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A Systematic Mapping of Error Analysis As Integrative Activity in Mathematics Classroom

Sanddy H. Madera*, Jennifer O. Parcutilo

University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines
*Corresponding author: madera.sanddy0330@gmail.com

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Abstract The lack of practical and sustainable strategies for incorporating error analysis into mathematics classrooms is a significant research gap in mathematics education examined in this systematic mapping review. In order to determine common instructional goals, sample characteristics, mathematical domains, research design, strategies, types of errors addressed, and reported learning outcomes, thirteen empirical studies published between 2017 and 2025 were analyzed. The findings show that while error analysis improves problem-solving skills, metacognitive development, and conceptual understanding, its use can be demanding for teachers and students. Students often struggle to analyze and articulate their errors, notably when guidance is lacking, and teachers must deal with heavier workloads, time restraints, and specialized training requirements. While international research emphasizes the potential of artificial intelligence tools to support real-time feedback and lower instructional demands, local studies mainly rely on conventional, teacher-led methods. The review recommends a hybrid model that blends AI-enhanced tools with teacher facilitation to support error analysis's scalable, efficient, and context-responsive integration in mathematics classrooms.

Keywords: *error analysis, mathematics classroom innovation, AI in mathematics education*

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1. Introduction

Error analysis is becoming more popular to help students learn mathematics by using their mistakes and misunderstandings to help them comprehend mathematics better. Students are encouraged to think about how they think by systematically finding, analyzing, and resolving their mistakes. This teaching strategy helps them become clearer about their ideas, strengthen their metacognitive skills, and improve at solving problems [1]. Early intervention in the learning process is critical since persistent mathematics misconceptions can make it harder to be successful in school in the long term [2,3]. Also, studies show that interacting with right and wrong answers makes students more interested, helps them remember what they have learned, and improves their critical thinking skills [4,5].

Even though error analysis is widely acknowledged to have pedagogical value, little is known about how to apply it in actual classroom settings in a way that is both sustainable and effective. The practical realities of its integration, especially the logistical, instructional, and cognitive demands it places on teachers and students, are rarely covered in the currently available literature. Even though research like Lacerna [6] shows that it improves student performance, a conspicuous dearth of studies looks at the day-to-day difficulties that arise when used consistently, particularly in settings where teachers are already overworked. Large class sizes, limited resources, and a variety of learner needs make it extremely difficult to implement sophisticated teaching techniques like error analysis in the Philippine educational system, making this gap particularly significant. Error analysis's potential to be both practical and successful in regular mathematics classrooms is limited by the lack of targeted research into these implementation challenges, which impedes the creation of valuable recommendations and essential support for educators.

This systematic review fills a critical gap in the literature by investigating the conceptualization and application of error analysis as an integrative activity in mathematics classrooms, especially its practical and sustainable implementation. The review aims to synthesize findings about instructional purposes, sample characteristics, mathematical domains, research designs, implementation strategies, and reported learner outcomes by drawing on local and foreign studies. It also examines the difficulties and restrictions researchers and practitioners face when integrating error analysis into mathematics classrooms in response to the scant attention paid to real-world constraints. This review attempts to determine what kinds of support, enabling conditions, and instructional reinforcements are required to implement error analysis successfully and sustainably—particularly in ways that lessen the burden on teachers and students in resource-constrained educational contexts like the Philippines—by mapping current approaches and empirical evidence.

1.1. Research Questions

1. What is the scope of error analysis as integrative activity in the mathematics classroom in terms of:
    1.1 purpose;
    1.2 sample;
    1.3 mathematical domains covered;
    1.4 research design;
    1.5 strategies;
    1.6 mathematical errors addressed; and
    1.7 the reported outcomes?
2. What challenges and limitations have researchers encountered in implementing error analysis in mathematics classroom?

2. Method

This study employed the Systematic Mapping of Literature methodology outlined by Petersen et al. [7] to ensure a structured, transparent, and methodologically sound review process. The inquiry began with the formulation of focused research questions designed to investigate how error analysis is effectively integrated into mathematics instruction as a purposeful classroom activity. A clear set of inclusion and exclusion criteria was established based on the review's objectives to ensure the relevance and quality of the studies included.

2.1. Search Strategy

A comprehensive literature search was conducted to identify relevant data-driven studies on integrating error analysis as a classroom activity in mathematics education. The search was closed to traditional pedagogical implementations and recent innovations involving artificial intelligence (AI) tools to support or facilitate error analysis in instructional settings. To align with the study’s objectives, a set of targeted keyword combinations was used, including: “error analysis activity,” “student errors,” “student mistakes,” “mathematics education,” and “reflective learning.” Boolean operators (AND, OR) were applied to maximize search sensitivity and retrieve diverse yet relevant literature.

The search was limited to peer-reviewed journal articles, graduate theses, and dissertations published between January 2017 and March 2025 to encompass established and emerging research. Only studies written in English or Filipino were included. Emphasis was placed on works that examined error analysis as an interactive and integrative instructional strategy situated within classroom teaching and learning processes across various educational levels and mathematical domains.

2.2. Result Filters

The articles were selected according to the following Inclusion and Exclusion Criteria:

Table 1. Inclusion and Exclusion Criteria of Article Selection

Inclusion Criteria	Exclusion Criteria
1. focus on error analysis mathematics education at any level;	1. focus on error analysis in non-math subjects;
2. studies written in English or Filipino;	2. studies not written in English or Filipino;
3. integrated as classroom activity; and	3. integrated as non-classroom activity; and
4. studies published between January 2017 and May 2025	4. duplicate reports of the same database

Thirteen (13) studies were selected from an initial pool of 381 retrieved records after applying the criteria. The selection process followed a rigorous two-stage screening procedure. In the first stage, titles and abstracts were reviewed to assess alignment with the research objectives. In the second stage, full-text articles of shortlisted studies were examined in detail to confirm their relevance—particularly their integration of error analysis as an instructional strategy within classroom settings.

The selected articles provide a comprehensive perspective on implementing error analysis across diverse educational contexts by incorporating Philippine-based and international studies. The final synthesis included only those studies that integrated error analysis as an active learning strategy in mathematics classrooms, either through teacher-led instruction or with the support of technological tools such as artificial intelligence

Table 2. List of Articles Categorized as Local-based and Foreign Studies

Category	Number of Articles	References
Local-Based Studies	5	Casiño & Tan (2025); Lacerna (2024); Bautista (2022); Peligro et al. (2018); Garcia (2017)
Foreign Studies	8	Lin et al. (2025); Xu et al. (2024); Sancar & Özkaya, (2024); Washburn (2024); Khasawneh et al. (2023); Khasawneh et al. (2022); Morkoyunlu & Altun (2022); Rushton (2018)

Table 2 displays the geographic distribution of the thirteen (13) reviewed studies based on their contextual origin. Five (5) studies are classified as local, with three (3) conducted in Mindanao and two (2) in Luzon. No studies are identified from the Visayas region.

The remaining eight (8) studies are foreign and conducted in various international contexts. These include countries such as China, Turkey, Jordan, and the United States of America, among others.

3. Results and Discussions

This section summarizes the results obtained from the 13 primary articles analyzed, considering each of the research questions.

3.1. Scope of Integration of Error Analysis as Integrative Activity in Mathematics Classroom

Table 3. Scope of Integration of Error Analysis as Integrative Activity in Mathematics Classroom

References	Purpose	Sample	Mathematical Domain	Research Design	Strategies	Mathematical Errors Involved	Reported Outcomes
Casiño & Tan (2025)	Compare explicit instruction and error analysis effectiveness	First Year College	Statistics, Business Mathematics	Quasi-Experimental	Comparative instructional design: one group taught via error analysis, the other via explicit instruction; individual written activities and summative tests	Misconceptions, Procedural Errors	Explicit instruction yielded higher scores, suggesting effectiveness may depend on context and learner readiness
Lin et al. (2025)	Use GPT-4 in error analysis to improve problem-solving	Grade 5	Geometry	Quasi-Experimental	GPT-4-generated erroneous solutions reviewed in small group discussions; teacher-guided reflection; peer correction cycles	Procedural, Conceptual, Semantic, Computational Errors	Boosted critical thinking, confidence, metacognition; especially helped low-achieving students
Xu et al. (2024)	Improve efficiency using AI for real-time error analysis	Elementary	General Math	Quasi-Experimental	Virtual AI Teacher (VATE) using LLMs to analyze drafts and provide on-the-spot feedback; students revised work iteratively	Computational, Procedural Errors	Achieved 78.3% accuracy in AI detection; enhanced engagement, learning efficiency, and student satisfaction
Lacerna (2024)	Enhance problem-solving skills via error analysis	Grade 9	Trigonometry	Mixed-Method	Developed contextual lesson exemplars incorporating error analysis at key learning points; students reflected on errors using Newman prompts	Newman Error Indicators	Notable gains in problem-solving; helped correct deep-seated misunderstandings
Sancar & Özkaya, (2024)	Investigate error-based tasks for fraction learning	Grade 6	Fractions	Mixed-Method	Error-based activity worksheets followed by guided reflection; class-wide discussion on common errors	Conceptual, Operational Errors	Improved understanding; facilitated misconception identification and active engagement
Washburn (2024)	Assess error analysis in improving foundational skills	Grade 4	Basic Operations	Quantitative (Pre-Post)	Peer reviews; oral reasoning; grouping by error types; explicit error-spotting tasks in class	Computational, Conceptual, Procedural Errors	Significantly improved scores and comprehension; increased motivation and cognitive engagement
Khasawneh et al. (2023)	Improve classroom interaction via error analysis	Grade 7	Proportional Reasoning	Mixed-Method	Constructivist model: students identify and discuss errors collaboratively; teacher acts as facilitator	Procedural, Conceptual Errors	Promoted active learning, verbal interaction, and self-explanation routines
Khasawneh et al. (2022)	Evaluate learning gains from error-based instruction	Grade 7	Proportional Reasoning	Quasi-Experimental	Paired erroneous and correct examples; students justified or corrected mistakes	Procedural, Conceptual Errors	Marked gains in reasoning and learning enjoyment; positive attitudes toward math learning
Bautista (2022)	Explore formative error analysis and performance	Grade 9	Geometry	Quasi-Experimental	Formative assessment cycle: pretest-error analysis-feedback-retest; teacher feedback included guided questioning	Not Explicitly Defined	Indicated potential in formative learning, though not statistically significant
Morkoyunlu	Assess effect	College	Algebra,	Qualitative	Reflective journals	Conceptual,	Promoted

References	Purpose	Sample	Mathematical Domain	Research Design	Strategies	Mathematical Errors Involved	Reported Outcomes
& Altun (2022)	on reflective thinking in pre-service teachers	(Pre-service)	Geometry, Proof	Case Study	scored using Kember's framework; weekly error reviews; self-evaluation essays	Habitual Thinking Errors	transition from habitual to critical reflection; enhanced error awareness
Peligro et al. (2018)	Improve geometric proof understanding	Grade 10	Geometry	Quasi-Experimental	Error-focused group activities; 'Find an expert' tasks; guided journaling and teacher prompts	Conceptual Errors	Improved conceptual understanding; peer collaboration enriched reflective skills
Rushton (2018)	Explore retention from mixing correct/error examples	Grade 7	Equations/ Inequalities	Mixed-Method	Homework with embedded erroneous solutions; in-class corrections; teacher-led discussions	Procedural, Conceptual Errors	No short-term gains, but significantly better retention after delay; increased engagement
Garcia (2017)	Correlate error analysis, metacognition, problem-solving	College (First Year)	Precalculus	Quantitative Correlational	Students coded errors post-problem solving; categorized via detailed error taxonomy (e.g., notational, logical, etc.)	Multiple types: Procedural, Logical, Strategic, etc.	High error analysis proficiency linked to strong metacognitive and problem-solving skills

The analysis of the studies in Table 3 shows several prevailing patterns regarding error analysis as an integrative activity in mathematics classrooms. From the reviewed literature, the primary goal of using error analysis is to encourage students to reflect on their errors and misconceptions to enhance their mathematical understanding. While earlier research often focused solely on improving achievement, more recent studies emphasize broader cognitive and affective outcomes like critical thinking, confidence, and metacognitive awareness. This pedagogical shift results from a growing awareness of error analysis as a teaching strategy and a methodology supporting all-encompassing learning.

Most research on learner demographics focuses on middle schoolers, especially those in Grades 5 through 10, emphasizing the strategy's applicability in cognitive development. Error analysis has value beyond foundational education and can support professional development and pedagogical training, as demonstrated by some studies that include college-level and pre-service teachers. Although a wide range of mathematical topics are covered, geometry and proportional reasoning are the most commonly integrated topics, probably because of their abstract nature and high student misunderstandings. Other areas, like statistics, algebra, and trigonometry, are also heavily represented, highlighting the strategy's wide range of applications.

In order to measure both performance outcomes and qualitative elements of learning, like engagement and reflection, the majority of studies use mixed-method or quasi-experimental research designs. These designs offer a balanced perspective on error analysis as a cognitive and social process, making them appropriate for classroom-based interventions. In terms of instructional strategies, two major clusters emerge. The first includes traditional, teacher-led approaches—such as group discussions, lesson exemplars, reflective journaling, and formative assessments—prevalent in Philippine-based studies. The second, found in more recent international studies, involves the integration of artificial intelligence (AI), such as GPT-4 and virtual AI tutors, which leverages the conduct of error analysis activity in mathematics classrooms by providing real-time error detection and personalized feedback. This emerging model represents a shift toward scalable, adaptive learning environments that reduce the burden on teachers while enhancing student support.

Although many different kinds of errors are addressed, procedural, conceptual, and computational errors are the most frequently mentioned. Semantic, notational, and strategic errors were covered in some studies through structured frameworks like Newman's Error Analysis or customized taxonomies. A key trend is the emphasis on conceptual errors, indicating a pedagogy of fostering substantial understanding rather than just correcting surface-level mistakes. Numerous studies have documented generally favorable results, such as enhancements in retention, conceptual understanding, problem-solving abilities, and metacognition. However, some research points out that improvements in academic performance might not always happen immediately, with longer-term gains or improvements in affective domains like confidence and engagement showing larger benefits.

One noteworthy finding is that in the Philippine-based studies, no technology is incorporated in the error analysis activity, which supported the idea that despite being pedagogically rich, implementations rely primarily on teacher facilitation, which burdens teachers who might not have the necessary resources or training. In contrast, international research shows that utilizing AI technologies to conduct error analysis activities in mathematics classrooms is an excellent strategy. These tools are promising, but they also make people worry about how relevant they are to the situation, how accurate they are, and how easy they are to get to, especially in places with few resources.

3.2. Challenges and Limitations Researchers Encountered in the Integration of Error Analysis as Integrative Activity in Mathematics Classroom

Despite its demonstrated potential, several systemic and practical obstacles prevent error analysis from being widely and sustainably implemented in mathematics classrooms. The inability of students to identify, express, and classify their mistakes is a significant issue in several studies. Garcia [8] observed that students, particularly those with weaker metacognitive skills, struggled to analyze the reasoning behind their mistakes. Lacerna [6] discovered that students made encoding and comprehension mistakes even after structured error-analysis interventions. These key results show that conceptual misunderstandings could persist if scaffolded instruction and guided feedback are not provided.

Another significant limitation lies in teacher preparedness. Error analysis requires teachers to possess a firm grasp of diagnostic pedagogy, the ability to design reflective tasks, and the skill to facilitate discussions that turn errors into learning opportunities. However, Peligro et al. [9] noted that many educators lacked sufficient training in implementing error-based activities, particularly in higher-level topics like geometric proofs. Bautista [10] further emphasized that designing practical formative assessments around error analysis is time-intensive and often adds to teachers' workload. These demands can discourage implementation, especially in under-resourced settings with minimal teacher support systems.

Another persistent issue that surfaced was time constraints. Due to error analysis's reflective and dialogic nature, students need more time in class to recognize, discuss, and correct their mistakes. According to Lacerna [6], this lengthy time requirement frequently made it difficult for teachers to cover the entire curriculum, creating a conflict between breadth of content coverage and depth of understanding. Additionally, while many studies reported cognitive and affective gains, some, such as Bautista [10] and Casiño & Tan [11], found that error analysis did not always translate into statistically significant improvements in achievement scores compared to traditional methods like explicit instruction. This signals that the effectiveness of error analysis as an integrative activity in mathematics classrooms depends on the content's nature, the student's developmental level, and how the strategy was implemented.

From a scalability perspective, most studies remain limited to small-scale interventions or single-classroom contexts. Thus, the generalizability of findings is restricted, and the need for broader implementation studies is highlighted. Furthermore, while promising, integrated technology, particularly artificial intelligence, introduces a new set of challenges. International studies demonstrated that AI tools can enhance the efficiency of error detection and feedback, yet these platforms require sufficient accuracy, contextual awareness, and teacher training for effective deployment. Xu et al. [12] reported a detection of a curacy of 78.3%, which, while impressive, still leaves room for misclassification and student confusion. In addition, the infrastructure and digital literacy required to support these tools may not yet be widely available in many educational systems, especially in developing regions like the Philippines.

Finally, error analysis integration in mathematics classroom ultimately depends on curriculum alignment, consistent teacher development, enough instructional time, and, where appropriate, access to and training in emerging technologies. To fully realize error analysis's pedagogical potential as a method for encouraging more in-depth, reflective, and customized mathematics learning, these constraints must be addressed.

4. Conclusion

This systematic review mapped the landscape of error analysis as an integrative classroom activity in mathematics classrooms, examining thirteen empirical studies conducted locally and internationally. The findings demonstrate that error analysis is a powerful pedagogical strategy that improves students' conceptual understanding, metacognitive skills, and mathematical problem-solving. It provides a structured means to transform mistakes into learning opportunities, encouraging students to reflect, engage more deeply with mathematical ideas, and take ownership of their learning.

Two prevailing implementation models emerged from the studies: traditional teacher-led approaches and technologically assisted models—most notably, those integrating artificial intelligence (AI). While teacher-guided strategies such as lesson exemplars, group discussions, reflective journals, and formative assessments have effectively cultivated conceptual insight and classroom interaction, they are often constrained by practical factors such as teacher readiness, time demands, and instructional load. On the other hand, AI-enhanced approaches, as evidenced in recent international studies, show promising results in real-time error detection, iterative feedback, and personalized learning, thereby reducing teacher burden and scaling the approach for larger or more diverse classrooms.

However, these technological innovations are largely absent in local studies, relying on traditional models. These findings highlight a critical research and implementation gap in the Philippine context, where challenges related to infrastructure, digital literacy, and pedagogical training still limit the adoption of AI-driven education tools. Furthermore, while most studies reported positive learning outcomes, results also suggest that the impact of error analysis varies depending on the mathematical domain, student readiness, and instructional design. In some cases, explicit instruction outperformed error analysis in immediate achievement outcomes, suggesting that the strategy is most effective when thoughtfully aligned with learner needs and content complexity.

To fully realize the potential of error analysis in mathematics classrooms, especially in resource-constrained environments, a hybrid implementation model is recommended—one that blends the strengths of technology with the irreplaceable role of the teacher. Sustained professional development, localized curriculum integration, and equitable access to supportive technologies are key to making error analysis a scalable, sustainable, and effective instructional strategy. For practical implementation in the Philippine context, education stakeholders should invest in low-cost, modular teacher training programs focused on error-based pedagogy delivered through regional education centers or blended online formats. In parallel, DepEd and partner institutions can pilot AI-supported tools that operate offline or via mobile apps to assist with basic error detection and feedback—making them accessible even in schools with limited internet connectivity. As the educational landscape evolves, embracing pedagogical rigor and technological innovation will be essential to fostering deeper, more meaningful mathematics learning.

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