dihitung secara terpisah dengan penyebut 18 respons dan tidak dimaksudkan berjumlah 100%. Temuan ini menunjukkan perlunya pembelajaran yang memadukan penjelasan konsep, representasi matematis yang eksplisit, pemeriksaan prosedur, dan penulisan kesimpulan secara lengkap.

Kata kunci: Analisis Kesalahan; Geometri Lingkaran; Pemecahan Masalah Matematika; Prosedur Newman

INTRODUCTION

Mathematics plays an important role in developing students' logical, critical, analytical, and systematic thinking. Through mathematics learning, students are expected not only to understand concepts and perform calculations but also to apply mathematical knowledge to analyze situations,

establish relationships, and solve problems systematically. Mathematical problem-solving is therefore an essential competency in mathematics education. However, students may experience difficulties when translating mathematical information into appropriate representations, selecting relevant concepts, determining solution strategies, and interpreting the results obtained. These difficulties indicate that successful mathematical problem-solving involves more than computational accuracy; it also requires conceptual understanding, reasoning, and the ability to connect different mathematical representations (Verschaffel et al., 2020; Pongsakdi et al., 2020).

Geometry is one of the important branches of mathematics because it develops students' spatial reasoning and their ability to understand relationships among mathematical objects. Nevertheless, geometry often presents challenges because students are required to coordinate visual representations, geometric properties, mathematical symbols, and logical reasoning. In particular, circle geometry involves several interconnected concepts, including angles, radii, diameters, circumference, and equations of circles. Students must understand the relationships among these concepts and select appropriate mathematical procedures to solve different types of problems. For example, solving problems involving inscribed angles requires students to recognize relationships between central and inscribed angles, whereas calculating the circumference of a circle requires an understanding of the relationship between diameter, radius, and the constant π. Similarly, determining the equation of a circle requires students to connect geometric properties with algebraic representations. These different demands may create difficulties when students have not developed a sufficiently strong conceptual foundation. Naufal et al. (2021) explains that geometric thinking develops through progressive levels of understanding, and students' difficulties may emerge when they are required to move from visual recognition toward analytical reasoning and formal deduction.

Previous studies have reported that students' mathematical problem-solving abilities in circle-related problems remain a challenge (Kurniawati et al., 2018). Students' difficulties may appear in several forms, including conceptual misunderstandings, inappropriate selection of formulas, incorrect mathematical procedures, and inaccurate presentation of final answers. Lutfia (2021) also identified that students' errors may be conceptual, procedural, or related to carelessness. These errors are interconnected because a weakness in understanding mathematical concepts can influence the selection of solution strategies and the accuracy of subsequent calculations. Research by Sugandi et al. (2022) on analytical geometry problems involving circles and conic sections also identified conceptual, procedural, and technical errors in students' solutions. Therefore, error analysis should not focus solely on whether the final answer is correct or incorrect. Instead, it should examine the entire solution process to identify where and why students experience difficulties.

One framework that can be used to investigate students' mathematical errors systematically is Newman's Error Analysis (NEA). Newman classifies errors into five categories: reading errors, comprehension errors, transformation errors, process skills errors, and encoding errors (Mubarokah & Amir, 2024). Reading errors occur when students fail to recognize or interpret important information in a problem. Comprehension errors arise when students cannot adequately understand the meaning of the problem or identify what is being asked. Transformation errors occur when students are unable to translate the information into an appropriate mathematical model, formula, or strategy. Process skills errors refer to mistakes in carrying out mathematical procedures or calculations, while encoding errors occur when students fail to communicate or write the final answer appropriately. This classification provides a systematic framework for examining students' difficulties at different stages of mathematical problem-solving rather than treating all incorrect answers as the same type of error.

The application of Newman-based analysis is particularly relevant to geometry because solving geometric problems requires students to coordinate information presented through written statements, diagrams, mathematical symbols, and computational procedures. A student, for example, may correctly

read the information provided in a circle problem but fail to understand the geometric relationship represented in the diagram. Another student may understand the concept but select an inappropriate formula or make an error during algebraic calculations. Such differences indicate that incorrect answers may originate from different stages of the problem-solving process and therefore require different instructional responses. Mustaghisa and Chandra (2024a) emphasize the value of combining students' written work with interviews to obtain a deeper understanding of the reasoning underlying their errors. Furthermore, Dewi et al. (2020) demonstrated that students' geometric errors can be examined through the integration of Newman's error categories and Van Hiele's levels of geometric thinking. This suggests that students' errors may also be associated with their ability to recognize geometric properties, establish relationships, and develop more advanced geometric reasoning.

Recent international research further demonstrates the relevance of Newman-based analysis in geometry education. Asare et al. (2026), in their study published in Frontiers in Education, examined senior high school students' errors in solving circle theorem problems using Newman's Error Analysis. Their findings indicated that transformation errors and process skills errors were the most frequently observed categories, followed by comprehension, reading, and encoding errors. Interviews also revealed difficulties in visualizing geometric relationships, managing multistep reasoning, understanding mathematical terminology, and applying appropriate procedures. These findings reinforce the importance of examining not only the types of errors but also the factors that students perceive as contributing to their difficulties. However, the study focused specifically on circle theorem problems, whereas circle geometry encompasses other mathematical content that requires different forms of conceptual understanding and representation.

A similar issue was identified during preliminary observations at SMA GKST 1 Tentena. Most students obtained scores below the minimum mastery criterion on a mathematics test covering circle-related topics. This initial finding indicates that students may still experience difficulties in understanding and applying circle concepts. However, the preliminary test scores alone cannot explain the specific stages at which these difficulties occur. It is therefore necessary to investigate students' written solutions and explore their reasoning through interviews to obtain a more detailed understanding of the errors they make. Such an investigation is important because identifying the specific categories of errors can provide teachers with more relevant information for designing instructional strategies that address students' actual learning difficulties.

Although previous studies have examined students' errors using Newman's framework across various mathematical topics, further investigation is needed to understand how these errors appear across different circle-related concepts at the senior high school level. In particular, the present study examines three types of circle-related tasks: inscribed angles, circle circumference, and the equation of a circle. These topics were selected because they involve different but interconnected mathematical demands, ranging from understanding geometric relationships and applying formulas to translating geometric information into algebraic representations. In addition, this study combines written responses with task-based interviews to identify students' error categories and explore the reasoning associated with those errors. Unlike studies that focus exclusively on circle theorems or a single circle-related concept, this study provides a context-specific description of students' errors across three different areas of circle geometry at SMA GKST 1 Tentena. Its contribution lies in examining how the five categories of Newman errors manifest across these tasks and identifying instructional considerations based on the difficulties revealed by the students' responses.

Based on this background, this study aimed to (1) identify and describe Grade 11 students' errors in solving circle geometry problems using Newman's five categories, namely reading, comprehension, transformation, process skills, and encoding errors; and (2) describe the factors that appear to be associated with these errors based on students' written responses and task-based interviews. The

findings are expected to provide teachers with a more detailed understanding of students' difficulties in solving circle geometry problems and serve as a basis for developing instructional approaches that strengthen conceptual understanding, geometric reasoning, mathematical representation, procedural accuracy, and the ability to communicate mathematical solutions.

METHOD

This study used a qualitative approach with a descriptive design to describe students' errors in solving circle problems without introducing any instructional treatment or intervention. A qualitative descriptive design is appropriate when researchers aim to provide a comprehensive description of a phenomenon based on participants' experiences and collected data (Sandelowski, 2000). The study was conducted at SMA GKST 1 Tentena, Poso Regency, Central Sulawesi, Indonesia. Six Grade 11 students were purposively selected based on a diagnostic test: two with high, two with moderate, and two with low mathematical ability. The diversity of errors in their written responses was also considered when selecting participants. Purposive sampling enables researchers to select participants who can provide relevant and information-rich data in accordance with the research objectives (Malterud et al., 2016). Because the sample was small and non-random, the findings are intended to explain the cases examined rather than estimate the prevalence of errors in the wider student population.

Data was collected through a written test, task-based interviews, and documentation. The test consisted of three open-ended problems covering inscribed angles, circle circumference, and the equation of a circle. Semi-structured interviews asked students to explain how they read the problems, understood the information, selected a mathematical model or formula, performed calculations, and wrote their final answers. Documentation included students' answer sheets and visual records produced during the research. Participants' identities are not disclosed in the report. Combining multiple data collection techniques allows researchers to examine a phenomenon from different sources and strengthen the credibility of qualitative findings through methodological triangulation (Carter et al., 2014).

The research instruments comprised a written test and an interview guide developed in accordance with the study objectives and Newman error indicators. The source manuscript states that the instruments were reviewed by mathematics education lecturers and practitioners to assess their relevance and appropriateness. However, the number of reviewers, assessment criteria, and validation results were not reported in detail. The authors should add these details if the relevant records are available. The use of written tests and interviews based on Newman's framework is consistent with previous studies that have employed these instruments to identify and explore students' mathematical errors (Elsa & Sudihartinih, 2020; Triliana & Asih, 2019).

The research was conducted in preparation, data-collection, and analysis stages. Preparation involved preliminary observations, obtaining research permission, and developing and reviewing the instruments. During data collection, the test was administered to the selected participants, their responses were examined for indications of errors, and interviews were conducted to clarify the reasoning behind their solution steps. The final stage involved organizing the test and interview data and preparing the report. The dates and duration of data collection were not provided in the source manuscript and should be added based on the original research records.

Data analysis followed the interactive model of Miles, Huberman, and Saldaña (2014), which comprises data condensation, data display, and conclusion drawing and verification. These three components are interconnected and occur iteratively throughout the research process rather than as strictly sequential stages. Relevant data were selected and grouped according to Newman's error categories, then presented in tables and descriptive narratives. Written responses were compared with

interview accounts to examine the consistency of interpretations. Comparing different data sources also supports the credibility of qualitative interpretations by allowing researchers to examine whether the findings are supported by multiple forms of evidence (Carter et al., 2014). For transparency, the final manuscript should specify who performed the coding, how category decisions were made when a response contained multiple errors, and how differences in interpretation were resolved; these details were not fully explained in the source manuscript.

Errors were classified into Newman's five categories: reading, comprehension, transformation, process skills, and encoding. The operational indicators are summarized in Table 1 based on Elsa and Sudihartinih (2020). These categories provide a systematic framework for identifying the stages at which students experience difficulties when solving mathematical problems (Karnasih, 2015; Triliana & Asih, 2019). Frequencies were calculated from 18 student responses to three problems (six students × three problems). Because a single response could contain more than one error category, the categories were not treated as mutually exclusive. The percentage for each category was calculated by dividing its frequency by 18 responses and multiplying by 100%. Students' errors were analyzed using the five categories in Newman's procedure. The operational indicators used to classify errors are summarized in Table 1.

Table 1. Error Indicators Based on Newman's Procedure

Error Category	Indicator
Reading	The student is unable to recognize or read terms, symbols, or essential information in the problem.
Comprehension	The student does not understand the information given or what is being asked.
Transformation	The student cannot construct a mathematical model or select an appropriate mathematical relationship from the information in the problem.
Process skills	The student makes errors in arithmetic operations, signs, or solution procedures.
Encoding	The student does not write a complete final answer or does not respond appropriately to the problem requirements.

(Elsa & Sudihartinih, 2020)

RESULTS AND DISCUSSION

Results

The analysis covered 18 responses, comprising six students' answers to three open-ended problems. Responses were classified using Newman's five error categories and interpreted alongside task-based interview data. The frequency of errors for each problem is presented in Table 2. Percentages were calculated using 18 responses as the denominator. Because multiple categories could occur in one response, the percentages across categories do not sum to 100%.

Table 2. Frequency of Students' Errors Across Three Problems

Error Category	Problem 1	Problem 2	Problem 3	Total	Percentage
Reading	0	1	0	1	5.6%
Comprehension	2	1	3	6	33.3%
Transformation	1	0	5	6	33.3%
Process skills	1	4	4	9	50.0%
Encoding	0	2	3	5	27.8%

Table 2 shows that process-skill errors were recorded most frequently, with nine cases out of 18 responses (50.0%). Comprehension and transformation errors each occurred six times (33.3%), encoding errors occurred five times (27.8%), and reading errors occurred once (5.6%). These figures represent the frequency of each category among the responses analyzed, not the percentage of students

who experienced each type of error. Process-skill errors appeared most frequently in Problems 2 and 3, whereas transformation errors appeared most frequently in Problem 3.

Discussion

The results indicate that errors occurred not only when students read information, but also when they interpreted problem requirements, constructed mathematical representations, carried out procedures, and communicated final answers. Process-skill errors were the most frequent category in this set of responses. However, because the study involved six purposively selected participants, these results should be understood as patterns within the cases examined and should not be statistically generalized to all Grade 11 students. The following discussion examines the five error categories by relating written responses to interview evidence as reported in the manuscript. Explanations of contributing factors are limited to factors indicated by the research data; they are not treated as causal relationships established through experimental testing.

Reading Errors

One reading error was identified in Problem 2, representing 5.6% of the 18 responses. In Newman's framework, reading errors involve difficulty recognizing words, symbols, or essential information in a problem (Halim & Rasidah, 2019). According to the analysis notes in the manuscript, the student applied a formula without attending carefully to relevant geometric information; the interview also indicated that the problem had not been read carefully. The low frequency suggests that this error was relatively uncommon in the data analyzed, but the single case demonstrates that familiarity with mathematical terminology does not necessarily ensure accurate selection of relevant information. This finding is broadly consistent with discussions of reading errors by Rahmawati and Dhian Permata (2018) and Dewi and Kartini (2021), although those studies addressed different problem contexts.

Comprehension Errors

Comprehension errors occurred six times (33.3%) and appeared across all three problems, particularly Problems 1 and 3. This category refers to difficulty understanding the information provided or identifying what the problem asks. In the circle-angle task, some students were reported to identify the measure of the central angle but fail to use the relationship that an inscribed angle subtending the same arc is half the central angle. Interview findings indicated a tendency to recall formulas without explaining the underlying geometric relationship. This interpretation is consistent with the Van Hiele perspective on the development of geometric reasoning (Mukarom et al., 2023) and research on comprehension errors in mathematical problem solving (Hartini & Setyaningsih, 2023). Because verbatim interview quotations were not included in the source manuscript, claims about students' reasoning should be strengthened with quotations or transcript excerpts in the final version.

Comprehension errors should be distinguished from transformation errors. In the comprehension category, the main problem is interpreting the information and requirements of the task. In the transformation category, students may understand the information but fail to select an appropriate mathematical relationship, formula, or model. This operational distinction is important for consistent coding and for avoiding unclear double-counting of the same error.

Transformation Errors

Transformation errors occurred six times (33.3%) and were most frequent in Problem 3, which concerned the equation of a circle. These errors occurred when students could not convert the given information into a mathematical model or select an appropriate form of the equation. The response

shown in Figure 1 suggests difficulty converting between the general and standard forms of a circle equation, particularly when completing the square. This pattern indicates difficulty connecting algebraic structure with the representation of a circle equation. It is consistent with Wijaya et al. (2014), who examined students' difficulties transforming information into mathematical representations, and Hidayah et al. (2024), who studied mathematical representation in circle-related tasks.

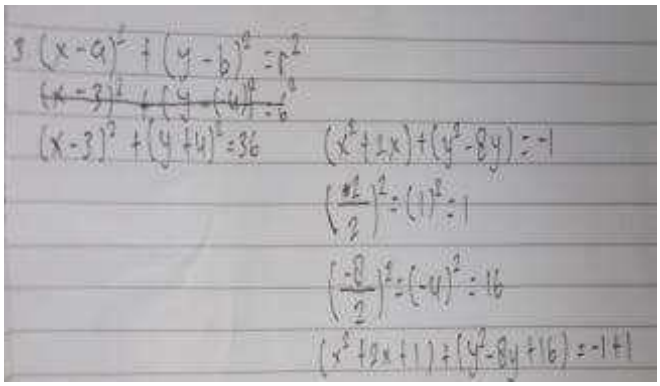


Figure 1. Example of a Transformation Error

Figure 1 highlights the need to present a legible image of the student's solution and briefly identify the specific incorrect step. The manuscript reports that the student had difficulty converting the general equation of a circle into standard form and vice versa. In the final revision, the authors should ensure that all symbols in the image are readable and explicitly indicate the incorrect algebraic operation. This explanation would make the link between the visual evidence and the assigned error category easier to verify.

Process-Skill Errors

Process-skill errors were the most frequent category, with nine cases (50.0%), particularly in Problems 2 and 3.

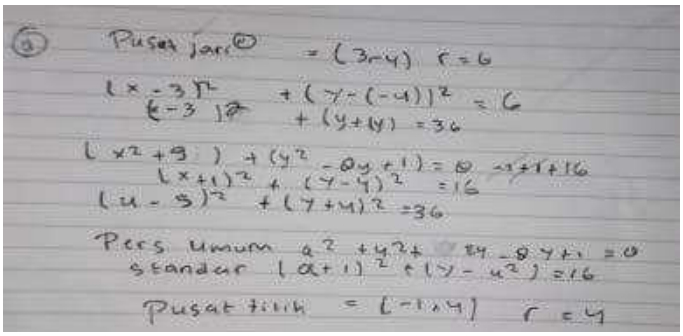


Figure 2. Example of a Process-Skill Error

Process-skill errors occurred when students selected a relevant formula or model but made mistakes during calculation. The manuscript reports arithmetic errors, incorrect use of signs, and procedural inaccuracies. In the chord problem, some students reportedly used the Pythagorean theorem but calculated a square root incorrectly; in the circle-equation problem, errors occurred when expanding squared expressions. These examples indicate that selecting the correct formula does not necessarily lead to accurate execution, as also discussed by Karnasih (2015).

The interviews indicated that carelessness and a tendency not to check answers were associated with these errors. This interpretation is consistent with Winarso et al. (2022), who discussed procedural errors in mathematical problem solving. One instructional implication is that teachers can ask students to show each calculation step, check operations and signs, and use substitution or estimation to assess

whether a result is reasonable. This is a pedagogical implication drawn from the observed pattern, not an intervention tested in this study.

Encoding Errors

Encoding errors occurred five times (27.8%) in Problems 2 and 3. These errors occurred when students did not present complete final answers, for example by omitting units or failing to write a conclusion that addressed the question. Some students were reported to have obtained a calculation result but omitted the appropriate unit or a relevant concluding statement. This category concerns the final stage of Newman's procedure: communicating the solution completely.

The interviews indicated that students were not accustomed to writing conclusions because this aspect was rarely emphasized during instruction. This finding is consistent with Payadnya (2021), who discussed incomplete responses to mathematics open-ended questions. Teachers could use a simple checklist: does the final answer address the question, are units included when needed, and is the conclusion stated clearly? As with the other categories, claims about classroom practices should be supported by interview quotations or observation records to make the interpretation transparent.

CONCLUSION

Based on the analysis of 18 responses from six Grade 11 students to three circle-related problems, process-skill errors were the most frequent (9 cases; 50.0%), followed by comprehension and transformation errors (6 cases each; 33.3%), encoding errors (5 cases; 27.8%), and reading errors (1 case; 5.6%). Percentages were calculated using 18 responses as the denominator, and because multiple error categories could occur in a single response, the percentages are not expected to total 100%. Written responses and interviews indicated difficulties in understanding geometric relationships, constructing mathematical representations, carrying out calculations accurately, and presenting complete final answers. Given the descriptive design and small sample, the findings cannot be statistically generalized. Future research should report coding and instrument-validation procedures in greater detail and include more participants and a wider variety of problems. In classroom practice, teachers may emphasize conceptual explanations, step-by-step calculations, and the communication and verification of final answers.

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