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ANALYSIS OF STUDENTS' MATHEMATICAL REPRESENTATION ERRORS IN SOLVING CIRCLE PROBLEMS

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Abstract

Mathematical representation plays an important role in solving geometry problems because students need to coordinate information across different forms of representation. This study aims to describe the characteristics and patterns of students' mathematical representation errors in solving circle problems. A descriptive qualitative approach was employed with 23 Mathematics Education students from one class. Data were collected through an essay test involving visual, symbolic, and verbal representations and analyzed to identify error characteristics and relationships among representations. The results revealed five main types of errors: visual representation errors; visual-to-symbolic transformation errors; errors in constructing and manipulating symbolic representations; errors in selecting appropriate concepts or symbolic representations; and verbal representation errors. The findings further indicate that, in several responses, errors continued across representations, particularly when inaccurate interpretation of geometric information was carried over into symbolic representations and verbal explanations. These findings suggest that effective problem solving in circle topics depends not only on the accuracy of individual representations but also on students' ability to coordinate information across representations. Therefore, analytic geometry instruction should explicitly engage students in constructing, translating, and examining relationships among visual, symbolic, and verbal representations.

Keywords: analytic geometry, circle, mathematical representation, representation errors

Abstrak

Representasi matematis memainkan peran penting dalam menyelesaikan masalah geometri karena siswa perlu mengoordinasikan informasi dalam berbagai bentuk representasi. Penelitian ini bertujuan untuk mendeskripsikan karakteristik dan pola kesalahan representasi matematis mahasiswa dalam menyelesaikan masalah lingkaran. Penelitian ini menggunakan pendekatan deskriptif kualitatif dengan melibatkan 23 mahasiswa Pendidikan Matematika dari satu kelas. Data dikumpulkan melalui tes esai yang melibatkan representasi visual, simbolik, dan verbal, kemudian dianalisis untuk mengidentifikasi karakteristik kesalahan serta hubungan antarreprentasi. Hasil penelitian mengungkapkan lima jenis kesalahan utama, yaitu: kesalahan dalam representasi visual; kesalahan dalam mentransformasikan representasi visual ke simbolik; kesalahan dalam menyusun dan memanipulasi representasi simbolik; kesalahan dalam memilih konsep atau representasi simbolik yang tepat; serta kesalahan dalam representasi verbal. Hasil penelitian juga menunjukkan bahwa pada beberapa respons, kesalahan berlanjut dari satu bentuk representasi ke bentuk representasi lainnya, terutama ketika interpretasi yang tidak tepat terhadap informasi geometris terbawa ke dalam representasi simbolik dan penjelasan verbal. Temuan ini menunjukkan bahwa pemecahan masalah yang efektif pada materi lingkaran tidak hanya bergantung pada ketepatan setiap representasi secara individual, tetapi juga pada kemampuan mahasiswa dalam mengoordinasikan informasi antarreprentasi. Oleh karena itu, pembelajaran geometri analitik perlu secara eksplisit melibatkan mahasiswa dalam membangun, menerjemahkan, dan mengkaji hubungan antara representasi visual, simbolik, dan verbal.

Kata kunci: geometri analitik, lingkaran, representasi matematis, kesalahan representasi

INTRODUCTION

Mathematical representation is an essential component of mathematics learning because it enables students to construct, organize, and communicate mathematical ideas through multiple forms, including visual, symbolic, and verbal representations. The

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appropriate use of these representations can support conceptual understanding and facilitate the development of strategies for solving mathematical problems (Erbilgin & Gningue, 2023; Thompson & Chappell, 2007). Representation also serves not merely as an outcome of mathematical thinking but as a means for exploring, monitoring, and developing problem-solving strategies (Stylianou, 2011). The ability to coordinate different representations further supports students in developing flexible understandings of mathematical relationships through processes of abstraction and generalization (Erbilgin & Gningue, 2023). These perspectives position mathematical representation as an integral part of constructing mathematical understanding rather than as a separate skill applied after conceptual learning has taken place.

Representation is particularly important in geometry because geometric objects and relationships involve multiple forms. Visual representations support spatial identification, while symbolic and verbal forms formalize and communicate relationships. Students' representation use is associated with cognitive and visuospatial abilities; reflective students show greater capacity to construct and translate representations (Rahmah et al., 2019), while students with stronger visuospatial abilities have been able to construct visual models despite experiencing difficulties in verbalizing their conclusions (Jumiarti et al., 2025). Thus, geometric competence involves coordinating representations within the same reasoning process.

Circle problems provide an ideal context for examining mathematical representations, as they require coordinating visual geometric information—such as centers and radii—with symbolic equations and verbal explanations. Visualizing these features supports their subsequent mathematical formalization (Magro & Valente, 2021). Consequently, solving these problems demands continuous consistency across representations rather than mere formula application, making the circle context perfect for studying how students construct and translate mathematical ideas in analytic geometry.

Coordinating representations also creates opportunities for errors when students construct diagrams, interpret information, identify centers or radii, select concepts, manipulate symbols, or explain reasoning. Previous studies report comprehension, transformation, process-skill, conceptual, computational, and strategic errors (Hajizah & Salsabila, 2024; Imswatama & Muhassanah, 2016; Puspita et al., 2025), as well as difficulties decoding information and persistent conceptual and procedural difficulties in geometry

(Hajizah & Salsabila, 2024; Listiani, 2019; Umar, 2025). However, these previous studies have predominantly focused on classifying errors into isolated categories such as conceptual versus procedural difficulties without sufficiently examining the interconnections among these errors across different representational forms.

While existing literature documents isolated geometry errors, a gap remains in understanding how an error in one representation cascades into another in circle problems. This study addresses this gap by viewing representations as interconnected cognitive processes. We define "visual representation" as the spatial construction of figures, "symbolic representation" as their translation into algebraic equations, and "verbal representation" as written explanations of reasoning. This selection is grounded in the theory that robust mathematical understanding requires fluid translation among visual, symbolic, and verbal modes (Erbilgin & Gningue, 2023).

This study moves beyond isolated error categories to trace how inaccuracies cascade across representations. By examining these cross-representational patterns, the study aims to uncover their pedagogical meanings and propose concrete, evidence-based instructional strategies for coordinating multiple representations.

METHODS

This descriptive qualitative study analyzed how students construct and coordinate visual, symbolic, and verbal representations when solving circle problems. Conducted in May 2026 at a university in Kolaka, Indonesia, the study involved 23 sixth-semester Mathematics Education students enrolled in a Plane Analytic Geometry course. Using total sampling, all 23 written responses were analyzed to describe error characteristics and their cross-representational relationships.

Data were collected using an open-ended representation test based on indicators relevant to circle topics. The instrument consisted of two main problems designed to elicit cross-representational processes. Question 1 required students to (a) visually represent points A and B on a Cartesian plane and construct a circle using segment AB as the diameter, (b) determine the center and radius based on the constructed image (visual-to-symbolic transformation), and (c) determine the circle's equation (symbolic). Question 2 required students to (a) determine the general equation of a circle given its center and a point it passes through (symbolic), and (b) explain the steps taken to find that equation (verbal).

This structure enabled the analysis of errors within and across representations. A response was categorized as an error in a specific representation if the student failed to meet the required indicator (e.g., an incorrect diagram for visual, an incorrect equation for symbolic, or an illogical explanation for verbal). Before data collection, experts validated the instrument for alignment with representation indicators, circle content, and study objectives. Validation ensured that the test elicited the required visual, symbolic, and verbal representations.

The revised instrument was administered to 23 participants, whose responses formed the primary data. To ensure analytical transparency, the qualitative data was first reduced by identifying inaccuracies in students' answers. Next, open coding labeled specific errors, which were then grouped based on shared characteristics. This iterative process yielded five main error types: visual representation, visual-to-symbolic transformation, symbolic construction and manipulation, concept or symbolic representation selection, and verbal representation errors.

Relationships were then traced to determine whether errors at one stage appeared in subsequent representations. To define a 'cascading error' (cross-representational error), clear criteria were established: an error is considered cascading if the incorrect output from one representational stage (e.g., a wrong center coordinate derived visually) is directly used as the input for the subsequent stage (e.g., substituting that wrong coordinate into the symbolic equation), rather than being a new, independent computational mistake.

To ensure the trustworthiness and analytical consistency of the qualitative findings, several strategies were employed. Data triangulation was conducted by cross-examining students' written responses across the different items (Question 1 and Question 2) to observe the consistency of their representation choices and error patterns. Interpretation relied on observable diagrams, expressions, calculations, and explanations. Because no interviews were conducted, interpretations were limited to patterns evident in written work.

RESULTS AND DISCUSSION

Overview of Mathematical Representation Errors

Analysis of the 23 students' written responses identified five main types of mathematical representation errors in solving circle problems: (1) visual representation, (2)

visual-to-symbolic transformation, (3) symbolic construction and manipulation, (4) concept or symbolic representation selection, and (5) verbal representation errors. These errors occurred at various stages, from interpreting geometric information to formulating equations and explaining solutions. The distribution of these errors among the participants is summarized in Table 1.

Table 1. Summarizes The Frequency of These Error Categories Across The 23 Participants

Error Type	Identified Subjects	Frequency (n)	Percentage (%)
Visual Representation	M1, M3, M5, M6, M14, M15, M16, M20	8	34.8
Visual-to-Symbolic Transformation	M1, M3, M5, M6, M14, M20	6	26.1
Symbolic Construction/Manipulation	M1, M8, M21, M22	4	17.4
Concept/Symbolic Representation Selection	M2, M4, M7, M9, M10, M11, M13, M14, M17, M23	10	43.5
Verbal Representation	M3, M5, M6, M9, M14, M22	6	26.1

As shown in Table 1, errors in selecting appropriate concepts or symbolic representations were the most frequent (43.5%). This was followed by visual representation errors at 34.8%. Errors in visual-to-symbolic transformation and verbal representation each occurred in 26.1% of the responses. Finally, errors in symbolic construction and manipulation were the least frequent, appearing in 17.4% of the responses.

Beyond these frequencies, analysis revealed that earlier inaccuracies often cascaded into subsequent representations. This reinforces that mastering mathematical representation requires coordinating meaning across forms rather than producing them in isolation (Erbilgin & Gningue, 2023). Therefore, circle problems demand consistent geometric information from visual construction to symbolic and verbal explanations.

Errors in Visual Representation and Its Transformation into Symbolic Form

Visual representation errors involved misinterpreting geometric elements like points, centers, and radii. These inaccuracies frequently cascaded into symbolic representations when students used flawed diagram data to formulate circle equations. Figure 1 illustrates this pattern in M14's response to Question 1. The error here meets the criteria for a cross-

representational error because the incorrect center and diameter derived from the visual stage were explicitly transferred and used as inputs for determining the radius and formulating the circle equation in the symbolic stage.

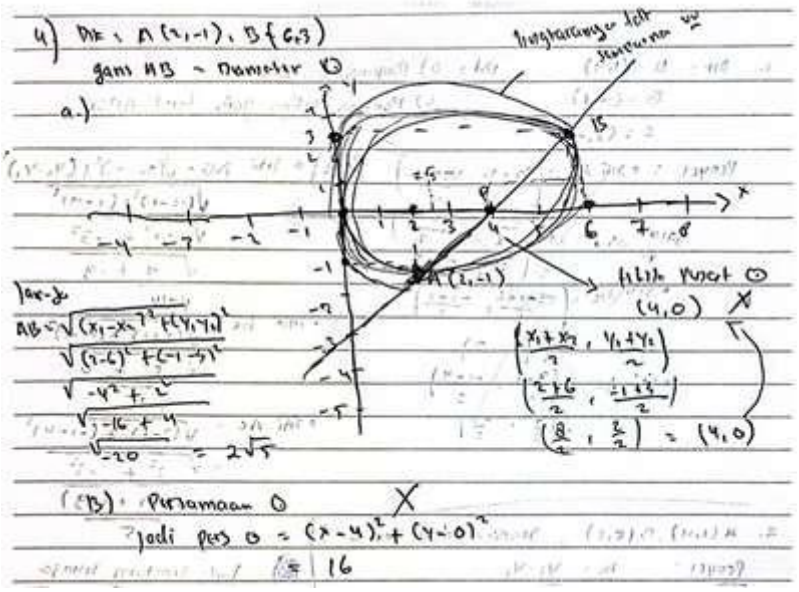


Figure 1. Visual and Visual-to-Symbolic Transformation Errors in M14's Response to Question 1

Similar characteristics were identified in M1, M3, M5, M6, M15, M16, and M20, although the specific errors varied. Their responses showed inaccuracies in interpreting or using geometric information to determine the center, diameter, or radius. For most of these students, these visual inaccuracies carried over into subsequent symbolic representations. However, M15 and M16 presented a unique case: they made visual errors but avoided visual-to-symbolic transformation errors. This occurred because they bypassed their own flawed diagrams entirely, relying instead on the textual information from the problem prompt to formulate their equations. This indicates a disconnected use of representations, where students treat drawing merely as a formal requirement rather than a functional tool for symbolic problem-solving.

M14 exemplifies this: an incorrect center and diameter directly caused a flawed radius and circle equation. This proves visual representation is foundational, not merely illustrative, as diagram errors persist symbolically. This aligns with Sudihartinih (2018), who found that early misinterpretations of circle elements hinder subsequent solutions. Similarly, Sudihartinih & Purniati (2020) reported that students with low geometric thinking view conics

holistically without examining elemental relationships, making them prone to construction and interpretation errors.

Visual-to-symbolic transformation errors in M1, M3, M5, M6, M14, and M20 highlight difficulties in transferring geometric information without losing mathematical meaning. This aligns with Asmar & Delyana (2020) who found students frequently struggle at the transformation stage, failing to convert geometric data into correct equations. From a cognitive perspective, this suggests a breakdown in translation between spatial-visual processing and algebraic reasoning. Solving circle problems requires not only formula mastery but also accuracy in transferring the cognitive schema of a geometric object into its corresponding symbolic formulation.

Errors in Symbolic Representation

Symbolic representation errors took two forms: manipulating expressions (flawed substitutions or algebra) and selecting inappropriate concepts. For example, M1 correctly identified the center (4,1) but calculated an incorrect radius. Substituting this flawed value yielded an incorrect equation, demonstrating how a single mathematical error cascades through subsequent symbolic procedures.

A different symbolic error occurred in M2, M4, M7, M9, M10, M11, M13, M14, M17, and M23, who erroneously applied a line equation to a circle problem. As illustrated in Figure 2, M4 used a two-point line equation instead of deriving the circle equation, demonstrating a clear mismatch between the required mathematical object and the selected symbolic representation.

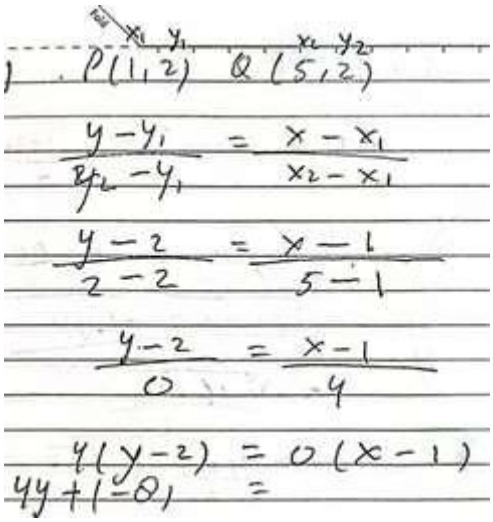


Figure 2. Error in Selecting a Symbolic Representation in M4's Response to Question 2

The use of a line equation was also identified in M2, M7, M9, M10, M11, M13, M14, M17, and M23. These responses showed the same mismatch between the required mathematical object and the selected symbolic representation, although their solution procedures varied.

The two symbolic errors identified—equation manipulation and concept selection—showed different characteristics and carry different pedagogical meanings. In M1, M8, M21, and M22, the issue was procedural; an incorrect radius from an earlier stage led to incorrect algebraic manipulation, although the equation structure was correct. This cascading pattern is consistent with the findings of Hajizah & Salsabila (2024), who applied Newman's Error Analysis framework to analytic geometry problems and found that transformation errors tend to lead to process-skill and encoding errors because the initial information error carries through to the final solution.

However, concept-selection errors (e.g., using a line equation instead of a circle equation) are more fundamental. Pedagogically, this indicates a conceptual difficulty in recognizing the defining characteristics of mathematical objects, rather than merely a computational mistake. Students experiencing this error likely view formulas as interchangeable procedural tools rather than symbolic representations of distinct geometric forms (a line versus a circle). Imswatama & Muhassanah (2016) similarly found conceptual errors among mathematics education students involving difficulties distinguishing the characteristics and solution procedures of lines and circles. From a semiotic representation perspective, Ramadani et al. (2025) also showed that representation errors may originate from inaccurate interpretation of a geometric object before it is expressed symbolically. Thus, these errors suggest that some students had not fully understood the distinctive characteristics of the circle equation, particularly the center and radius as its determining parameters, compared with the linear equation.

Errors in Verbal Representation and Inconsistency Across Representations

Verbal representation errors involved incomplete, irrelevant, or inconsistent explanations, which sometimes occurred despite correct procedural steps. This highlights varying abilities in communicating mathematical reasoning. For instance, M3 listed steps

without explaining their relationships, M5 included unnecessary procedures, and M6 lacked underlying reasoning. Conversely, the verbal explanations of M9, M14, and M22 directly reflected their earlier conceptual or symbolic inaccuracies.

Figure 3 illustrates inconsistency in mathematical representation within M13's responses to Questions 1 and 2. M13 used a line equation in Question 1 but a circle equation in Question 2 and obtained an appropriate result. This contrast indicates that the student's representation choices were inconsistent across problem contexts.

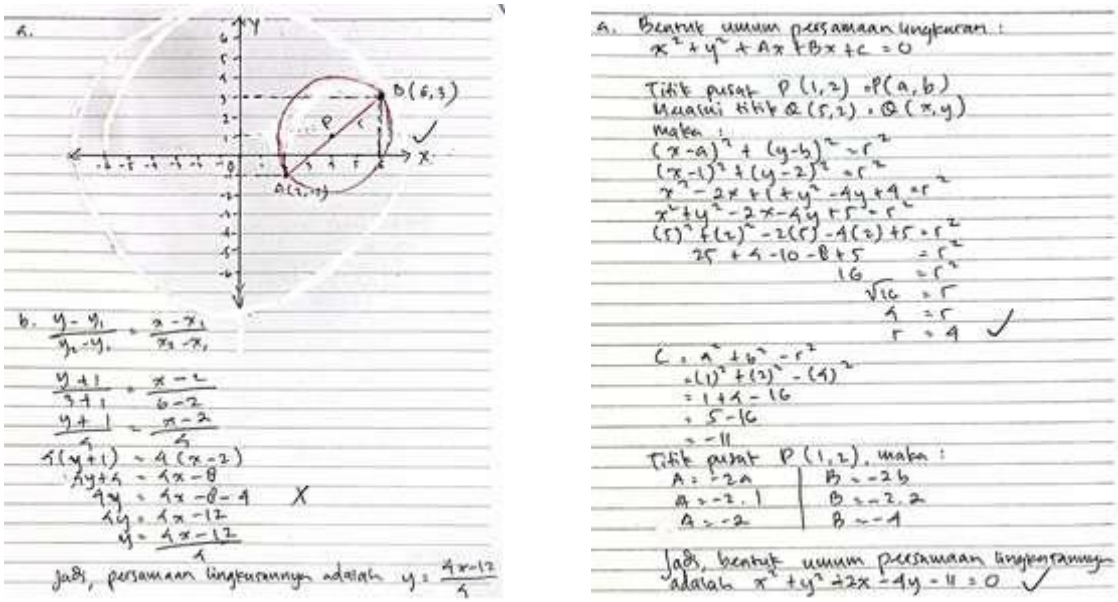


Figure 3. Inconsistency in Mathematical Representations Use in M13's Responses to Questions 1 and 2

Verbal errors—such as incomplete (M3), irrelevant (M5), or insufficiently reasoned explanations (M6)—demonstrate that communicative and procedural abilities do not always develop concurrently. This aligns with Reinhold et al. (2020) who noted that verbal reasoning contributes distinctly from numerical and spatial abilities. Consequently, some students struggle verbally despite symbolic accuracy, while others (M9, M14, M22) merely reflect their symbolic inaccuracies in their verbal explanations.

Furthermore, M13's inconsistency—applying a linear equation in one context but a circle equation in another—shows that accurate representation selection requires recognizing specific object characteristics and adapting to problem demands, not just procedural mastery. Consistent with Rahmah et al. (2019), this highlights the necessity of strengthening representation selection through practice across varied geometric contexts.

Cross-Representation Patterns

Analysis across representations showed that errors could carry over from one representation to another. In several responses, visual inaccuracies affected the determination of mathematical elements and subsequent symbolic formulations, while symbolic errors were reflected in verbal explanations, creating related inaccuracies throughout the solution process.

The most comprehensive pattern appeared in M14, whose response contained errors in visual representation, visual-to-symbolic transformation, equation formation, and verbal explanation. In contrast, Figure 4 shows M12's responses to Questions 1 and 2 as an example of consistent coordination among visual, symbolic, and verbal representations. Similar consistencies were also demonstrated by M18 and M19. M12 correctly determined the center as (4,1), obtained $r = \sqrt{8}$, formulated the standard and general circle equations, and appropriately explained the solution procedure.

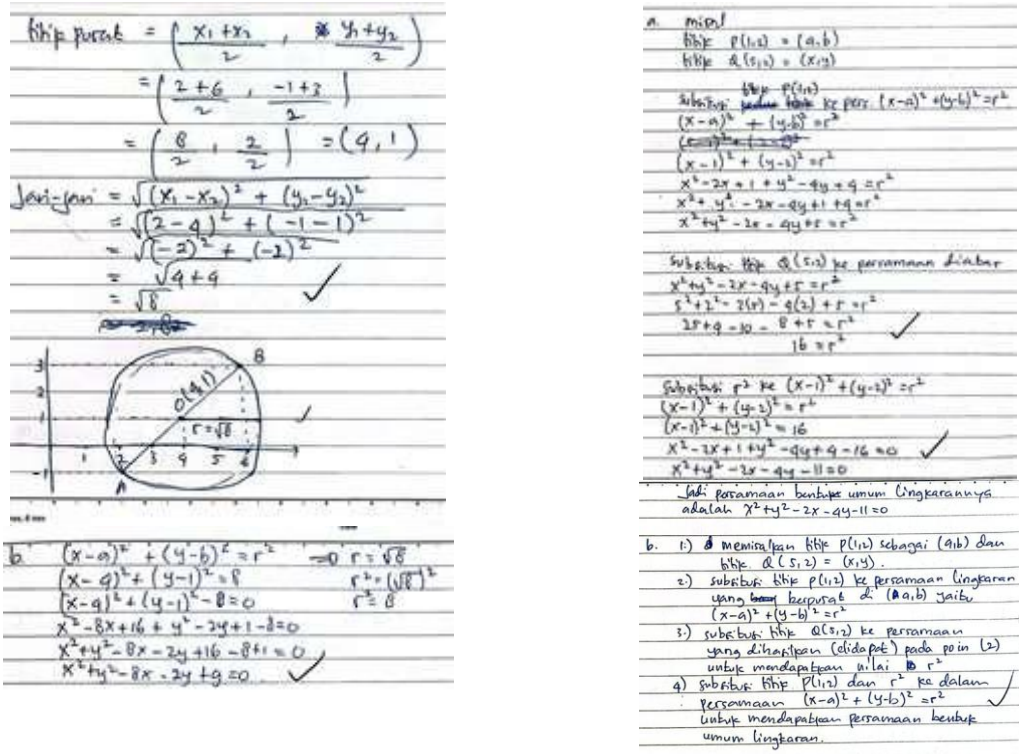


Figure 4. Consistent Use of Visual, Symbolic, and Verbal Representations in M12's Responses to Questions 1 and 2

The contrast between M14's cascading inaccuracies and the consistency shown by students like M12, M18, and M19 across visual, symbolic, and verbal forms demonstrates that solving circle problems requires maintaining mathematical meaning across representations,

not just mastering them individually. This aligns with Husain et al., (2025) who found that technology-supported learning strengthens students' ability to connect and transform mathematical ideas across representations. Similarly, Guci et al. (2024) showed that coordinating multiple representations yields more coherent solutions, whereas relying on a single form increases susceptibility to subsequent errors. From a representation theory perspective, cross-representation errors occur because the translation process requires cognitive flexibility to map meaning from one semiotic system to another. When the initial encoding (e.g., the visual model) is flawed, the subsequent decoding and re-encoding into symbols or text will inherently carry that flaw if the student lacks the metacognitive ability to monitor and verify consistency across formats.

These findings suggest instruction must explicitly train students to construct, translate, and verify representational connections rather than focus solely on final answers. Because weak foundational concepts often carry over into complex problems (Hartini, 2020), addressing visual errors early is crucial to prevent subsequent structural mistakes (Inganah et al., 2021). Furthermore, interconnecting visual and symbolic forms fosters relational understanding over mere procedural memorization (Amir et al., 2021).

Overall, students' errors were multi-staged and interrelated—spanning visual interpretation, symbolic transformation, and verbal explanation. This highlights the need for analytic geometry instruction that integrates algebraic procedures with the explicit coordination of multiple representations as a unified mathematical thinking process (Erbilgin & Gningue, 2023; Guci et al., 2024).

CONCLUSION

This study concludes that students' errors in solving circle problems span visual, symbolic, and verbal domains—encompassing construction, transformation, selection, manipulation, and explanation—and frequently cascade across representations. Applying inappropriate models, such as using a line equation for a circle, indicates these errors stem from conceptual deficits rather than mere computational mistakes. Ultimately, solution quality relies heavily on the student's ability to maintain and coordinate mathematical meaning across multiple representations.

These findings offer concrete instructional implications for Plane Analytic Geometry. Rather than treating representations sequentially, instruction should integrate them

concurrently. Specific strategies include representation-mapping exercises—where students explicitly connect diagram elements to their corresponding algebraic symbols and written descriptions—and error-analysis tasks. By evaluating cascading errors (e.g., M14) to pinpoint translation breakdowns, these targeted activities foster both procedural accuracy and a coherent understanding of the relational structure among mathematical representations

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REFERENCES

Amir, M. F., Wardana, M. D. K., & Usfuriah, D. (2021). VISUAL AND SYMBOLIC REPRESENTATION FORMING: A CASE OF RELATIONAL UNDERSTANDING ON ELEMENTARY STUDENT. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(4), 2014–2028. https://doi.org/https://doi.org/10.24127/ajpm.v10i4.4361

Asmar, A., & Delyana, H. (2020). Analysis of student error in completion analytical geometry problems in circle and sphere material. *Journal of Physics: Conference Series*, *1554*. https://doi.org/10.1088/1742-6596/1554/1/012037

Erbilgin, E., & Gningue, S. M. (2023). Using the onto-semiotic approach to analyze novice algebra learners' meaning-making processes with different representations. *Educational Studies in Mathematics*, *114*, 337–357. https://doi.org/https://doi.org/10.1007/s10649-023-10247-8

Guci, A. A. J., Ismaimuza, D., & Lefrida, R. (2024). Profil Penyelesaian Soal Geometri Analitik Datar Mahasiswa Camper Berdasarkan Gaya Kognitif. *Mathema: Jurnal Pendidikan Matematika*, *6*(1), 127–140.

Hajizah, M. N., & Salsabila, E. (2024). Analisis Kesalahan Mahasiswa dalam Menyelesaikan Masalah Geometi Analitik Berdasarkan Newman's Error Analysis. *Plusminus: Jurnal Pendidikan Matematika*, *4*(1), 191–198. https://doi.org/https://doi.org/10.31980/plusminus.v4i1.1749

Hartini, H. (2020). Profil kesalahan konseptual dan prosedural mahasiswa STKIP Paris Barantai dalam menyelesaikan soal geometri analitik datar. *Cendekia: Jurnal Ilmiah Pendidikan*, *8*(1), 22–31. https://doi.org/https://doi.org/10.33659/cip.v8i1.147

Husain, D. S., Meiliati, R., Nuralda, Aswin, & Salido, A. (2025). Application of Project-Based Learning Assisted by Microsoft Mathematics to Improve Students' Mathematical Representation Ability. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *14*(4). https://doi.org/http://dx.doi.org/10.24127/ajpm.v14i4.14250

Imswatama, A., & Muhassanah, N. (2016). ANALISIS KESALAHAN MAHASISWA DALAM MENYELESAIKAN SOAL GEOMETRI ANALITIK BIDANG MATERI GARIS DAN LINGKARAN. *Suska Journal of Mathematics Education*, *2*(1), 1–12. https://doi.org/https://doi.org/10.24014/SJME.V2I1.1368

Inganah, S., Nabila, A. I., & Putri, O. R. U. (2021). KESALAHAN KONSTRUKSI KONSEP MATEMATIS DALAM PROSES REPRESENTASI VISUAL MAHASISWA. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *10*(3), 1776–1786. https://doi.org/https://doi.org/10.24127/ajpm.v10i3.3993

Jumiarti, Sukmawati, & Muzaini, M. (2025). Measuring the Mathematical Representation Ability of Vocational High School Students in Solving Geometry Problems. *Indonesian Journal of Research and Educational Review*, *5*(1), 636–650. https://doi.org/https://doi.org/10.51574/ijrer.v5i1.4511

Listiani, T. (2019). Analisis Kesalahan Mahasiswa Pendidikan Matematika Dalam Menyelesaikan Soal Geometri Pada Topik Bangun Ruang. *JOHME: Journal of Holistic Mathematics Education*, *3*(1), 44–62. https://doi.org/10.19166/JOHME.V3I1.1708

Magro, T. D., & Valente, M. (2021). On the representational role of Euclidean diagrams: representing qua samples. *Synthese*, *199*, 3739–3760. https://doi.org/https://doi.org/10.1007/S11229-020-02953-0

Puspita, N., Caswita, & Wijaya, A. P. (2025). Analisis Kesalahan Kemampuan Representasi Matematis dalam mengerjakan Soal Matematika Materi Statistik. *Mandalika Mathematics and Educations Journal*, *7*(4), 1774–1788. https://doi.org/https://doi.org/10.29303/jm.v7i4.10577

Rahmah, F., Muhsetyo, G., & Irawati, S. (2019). Student Mathematical Representation Ability with Reflective Cognitive Style in Solving Geometric Problems. *Jurnal Pendidikan Sains*,

7(4), 132–138. https://doi.org/https://doi.org/10.17977/jps.v7i4.12892

Ramadani, A. P., Suryaningrum, C. W., & Fatqurhohman. (2025). Analisis kesalahan representasi semiotik siswa SMP dalam menyelesaikan masalah segitiga. *Delta-Pi: Jurnal Matematika Dan Pendidikan Matematika*, *14*(1), 105–119. https://doi.org/https://doi.org/10.33387/dpi.v14i1.9962

Reinhold, F., Hofer, S., Berkowitz, M., & Strohmaier, A. (2020). The role of spatial, verbal, numerical, and general reasoning abilities in complex word problem solving for young female and male adults. *Mathematics Education Research Journal*, *32*(2), 189–211. https://doi.org/https://doi.org/10.1007/s13394-020-00331-0

Stylianou, D. A. (2011). An examination of middle school students' representation practices in mathematical problem solving through the lens of expert work: towards an organizing scheme. *Educational Studies in Mathematics*, *76*, 265–280. https://doi.org/https://doi.org/10.1007/s10649-010-9273-2

Sudihartinih, E. (2018). STUDENTS' ERRORS ON THE CIRCLE CONCEPT IN BASIC MATHEMATIC LECTURES. *Erudio Journal of Educational Innovation*, *5*(2), 10–16. https://doi.org/https://doi.org/10.18551/erudio.5-2.2

Sudihartinih, E., & Purniati, T. (2020). Students' Mistakes and Misconceptions on the Subject of Conics. *International Journal of Education*, *12*(2), 92–129. https://doi.org/10.17509/ije.v12i2.19130

Thompson, D. R., & Chappell, M. F. (2007). Communication and Representation as Elements in Mathematical Literacy. *Reading and Writing Quarterly*, *23*(2), 179–196. https://doi.org/https://doi.org/10.1080/10573560601158495

Umar, A. (2025). Kesalahan Konseptual dan Prosedural Mahasiswa Calon Guru Matematika dalam Menyelesaikan Soal Non-Rutin pada Topik Pencerminan. *JUMPER: Jpurnal of Educational Multidisciplinary Research*, *4*(2), 148–158. https://doi.org/10.56921/jumper.v4i2.312