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Analyzing Trigonometry Learning Gaps: A Systematic Review of Error Patterns Among Indonesian Students

Rahman Nul Hakim [1] *
[1]Mathematics Education Study Program, Universitas Lambung Mangkurat

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***Correspondence Address:**
rahmanhakim.rnh@ulm.ac.id

Abstract: Trigonometry continues to pose a significant challenge for Indonesian learners, with recurring mistakes impeding their academic development. This comprehensive literature review explores the various types of error patterns in trigonometry and examines the educational factors that contribute to these challenges. Utilizing the PRISMA framework, we reviewed six pertinent studies from an initial selection of 279 publications. The results classify errors into four primary categories: comprehension errors (misinterpreting problems), transformation errors (selecting incorrect formulas), process skill errors (mistakes in calculations), and encoding errors (issues with presenting final answers). These errors were linked to several educational factors, including deficiencies in foundational knowledge, an overreliance on memorization, insufficient problem-solving instruction, and assessment approaches that prioritize outcomes rather than the processes involved. The research underscores the necessity for pedagogical changes that prioritize conceptual understanding, real-world applications, and the development of metacognitive skills. These findings offer important recommendations for educators and policymakers who aim to enhance trigonometry teaching in Indonesia and comparable educational settings.

INTRODUCTION

Mathematics is a cornerstone of intellectual development, fostering analytical reasoning, systematic logic, and problem-solving skills essential for academic and professional success. Research underscores its critical role in disciplines like engineering and physics (Adillaningtyas & Syamsuri, 2024), while also cultivating the cognitive agility needed to interpret data, strategize effectively, and adapt to global challenges (Hakim & Andayani, 2024; Hakim, Suhendra, & Arifin, 2025). As a pillar of 21st-century numeracy, it transcends mere content mastery, shaping creativity, resilience, and collaborative aptitude skills vital for navigating modern complexities. However, persistent conceptual gaps, particularly in foundational areas like trigonometry, hinder students' ability to harness these competencies, demanding targeted analysis to address systemic learning barriers.

Trigonometry is an undeniably crucial and essential branch of mathematics, serving as a foundation for a wide array of fields including engineering, physics, architecture, and computer science, and it plays a significant role in bolstering and enriching these disciplines in countless ways (Anggraini, 2022; Geeta Rani et al., 2023). Its varied applications span a wide range of tasks, from the detailed design and construction of sophisticated structural systems to the precise analysis of complex wave patterns, as well as the creative development of advanced

algorithms that are fundamental in the field of computer programming. Even though trigonometry holds considerable significance and relevance in contemporary education, many students face numerous obstacles in fully comprehending and mastering the basic concepts of trigonometry (Kurniati, Suhendra, Priatna, & Prabawanto, 2022), often resulting in significant learning gaps that can impede their overall academic advancement. If these learning gaps remain unresolved, they can severely affect students' academic performance and may also restrict the educational and career opportunities accessible to them in the future (Hamzah, Maat, & Ikhsan, 2021).

This systematic review is aimed at thoroughly analyzing the specific error patterns demonstrated by Indonesian students as they navigate the challenging domain of trigonometry, with the goal of revealing the intricacies of their learning journeys. By carefully identifying and scrutinizing the common misconceptions alongside the specific challenges that notably contribute to these learning gaps, this research seeks to offer a comprehensive and detailed insight into the issues and difficulties currently experienced. Through a meticulous synthesis of existing studies that focus on evaluating student performance and analyzing errors, we aspire to shed light on the fundamental factors that significantly impact trigonometric understanding within the Indonesian educational context, thereby enriching our collective knowledge in this vital area of study.

While numerous studies have investigated students' performance in mathematics at large, only a small number have systematically reviewed patterns of student errors specifically in trigonometry within the Indonesian framework. Earlier research often emphasizes conceptual understanding or the effectiveness of teaching methods, but neglects to compile and synthesize the recurring types of student errors that persist across various educational environments. This presents a distinct research gap, as a holistic grasp of these error patterns is vital for addressing learning challenges in a focused and informed way.

To fill this gap, this study employs a systematic literature review (SLR) approach, following the PRISMA protocol, as an appropriate technique to gather, categorize, and evaluate research findings on trigonometric error patterns from various empirical studies. In contrast to isolated classroom-based investigations or single-cohort experiments, the SLR method provides a broader, evidence-based perspective that facilitates the identification of consistent themes and trends across diverse contexts. This comprehensive understanding will guide more nuanced and evidence-informed strategies aimed at bridging learning gaps in trigonometry. Grasping these complex error patterns transcends mere academic exercise; it constitutes a vital step for educators and policymakers dedicated to enhancing educational outcomes.

By identifying the common pitfalls and misconceptions that students often face, it becomes feasible to create targeted interventions specifically designed to improve student understanding and proficiency in trigonometric concepts. Such interventions may take various forms, including the development of customized instructional strategies that address diverse learning needs, the enhancement of curricular resources that promote effective teaching, and the provision of professional development opportunities for educators, all aimed at cultivating a stronger mathematical foundation for students.

Furthermore, this review aims to contribute meaningfully to the broader conversation surrounding mathematics education, providing valuable insights that may inform and enhance

teaching practices and curricular enhancements not only within Indonesia but also in other educational contexts facing similar challenges. By thoughtfully tackling these pressing issues and challenges, we aspire to create pathways for improved educational outcomes that will ultimately foster a deeper appreciation and understanding of mathematics among students, nurturing a positive and enriching learning atmosphere.

METHOD

This research utilizes a systematic literature review (SLR) following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to maintain methodological integrity and clarity (Moher et al., 2009). The SPIDER tool (Sample, Phenomenon of Interest, Design, Evaluation, Research type) was employed to develop two research queries:

RQ1: What types of error patterns in trigonometry are frequently observed among Indonesian students?

RQ2: What educational factors lead to students' persistent mistakes in trigonometry?

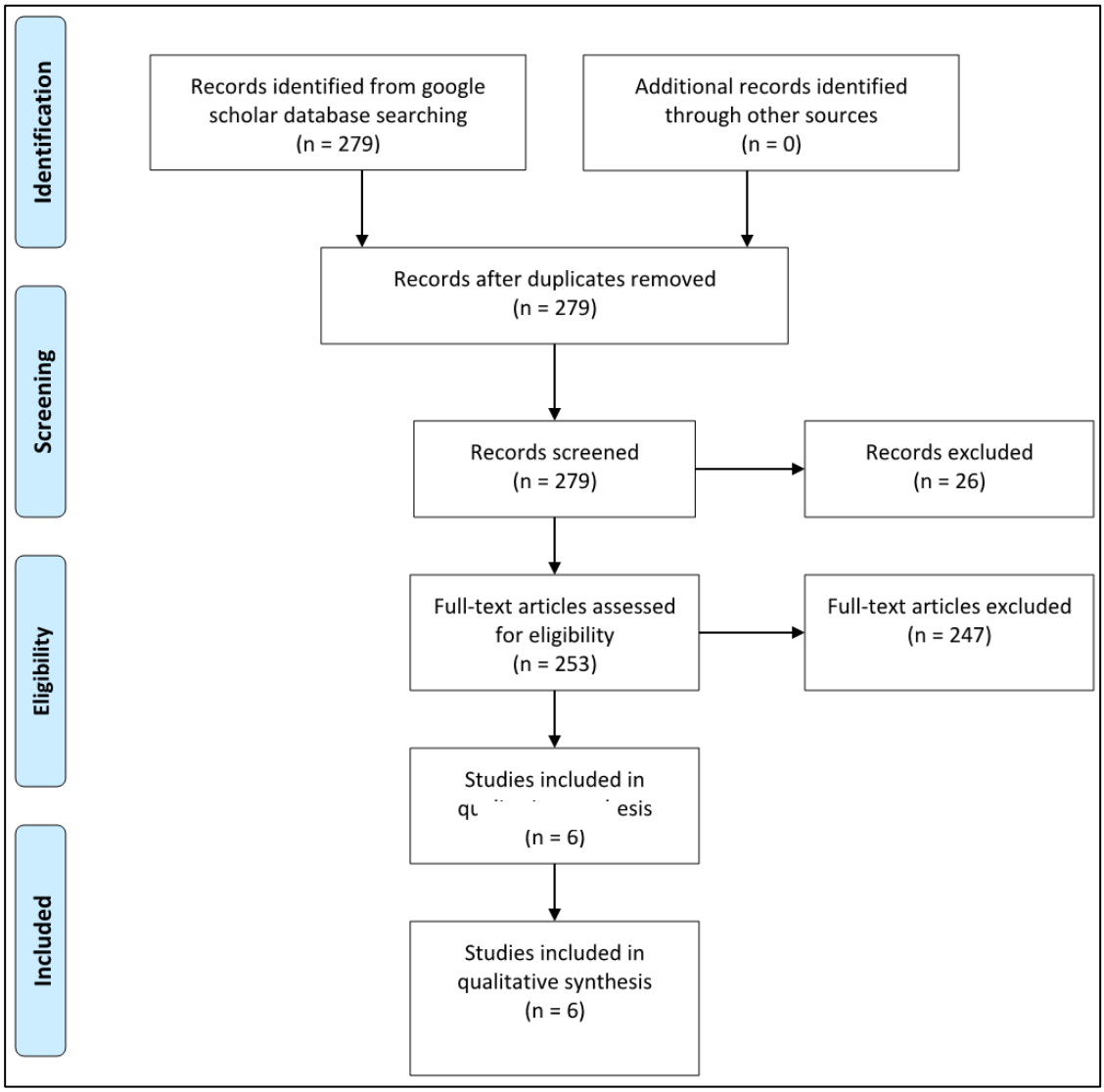

Figure 1. PRISMA diagram

Figure 1, which serves as a visual representation, effectively illustrates the detailed PRISMA diagram that was meticulously utilized throughout the course of this comprehensive research study.

Identification

A study was carried out using Google Scholar to find pertinent research that examines the error trends in trigonometry among students in Indonesia. The approach taken for the search involved utilizing particular keywords associated with trigonometric mistakes and educational difficulties, guaranteeing a thorough compilation of literature for evaluation. Consequently, the researchers broadened both the search terms and methodology to investigate as many potentially relevant studies as they could. For the search, the keywords employed were "student errors" OR "student misconceptions" AND "trigonometry" AND "Indonesia". Consequently, 279 journal articles were categorized during this phase of the process. This approach was designed to facilitate a wide-ranging and inclusive collection of pertinent academic literature.

Screening

The investigators employed a comprehensive array of inclusion and exclusion parameters in this methodological framework. Systematic review articles, monographs, and chapters from edited volumes were expressly omitted from the literature selection process. Furthermore, the investigators concentrated exclusively on scholarly articles disseminated in the English language to mitigate the potential complications associated with ambiguous or convoluted translations. Consequently, the investigators scrutinized articles published within the preceding decade. Following the screening process, 26 manuscripts were identified as not meeting the research criteria, yielding a final count of merely 253 articles. This meticulous selection procedure was implemented to ensure the relevance and integrity of the ultimate dataset.

Eligibility

The eligibility phase concluded with the discovery of incomplete academic articles. At first, journal publications that did not meet the specified criteria related to student errors or misconceptions in trigonometry were excluded from consideration. Following this, to ensure that all 247 articles met the established selection criteria and research objectives, a thorough review of each article's title, abstract, methodology, results, and discussion was performed. During this stage, 247 articles were eliminated due to their insufficient descriptions of student errors or misconceptions in trigonometry, or because the full text was not available. As a result, a total of 6 articles were selected for inclusion in the final phase of the review process.

Inclusion and Exclusion Criteria

Upon gathering insights from all acknowledged sources, the researchers utilized selection criteria, incorporating temporal aspects, document types, linguistic factors, and thematic areas, to filter out articles considered irrelevant to the core of our investigation. During the process of deciding which articles to include or exclude, it is crucial that the criteria for both inclusion and exclusion are clearly defined to ensure that the chosen studies align with the main research goals. Table 1 outlines the inclusion and exclusion criteria relevant to this systematic review,

in addition to the resulting research findings. It was confirmed that a total of 6 relevant articles and their associated full-text versions were obtained from these sources.

Table 1. Criteria for Inclusion and Exclusion.

Criteria	Inclusion	Exclusion
Title and Content	Discusses trigonometry learning and identifies student errors in mathematics education	Does not focus on trigonometry or does not analyze student errors
Year of Publication	Published between 2020 and 2025	Published before 2020 or after 2025
Type of Publication	Published in peer-reviewed journals or conference proceedings	Non-academic works (e.g., book chapters, theses, editorials)
Language	Written in English	Written in languages other than English
Area of Study	Belongs to the education field, especially mathematics education	Belongs to non-educational disciplines (e.g., engineering, pure math)
Accessibility	Full-text available and open access	Restricted access or no full-text availability

RESULTS AND DISCUSSION

Research Table 2 below showcases six articles that are analyzed in this systematic literature review. These articles were chosen based on the PRISMA diagram.

Table 2. Eligible Articles for Analysis

No.	Author	Title
1.	Dita, A., Hasani, Q. A., & Haryani, D. (2024)	Identification Of Student Errors in Solving Trigonometry Problems in Class X SMK Negeri 3 Palangka Raya
2.	Jannah, M., Pesik, A., Kumesan, S., Ermita, E., & Rahim, N. (2024)	Analysis Of Student Errors in Solving Equations and Inequalities Problems in Algebra and Trigonometry Based on Newman Procedure
3.	Rosana, A., Ma'ruf, A. H., & Triyono, A. (2024)	Analysis Of Student Errors in Solving Trigonometry Story Problems Based on Newman's Theory
4.	Sonjaya, O., & Jaenudin, A. (2024)	Analysis Of Student Errors in Solving Trigonometry Questions
5.	Fauzi, N. I., Sagita, L., Setiyani, & Wicaksono, B. (2022).	Analysis Of Student Errors in Solving Trigonometry Problems Based on The Newman Procedure
6.	Bayu, C. P., Yohanie, D. D., Handayani, A. D. (, Putri Bayu, C., Devita Yohanie, D., & Handayani, A. D. (2021)	Analysis Of Student Errors in Solving Comparative Trigonometry Problems of Right-Angled Triangles Based on Watson's Criteria

RQ1: What types of error patterns in trigonometry are frequently observed among Indonesian students?

A thorough examination of the six chosen studies uncovers various interrelated error patterns that Indonesian students consistently exhibit while tackling trigonometry problems. These errors can be systematically categorized using two main theoretical frameworks: Newman's Error Analysis (NEA) and Watson's Criteria, which together offer a detailed insight into where and why students encounter difficulties in trigonometric problem-solving.

The most frequently identified error category was comprehension errors (CE), where students fundamentally misinterpreted the problem requirements or failed to recognize crucial information. For example, Rosana, Ma'ruf, & Triyono (2024) discovered that 70% of students struggled to accurately extract and document given information from word problems, resulting in incorrect problem interpretations right from the beginning. Likewise, Fauzi, Sagita, Setiyani, & Wicaksono (2022) noted that many students could read the problems correctly but could not identify the necessary mathematical concepts or operations needed, especially in issues involving trigonometric identities or relationships between angles.

Transformation errors (TE) surfaced as another significant category, where students found it challenging to translate word problems into suitable mathematical models or to choose the correct trigonometric formulas. Sonjaya and Jaenudin (2024) recorded instances where students misapplied the Law of Sines or Cosines, even when the contextual clues of the problem clearly indicated which should be utilized. Bayu et al. (2021) further observed that 78% of students made transformation errors by either applying incorrect formulas or failing to establish accurate relationships among given quantities, particularly in right triangle trigonometry scenarios.

Process skill errors (PSE) were notably prevalent, appearing as miscalculations and procedural errors during problem-solving. Jannah, Pesik, Kumesan, Ermita, & Rahim (2024) indicated that 18.8% of mistakes arose from arithmetic errors, especially in calculations involving fractions, radicals, or angle conversions. These computational mistakes often compounded initial conceptual misunderstandings, pushing students further away from the correct answers. The studies also pointed out specific areas of difficulty, such as errors in simplifying trigonometric expressions, mishandling special angles, and incorrectly applying trigonometric identities.

Encoding errors (EE), where students adhered to correct procedures but made mistakes in delivering final answers, were recognized as another notable pattern. Dita, Hasani, & Haryani (2024) found that 70.16% of errors were linked to incorrect final answers, often due to missing units, improper rounding, or failing to provide complete solutions. This indicates that even when students grasped the conceptual framework, they frequently lost points due to presentation or communication deficiencies.

In addition to these primary categories, several studies uncovered conceptual gaps that underpinned many errors. Students often confused complementary and supplementary angles, misapplied the periodicity properties of trigonometric functions, or did not recognize when to implement reciprocal identities (Bayu et al., 2021; Fauzi et al., 2022). These basic misunderstandings frequently led to cascading errors throughout the problem-solving procedure. The consistency of these error patterns across multiple studies implies they signify systemic challenges in trigonometry education in Indonesia. The findings reveal that students face difficulties not only with individual concepts but also with the entire problem-solving process - from initial comprehension to the final presentation of solutions. This comprehensive perspective on error patterns offers valuable insights for creating targeted instructional interventions.

RQ2: What educational factors lead to students' persistent mistakes in trigonometry?

The systematic review revealed several educational factors that play a role in the continuation of these error patterns in the trigonometric performance of Indonesian students. These factors function at different levels within the educational framework, ranging from curriculum development to classroom teaching and student learning techniques. Gaps in foundational knowledge surfaced as a key underlying issue. Various studies indicated that students' struggles with trigonometry frequently originated from inadequate prerequisite skills in algebra and geometry. A significant number of students were not proficient with the Pythagorean theorem, properties of angles, or concepts of ratios that are essential for comprehending trigonometry (Bayu et al., 2021; Dita et al., 2024).

This resulted in an unstable base on which more complex trigonometric ideas were constructed, leading to a build-up of misunderstandings. The conventional teaching methods common in many Indonesian classrooms were recognized as another major factor. Fauzi et al. (2022) noted that instruction often prioritized rote memorization of formulas and procedures rather than fostering a deep conceptual understanding. This led to students who could recall trigonometric identities but struggled to determine the appropriate moments or methods for applying them in problem-solving scenarios.

The excessive dependence on algorithmic methods left students unprepared to tackle non-routine problems or draw conceptual links between various trigonometric ideas. Instructional deficiencies in solving word problems were especially prominent. Rosana et al. (2024) discovered that students had inadequate practice in converting real-world situations into mathematical models, which resulted in ongoing challenges with application problems. Many educators emphasized primarily computational elements of trigonometry, overlooking the importance of developing modeling and problem-formulation skills crucial for addressing contextual problems.

Cognitive and emotional factors also significantly influenced error persistence. Sonjaya and Jaenudin (2024) recorded instances where math anxiety and low self-efficacy prompted students to rush through problems or shy away from deeply engaging with difficult concepts. This often manifested as careless computational mistakes or hasty abandonment of problems. Furthermore, Jannah et al. (2024) observed that students frequently lacked metacognitive strategies for error checking and validation, thus missing chances to identify and rectify their mistakes.

The assessment methods routinely employed in trigonometry instruction were identified as yet another contributing factor. Several studies pointed out that assessments often prioritized final answers over the problem-solving processes (Bayu et al., 2021; Dita et al., 2024). This created a disincentive for students to demonstrate their work or think critically about solution paths, as typically, only the final result was graded. As a result, students cultivated habits of guessing or resorting to trial-and-error methods instead of systematic problem-solving strategies. Curriculum sequencing and time management emerged as systemic factors affecting error patterns.

Fauzi et al. (2022) noted that the swift pace of trigonometry instruction often failed to provide adequate opportunities for conceptual growth or error correction. Key concepts were often introduced in rapid succession without enough time allocated for mastery, resulting in a fragile understanding that faltered when students faced more complex challenges. Language and representation challenges were also highlighted in several studies. Rosana et al. (2024) found that students occasionally misinterpreted problems due to struggles with mathematical

terminology or symbolic representations. This was particularly noticeable in word problems where an accurate interpretation of language was crucial for establishing correct solutions.

The persistence of these error patterns across various studies indicates they are deeply ingrained in the current educational framework. Nonetheless, the consistency of findings also offers clear guidance for targeted interventions that could greatly enhance students' learning outcomes in trigonometry.

CONCLUSION

The systematic review highlights persistent error patterns in Indonesian students' trigonometry learning, primarily falling into comprehension, transformation, process skill, and encoding errors. These mistakes are deeply rooted in educational shortcomings, including weak foundational knowledge, overreliance on memorization, insufficient problem-solving instruction, and assessment methods that neglect the problem-solving process. Additionally, cognitive and emotional factors, such as math anxiety and low self-efficacy, further exacerbate these difficulties.

To address these challenges, a shift in instructional strategies is necessary emphasizing conceptual understanding over rote learning, integrating real-world problem-solving tasks, and fostering metacognitive skills for error detection. Future research should investigate the effectiveness of targeted interventions, such as adaptive learning tools and teacher training programs, to improve trigonometry education in Indonesia. By addressing these systemic issues, educators can help students build a stronger, more applicable understanding of trigonometric concepts.

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