

Error Analysis of Mathematics Education Students in Solving Problems in Analytic Geometry Course

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Abstract

This study aims to identify the challenges faced by Mathematics Education students in learning the Analytic Geometry course. A meta-analysis method was employed by systematically reviewing and analyzing 15 research articles from reputable educational journals that specifically address student difficulties in Analytic Geometry. The findings reveal that students commonly commit four main types of errors when solving Analytic Geometry problems: factual errors (e.g., misusing mathematical symbols), conceptual errors (e.g., misunderstanding or misapplying core definitions and principles), strategic errors (e.g., inability to formulate an appropriate problem-solving plan), and computational errors (e.g., miscalculations due to carelessness or procedural mistakes). These errors persist across students with varying academic achievement levels—low, medium, and high—indicating systemic gaps in conceptual understanding and problem-solving skills. The synthesis further highlights that deficiencies in decoding problem statements, modeling mathematical situations, and verifying final answers significantly contribute to overall performance issues. This study underscores the need for instructional strategies that emphasize deep conceptual understanding, structured problem-solving frameworks, and frequent exposure to varied problem types to mitigate these persistent errors.

Keywords: Analytic Geometry; Factual Errors; Conceptual Errors; Strategic Errors; Computational Errors

Introduction

Mathematics education at the undergraduate level aims not only to transmit mathematical content knowledge but also to cultivate critical thinking, logical reasoning, and problem-solving competencies essential for future educators. Among the core components of this curriculum, geometry occupies a central role due to its dual nature as both an abstract theoretical discipline and a practical tool for modeling real-world spatial relationships. Its foundational status in mathematics makes it indispensable for developing the cognitive structures necessary for advanced mathematical thinking.

Despite its theoretical and pedagogical importance, geometry—particularly at the tertiary level—remains one of the most cognitively demanding domains for students. Numerous studies have documented persistent difficulties among pre-service mathematics teachers in visualizing, representing, and reasoning about geometric concepts. These challenges are often compounded by the transition from synthetic geometry (based on axioms and proofs) to analytic geometry (which integrates algebraic techniques with geometric interpretation), a shift that requires both symbolic fluency and spatial intuition.

Analytic Geometry, as a bridge between algebra and geometry, serves as a critical juncture in the mathematics curriculum. It enables students to translate geometric problems into algebraic equations and vice versa, fostering a deeper understanding of mathematical structures. Mastery of this subject is essential not only for succeeding in advanced courses such as transformation geometry, differential geometry, or linear algebra but also for effectively teaching secondary-level geometry with conceptual clarity and coherence.

However, empirical evidence consistently indicates that students in Mathematics Education programs struggle significantly with Analytic Geometry tasks. Common manifestations include misinterpretation of coordinate systems, incorrect application of distance and midpoint formulas, confusion among conic sections, and inability to connect graphical representations with algebraic expressions. These difficulties often stem from fragmented prior knowledge, weak spatial reasoning skills, and an overreliance on procedural memorization rather than conceptual understanding.

To address these challenges effectively, it is imperative to first identify and categorize the types of errors students commit. Understanding whether errors are factual, conceptual, strategic, or computational informs targeted instructional interventions. Error analysis, therefore, is not merely a diagnostic tool but a pedagogical necessity for improving both teaching practices and learning outcomes in geometry education.

Given the growing body of localized research on student errors in Analytic Geometry across Indonesian higher education institutions, a synthesis of these findings becomes both timely and valuable. While individual studies offer context-specific insights, a meta-analytic approach allows for the identification of cross-institutional patterns, common error typologies, and underlying cognitive obstacles. Such synthesis contributes to a more robust evidence base for curriculum design and teacher preparation.

This study responds to that need by conducting a systematic meta-analysis of empirical research on student errors in Analytic Geometry within Mathematics Education programs in Indonesia. By consolidating findings from multiple studies, this paper seeks to map the landscape of student difficulties, classify recurring error types, and propose evidence-based recommendations for enhancing instructional quality and student learning in this pivotal mathematical domain.

Geometry is one of the compulsory courses in the curriculum of the Mathematics Education study program. According to Susanti and Kurniawan (2019), geometry is a branch of mathematics that deals with the size, position, and shape of objects. Similarly, Budiarto and Artiono (2019, p. 9) emphasize that studying geometry plays a crucial role in developing students' problem-solving skills. In the Mathematics Education program, the geometry course not only serves as a foundational subject but also acts as a prerequisite for Analytic Geometry.

Analytic Geometry generally encompasses the study of lines in two-dimensional space ($\mathbb{R}^2$), lines and planes in three-dimensional space ($\mathbb{R}^3$), and conic sections such as circles, parabolas, ellipses, and hyperbolas. This course also provides the theoretical basis for advanced topics such as Transformation Geometry and Axiomatic Geometry Systems. Through the study of Analytic Geometry, students are expected to develop a solid understanding of planar geometric figures and the positional relationships among lines and other geometric elements.

Analytic Geometry, also known as coordinate geometry, fundamentally redefines geometric inquiry by introducing algebraic methods to analyze spatial relationships. At its core, the subject involves representing geometric objects—such as points, lines, and curves—using coordinates and equations within Cartesian systems. In two-dimensional space ($\mathbb{R}^2$), students explore the properties of lines, distances, slopes, and angles through linear and quadratic equations. This algebraic representation allows for precise calculation and generalization, transforming visual intuition into formal mathematical reasoning.

The scope of Analytic Geometry extends naturally into three-dimensional space ($\mathbb{R}^3$), where students examine the equations and orientations of lines and planes. This expansion introduces greater complexity, as spatial visualization and vector-based reasoning become essential. Concepts such as direction vectors, normal vectors, and parametric equations enable learners to describe and manipulate geometric entities in three dimensions. Mastery of these ideas is critical not only for advanced pure mathematics but also for applications in physics, engineering, computer graphics, and data science.

A central component of the Analytic Geometry curriculum is the study of conic sections—curves formed by the intersection of a plane and a cone. These include circles, parabolas, ellipses, and hyperbolas, each defined by distinct algebraic equations and geometric properties. Understanding conics requires students to fluently move between graphical, symbolic, and verbal representations. This multimodal engagement reinforces the interconnectedness of mathematical domains and cultivates representational flexibility, a key competency for future mathematics educators.

Beyond content mastery, the course is designed to develop higher-order cognitive skills. Students are expected to interpret geometric situations, formulate appropriate algebraic models, execute solution strategies, and validate results—all while maintaining coherence between geometric meaning and symbolic manipulation. This integrative approach fosters deep conceptual understanding, enabling pre-service teachers to not only solve problems but also explain underlying principles and anticipate common student misconceptions in secondary classrooms.

Moreover, Analytic Geometry serves as a critical theoretical foundation for subsequent advanced courses in the mathematics education curriculum. It underpins the study of Transformation Geometry, where concepts like rotation, reflection, and translation are analyzed using matrix algebra and coordinate mappings. It also informs Axiomatic Geometry Systems by providing concrete models for abstract postulates. Thus, proficiency in Analytic Geometry is not merely an endpoint but a gateway—equipping future educators with the analytical tools necessary to navigate and teach increasingly sophisticated mathematical ideas.

Despite its importance, Analytic Geometry remains a challenging subject for many undergraduate students in Mathematics Education. Imswatama and Muhassanah (2016, p. 2) report that student performance in this course is often unsatisfactory, primarily due to difficulties in grasping abstract geometric concepts and a lack of precision in problem-solving. Zahra (2019) further observes that nearly all Mathematics Education students encounter various difficulties in learning Analytic Geometry, including limited conceptual understanding and insufficient exposure to diverse and varied problem types.

These knowledge gaps frequently lead to systematic errors when students attempt to solve Analytic Geometry problems. Susanti and Kurniawan (2021, p. 10) identify ineffective teaching approaches—as failing to foster deep conceptual understanding—as a key contributing factor. This highlights the need for more varied, engaging, and conceptually rich instructional strategies that can enhance student motivation and comprehension in geometry learning.

Moreover, Budiarto (2011) categorizes student errors in geometry learning into three types of skill-related difficulties: (1) Verbal skills—evidenced by poor conceptual understanding, inability to analyze problem statements, and failure to connect related topics; (2) Visual skills—marked by inadequate comprehension of geometric elements and spatial relationships; and (3) Application skills—characterized by difficulties in correctly applying axioms, theorems, and definitions to solve problems.

These findings underscore the necessity of a comprehensive analysis of student errors in Analytic Geometry. Such an analysis can inform the design of targeted pedagogical interventions aimed at strengthening conceptual mastery and improving problem-solving accuracy among pre-service mathematics teachers.

Method

This study employed a meta-analysis approach, which involved a systematic literature review of scholarly journal articles addressing student difficulties in Analytic Geometry within Mathematics Education programs. Meta-analysis was selected as the research method to synthesize and generalize findings across multiple empirical studies, thereby identifying common patterns and types of student errors.

A total of 15 peer-reviewed journal articles were purposively selected based on their relevance to the research focus: challenges and errors encountered by undergraduate students in Mathematics Education when solving Analytic Geometry problems. The article selection process followed a structured four-stage procedure adapted from established systematic review protocols:

1. Topic identification: Defining the core research focus—student errors in Analytic Geometry within Mathematics Education.
2. Literature screening: Identifying and selecting relevant journal articles that specifically investigate student errors or learning difficulties in Analytic Geometry.
3. Thematic analysis and synthesis: Extracting, categorizing, and integrating key findings related to error types (e.g., factual, conceptual, strategic, computational) across the selected studies.
4. Review organization and reporting: Structuring the synthesized results into coherent analytical themes to support evidence-based conclusions.

All selected articles were published in accredited academic journals and met predefined inclusion criteria, including clear descriptions of participants, methodology, and error analysis frameworks. This systematic approach enhances the reliability and validity of the meta-analytic findings, offering a comprehensive overview of persistent challenges in Analytic Geometry instruction and learning.

Results and Discussion

This meta-analysis synthesized findings from 15 empirical studies published between 2016 and 2025 that investigated student errors in Analytic Geometry within Mathematics Education programs across Indonesian higher education institutions. The selected studies employed diverse analytical frameworks—including Newman’s Error Analysis, Polya’s problem-solving model, and qualitative error categorization—to identify recurring patterns in student difficulties. Table 1 presents an overview of the included studies.

Table 1. Summary of Reviewed Studies on Student Errors in Analytic Geometry

No.	TITLE OF STUDY	AUTHORS	YEARS	PARTICIPANTS	
1	Analysis of Factual and Conceptual Errors in Solving Spatial Analytic Geometry Problems	Syamsuddin Masud	2020	Mathematics students, FMIPA, UNM	
2	Student Errors in Analytic Geometry Based on Academic Achievement Levels	Fajar Arwadi, Asmaun, & Ruslan	2024	Mathematics students, UNM	Education
3	Error Analysis in Analytic Geometry Using Newman’s Error Analysis	Mimi Nur Hajizah & Ellis Salsabila	2024	Mathematics students, UNJ	Education
4	Errors in Solving Plane Analytic Geometry Problems: Lines and Circles	Aristya Imswatama & Nur’aini Muhassanah	2016	Mathematics students, UMS	Education
5	Analytic Geometry Problem-Solving Errors Through Polya’s Framework	Ninda Ika Murniasih & Rudhita Kislamiyanti Nur Karimah	2023	Mathematics students, UNWA	Education
6	Misconceptions in Conic Sections Among Pre-Service Teachers	Dian Pratiwi & Bambang Suryadi	2021	Mathematics students, UPI	Education
7	Cognitive Obstacles in Understanding Vector Equations in R^3	Rina Febriana & Hendra Wijaya	2022	Mathematics students, UNNES	Education

No.	TITLE OF STUDY	AUTHORS	YEARS	PARTICIPANTS	
8	Error Patterns in Coordinate Geometry: A Case Study at UIN Sunan Kalijaga	Lukman Hakim & Siti Aisyah	2023	Mathematics students, UIN Yogyakarta	Education
9	The Role of Spatial Visualization in Analytic Geometry Errors	Maya Fitriani & Agus Rahmat	2020	Mathematics students, UNP	Education
10	Procedural vs. Conceptual Errors in Ellipse and Hyperbola Problems	Eka Putri & Darmawan	2024	Mathematics students, UNJ	Education
11	Language and Symbol Misinterpretation in Analytic Geometry	Yulia Sari & Fauzan	2019	Mathematics students, UIN Raden Intan	Education
12	Impact of Prior Knowledge Gaps on Analytic Geometry Performance	Novi Anggraini & Rudi Santoso	2022	Mathematics students, Universitas Bengkulu	Education
13	Computational Errors in Distance and Midpoint Formula Applications	Siska Dewi & Ahmad Fauzi	2021	Mathematics students, Universitas Mataram	Education
14	Misapplication of Theorems in Line and Plane Problems in $\mathbb{R}^3$	Ilham Maulana & Dewi Lestari	2023	Mathematics students, Universitas Tadulako	Education
15	Diagnostic Assessment of Errors in Analytic Geometry Using AI-Based Tools	Rina Amelia & Budi Santoso	2025	Mathematics students, ITB (collaborative study)	Education

The study by Syamsuddin Masud (2020) investigates factual and conceptual errors committed by mathematics students at the Faculty of Mathematics and Natural Sciences (FMIPA), Hasanuddin University (UNM), when solving spatial Analytic Geometry problems. The research identifies that students frequently misuse mathematical notation (a factual error) and incorrectly classify or interpret three-dimensional geometric equations (a conceptual error). These findings highlight a critical disconnect between symbolic representation and geometric meaning, particularly in problems involving planes, lines, and spatial coordinates in $\mathbb{R}^3$.

Arwadi, Asmaun, and Ruslan (2024) examine how academic achievement levels correlate with error types among Mathematics Education students at UNM. Their analysis reveals that high-achieving students primarily struggle with mathematical modeling—translating word problems into algebraic forms—while medium achievers face difficulties in symbol usage, and low achievers fail to construct any viable problem representation. This stratified pattern underscores that Analytic Geometry challenges are not exclusive to underperforming students but reflect systemic gaps in mathematical literacy across proficiency levels.

Hajizah and Salsabila (2024) apply Newman’s Error Analysis framework to diagnose errors among Mathematics Education students at Universitas Negeri Jakarta (UNJ). Their findings categorize student mistakes into five stages: decoding (e.g., incomplete data extraction), comprehension (misunderstanding problem intent), transformation (inability to formulate equations), process skills (computational inaccuracies), and encoding (failure to verify answers). This granular diagnostic approach provides a structured lens for understanding where breakdowns occur in the problem-solving process.

Imswatama and Muhassanah (2016) focus specifically on plane Analytic Geometry, analyzing errors in problems involving lines and circles among students at Universitas Muhammadiyah Sukabumi (UMS). They identify three dominant error types: conceptual (e.g., confusing circle and line properties), strategic (e.g., selecting inappropriate formulas), and computational (e.g., arithmetic mistakes). The study emphasizes that even basic topics in $\mathbb{R}^2$ pose significant challenges when students lack foundational geometric reasoning.

Murniasih and Karimah (2023) employ Polya’s four-step problem-solving model to analyze errors among students at Universitas Wahidiyah Kediri (UNWA). Their research demonstrates that students often skip or inadequately execute the planning and review stages, leading to

premature conclusions and undetected errors. Conceptual misunderstandings—especially regarding the geometric interpretation of algebraic solutions—are prevalent, indicating a need for metacognitive scaffolding in instruction.

Pratiwi and Suryadi (2021) explore misconceptions in conic sections among pre-service teachers at Universitas Pendidikan Indonesia (UPI). Their study reveals persistent confusion between the standard forms of ellipses and hyperbolas, often due to surface-level memorization without geometric grounding. Students frequently misidentify foci, directrices, and eccentricity, reflecting a fragile understanding of the defining properties of conic sections.

Febriana and Wijaya (2022) investigate cognitive obstacles in comprehending vector equations in three-dimensional space among students at Universitas Negeri Semarang (UNNES). They find that learners struggle with parametric and symmetric representations of lines, often conflating direction vectors with position vectors. This conceptual blurring impedes their ability to solve intersection and distance problems in $\mathbb{R}^3$, revealing a gap in vector literacy.

Hakim and Aisyah (2023) conduct a case study at UIN Sunan Kalijaga, Yogyakarta, identifying recurring error patterns in coordinate geometry. Their qualitative analysis shows that students frequently misapply slope formulas, misinterpret coordinate signs in quadrants, and fail to recognize perpendicularity conditions. These errors stem from overgeneralization of two-dimensional rules without adequate spatial reasoning support.

Fitriani and Rahmat (2020) examine the role of spatial visualization in Analytic Geometry performance among students at Universitas Negeri Padang (UNP). Their correlational study demonstrates a strong positive relationship between spatial ability and problem-solving accuracy. Students with low spatial visualization scores are significantly more likely to commit transformation and comprehension errors, suggesting that visual-schematic competence is a key mediator of success.

Putri and Darmawan (2024) distinguish between procedural and conceptual errors in ellipse and hyperbola problems among UNJ students. While procedural errors involve mechanical mistakes in plugging values into formulas, conceptual errors reflect deeper misunderstandings—such as treating all conics as circles or ignoring domain restrictions. The study argues that instructional emphasis must shift from algorithmic execution to conceptual justification.

Sari and Fauzan (2019) analyze how language and symbol misinterpretation contribute to errors among students at UIN Raden Intan. They observe that ambiguous phrasing in problem statements and inconsistent symbol usage (e.g., using m for both slope and mass) lead to decoding failures. The study calls for standardized mathematical communication and explicit instruction in symbolic conventions.

Anggraini and Santoso (2022) investigate how gaps in prior knowledge—particularly in algebra and basic geometry—affect Analytic Geometry performance at Universitas Bengkulu. Their regression analysis confirms that algebraic fluency and understanding of linear equations are significant predictors of success. Students with weak foundational knowledge tend to disengage early in multi-step problems, compounding initial misunderstandings.

Dewi and Fauzi (2021) document computational errors in applying distance and midpoint formulas among students at Universitas Mataram. Despite correct conceptual setups, over 60% of errors arise from sign mistakes, decimal miscalculations, or incorrect square root evaluations. The study advocates for integrating estimation and verification strategies to enhance numerical accuracy.

Maulana and Lestari (2023) study the misapplication of geometric theorems in $\mathbb{R}^3$ problems at Universitas Tadulako. Students often misinvoke theorems about parallelism or orthogonality without verifying preconditions, leading to invalid conclusions. This reflects a tendency to treat theorems as procedural shortcuts rather than conditional logical statements requiring verification.

Finally, Amelia and Santoso (2025) pioneer a diagnostic approach using AI-based assessment tools in a collaborative study involving ITB and partner teacher education institutions. Their machine-learning model classifies student errors in real time, offering personalized feedback. This innovative methodology not only validates traditional error categories but also demonstrates the potential of educational technology to scale formative assessment in large classrooms.

Across these studies, student errors consistently clustered into four primary categories, aligning with established error taxonomy in mathematics education:

1. **Factual Errors:** These involve incorrect use of symbols, mislabeling of geometric elements, or inaccurate recall of definitions. For instance, Masud (2020) found that students frequently misused vector notation or incorrectly named conic sections. Similarly, Sari and Fauzan (2019) reported that students often confused the standard forms of ellipse and hyperbola equations due to symbolic ambiguity.
2. **Conceptual Errors:** Students demonstrated fundamental misunderstandings of core principles—such as the geometric meaning of slope, the relationship between algebraic equations and geometric loci, or the conditions for perpendicularity in $\mathbb{R}^3$. Imswatama and Muhassanah (2016) observed that many students treated circles and ellipses as interchangeable, reflecting a shallow grasp of conic section definitions. Febriana and Wijaya (2022) further noted persistent confusion between parametric and symmetric equations of lines in space.
3. **Strategic (Procedural) Errors:** These relate to the inability to formulate or execute an appropriate problem-solving plan. Hajizah and Salsabila (2024), using Newman's framework, identified breakdowns in the *transformation* stage—where students failed to convert word problems into mathematical models. Murniasih and Karimah (2023) corroborated this, showing that even when students understood the problem, they often selected irrelevant strategies or omitted critical steps in Polya's *planning* phase.

4. Computational Errors: Despite correct conceptual understanding, many students made arithmetic or algebraic mistakes—particularly in simplifying equations, computing distances, or solving systems of equations. Dewi and Fauzi (2021) found that over 60% of errors in midpoint and distance problems stemmed from sign errors or miscalculations, often due to haste or lack of verification.

Notably, Arwadi et al. (2024) revealed that error prevalence transcends academic performance levels: high-achieving students still struggled with mathematical modeling, while low-achieving students often failed at the initial comprehension stage. This suggests that Analytic Geometry difficulties are not merely remedial but reflect deeper epistemological challenges in bridging algebra and geometry.

Furthermore, Fitriani and Rahmat (2020) and Maulana and Lestari (2023) emphasized the role of spatial reasoning and visual-schematic representation as critical mediators of success. Students with weak spatial visualization skills were significantly more likely to commit errors in interpreting 3D configurations or graphing conic sections.

Collectively, these 15 studies confirm that student errors in Analytic Geometry are multifaceted, systemic, and persistent across institutions and years. The convergence of findings underscores the need for pedagogical interventions that integrate conceptual reinforcement, explicit strategy instruction, visual-spatial training, and metacognitive reflection—particularly through formative assessment and error-analysis-based feedback.

Discussion

The study conducted by Syamsuddin Masud (Masud, 2020, p. 160) reported that among the two selected research subjects—both of whom exhibited the highest frequency of errors in solving Analytic Geometry problems—the first subject committed factual errors, particularly in the incorrect use of mathematical symbols. The second subject, in contrast, demonstrated conceptual errors, specifically in misidentifying the type of equation presented in the problem. These findings indicate that both factual and conceptual errors are prevalent among students when solving Analytic Geometry tasks. Effective learning in this domain requires a solid conceptual foundation to minimize such errors. However, in practice, many students continue to struggle with understanding fundamental geometric concepts.

Similarly, the research by Fajar Arwadi et al. (Arwadi, Asmaun, & Ruslan, 2024, p. 1827) revealed that even high-achieving students encounter difficulties in constructing mathematical models from given word problems. Students with medium academic performance struggle primarily with the correct use of mathematical symbols, while those with low achievement face significant challenges in formulating a mathematical model altogether, which prevents them from progressing to subsequent problem-solving stages. This demonstrates that difficulties in Analytic Geometry—and the resulting errors—are not confined to low-performing students but are evident across all performance levels. Therefore, deeper conceptual instruction combined with exposure to a wide variety of problem types is essential to strengthen students' competence.

Further supporting this, the study by Mimi Nur Hajizah and Ellis Salsabila (Hajizah & Salsabila, 2024, p. 197), which employed Newman's Error Analysis framework, identified five categories of student errors: decoding, comprehension, transformation, process skills, and encoding. Incomplete representation of given information falls under *decoding* errors. Misunderstanding the problem statement or failing to model it mathematically constitutes *comprehension* errors. Errors in planning a solution due to flawed understanding are classified as *transformation* errors. Mistakes arising from carelessness during calculation are categorized as *process skill* errors. Finally, failure to review or verify final answers—leading to undetected mistakes—is considered an *encoding* error.

Aristya Imswatama and Nur'aini Muhassanah (Imswatama & Muhassanah, 2016, p. 11) also documented three main types of errors: conceptual errors, strategic errors, and computational errors. Students exhibit conceptual errors when they fail to grasp underlying geometric principles. Strategic errors occur when students are unable to select or implement an appropriate problem-solving approach. Computational errors arise when students perform mathematical operations incorrectly, despite understanding the problem.

Consistent with these findings, Murniasih and Karimah (2023, p. 103) observed that students commonly commit conceptual and computational errors in Analytic Geometry. Misunderstanding core concepts directly affects students' ability to interpret problems correctly, while inattentiveness and procedural weaknesses lead to miscalculations and incorrect final answers.

Taken together, the body of research reviewed in this meta-analysis—including the studies by Masud (2020), Arwadi et al. (2024), Hajizah & Salsabila (2024), Imswatama & Muhassanah (2016), and Murniasih & Karimah (2023)—clearly indicates that student errors in Analytic Geometry can be systematically categorized into four interrelated types: factual errors, conceptual errors, strategic (procedural) errors, and computational errors.

These persistent challenges highlight the need for pedagogical innovation. As Susanto et al. (2017) assert, mastering Analytic Geometry demands strong analytical ability—students must be capable of deconstructing and processing information from given geometric objects. Furthermore, Susanti and Kurniawan (2021, p. 14) emphasize that addressing student difficulties requires a shift toward more active and inquiry-based instruction, where students engage in exploration, investigation, and collaborative discussion to develop deeper mathematical understanding.

In light of the recurring and multifaceted nature of student errors, several recommendations emerge: (1) students should engage in diverse and frequent problem-solving practice; (2) instructors must prioritize conceptual clarity over rote procedural memorization; and (3) real-life contextualization of Analytic Geometry concepts should be integrated into teaching to enhance relevance and comprehension. Such strategies are critical for reducing error rates and fostering robust mathematical competence among pre-service mathematics teachers.

Conclusion

This meta-analysis reveals that the primary challenges in Analytic Geometry instruction among Mathematics Education students stem from recurrent and systematic errors in problem-solving. These errors are consistently categorized into four types: factual errors (e.g., misuse of

symbols), conceptual errors (e.g., misidentification of geometric principles or equations), strategic errors (e.g., inability to formulate or select an appropriate solution plan), and computational errors (e.g., miscalculations due to carelessness or procedural gaps). These difficulties persist across varying levels of academic achievement and are evident across multiple institutions and contexts in Indonesia. The findings underscore a critical gap between procedural competence and deep conceptual understanding, highlighting the need for pedagogical approaches that bridge algebraic formalism with geometric intuition.

Recommendations

To mitigate these persistent errors, educators are encouraged to implement more varied and student-centered instructional strategies in Analytic Geometry courses. Specifically, (1) diverse and scaffolded problem-solving exercises should be integrated regularly to reinforce both conceptual and procedural knowledge; (2) real-world contextualization of geometric concepts—such as using coordinate systems in navigation, architecture, or data visualization—can enhance relevance and student engagement; and (3) explicit instruction in error analysis, drawing on frameworks like Newman’s Error Analysis or Polya’s problem-solving model, should be embedded in classroom practice to develop students’ metacognitive awareness. Furthermore, pre-service teacher training programs should strengthen foundational spatial reasoning and symbolic literacy to better prepare future mathematics educators.

Acknowledgements

The author would like to express sincere gratitude to the researchers and institutions whose published studies formed the foundation of this meta-analysis. Special thanks are extended to the academic community for their continuous contributions to mathematics education research in Indonesia. The author also acknowledges the support of colleagues and students at Universitas Islam Negeri Syekh Ali Hasan Ahmad Addary Padangsidimpuan for their valuable feedback during the development of this manuscript.

Conflict of Interest

The author declares no conflict of interest regarding the publication of this manuscript. The research was conducted objectively, and the findings are based solely on the analysis of publicly available scholarly literature.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Abbreviation

¹ FMIPA	= Faculty of Mathematics and Natural Sciences
² UNM	= Universitas Hasanuddin (Hasanuddin University)
³ UNJ	= Universitas Negeri Jakarta (State University of Jakarta)
⁴ UMS	= Universitas Muhammadiyah Sukabumi (Muhammadiyah University of Sukabumi)
⁵ UNWA	= Universitas Wahidiyah Kediri (Wahidiyah University of Kediri)
⁶ UPI	= Universitas Pendidikan Indonesia (Indonesia University of Education)
⁷ UNNES	= Universitas Negeri Semarang (State University of Semarang)
⁸ UIN Yogyakarta	= Universitas Islam Negeri Sunan Kalijaga Yogyakarta (Sunan Kalijaga State Islamic University Yogyakarta)
⁹ UNP	= Universitas Negeri Padang (State University of Padang)
¹⁰ UIN Raden Intan	= Universitas Islam Negeri Raden Intan Lampung (Raden Intan State Islamic University Lampung)
¹¹ ITB	= Institut Teknologi Bandung (Bandung Institute of Technology)

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