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Enriching the Critical Thinking Skills of Grade 7 Students Through Error Analysis Approach

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ABSTRACT: Developing students' critical thinking skills remains a persistent challenge in many educational settings. This study aimed to evaluate students' perceptions of their ability to identify mathematical errors and to investigate how the Error Analysis Approach can enhance their critical thinking skills. A three-week teaching approach that utilized Error Analysis was conducted with 35 heterogeneous students, employing a mixed-methods sequential explanatory design. Quantitative data were analyzed using mean and standard deviation for perceptions in identifying errors (factual, procedural, conceptual, careless), frequency and percentage for test score distributions, and paired t-tests to assess significant improvements in mathematical critical thinking skills (Interpretation, analysis, evaluation, inference). Qualitative data were interpreted using Colaizzi's method. Survey results showed high perceived ability to identify errors, with overall mean scores ranging from 3.23 to 3.29. Significant differences between pre-test and post-test scores were observed on the paired t-tests ($p = 0.000$, $p < 0.05$). Interview data supported these findings, highlighting the development of analytical thinking skills, reflective thinking, and self-correction, as well as strengthened problem-solving efficiency and enhanced understanding and conceptual clarity. These findings suggest that the Error Analysis Approach effectively enhances students' critical thinking skills, supporting its integration into instructional strategies.

KEYWORDS: critical thinking skills, error analysis approach, mixed-method, perception, teaching approach, mathematics

I. INTRODUCTION

Most Mathematics teachers have spent most of their time in the past few decades teaching new ideas by showing how things worked. While this approach provides foundational knowledge, it often overlooks the crucial development of critical thinking skills, which are core competencies in the 21st century. Recent innovations in educational research have, however, highlighted the significant potential of error analysis as a means to enhance critical thinking.

In the field of education, Rogovaya et al. (2019) emphasized that critical thinking is essential, as it is relevant across all areas of knowledge and in daily life. Supporting this view, Firdaus et al. (2015) argued that critical thinking skills must be integrated into students' learning and that schools have a responsibility to foster and assess these skills through their teaching and learning practices.

Jablonka (2014) also highlights that students do not automatically develop critical thinking skills from their Mathematics classes. Instead, these skills are developed through teaching methods that encourage students to think critically and ask questions while working on challenging problems.

According to McLaren et al. (2016), incorporating error analysis in the classroom can significantly improve students' understanding. Error analysis not only deepens comprehension of the lesson but also enhances critical thinking skills by requiring students to generate, evaluate, and defend their insights. By identifying and explaining errors, students demonstrate their grasp of concepts and learn to construct convincing arguments (Booth et al., 2015).

Furthermore, engaging in this process allows students to use what they are learning to develop new perspectives and devise innovative solutions. Error analysis is particularly important during the introduction of new ideas, as it informs the teacher of what to explain, what to emphasize, and how to facilitate the grasp of new concepts to prevent errors from occurring.

Existing studies have demonstrated the effectiveness of error analysis in promoting self-reflection, identifying knowledge gaps, and developing problem-solving strategies. As Makamure (2021) stated, error analysis has been considered indispensable in

teaching mathematics, and the ability to model misconceptions through error analysis has been recognized as one of the most valuable abilities in mathematics instruction.

Most experts also believe that error analysis is an effective educational method for helping mathematics students recall what they have learned (Rushton, 2018). However, a gap remains in understanding the specific mechanisms through which error analysis contributes to the development of critical thinking skills, particularly in diverse academic settings.

II. METHOD

This research employed a mixed-methods sequential explanatory design comprising both quantitative and qualitative phases. The study employed this design to collect numerical data through surveys, pre-tests, and post-tests, and then conducted interviews to further explain the results based on the respondents' gained experiences. As noted by Taherdoost (2022), mixed-methods approaches integrate qualitative data from interviews with quantitative survey results, providing a comprehensive understanding and enhancing the analysis and findings of the study.

The quantitative data were collected through a perception survey of the respondents' ability to identify errors (factual, procedural, conceptual, and careless) and pre-tests and post-tests focused on four critical thinking domains: Interpretation, analysis, evaluation, and inference.Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarize results, while a paired t-test assessed the significance of difference before and after the implementation of the error analysis approach. Qualitative data were obtained through structured interviews with selected students to explore their experiences with the error analysis approach. These were analyzed using Colaizzi's method to identify recurring themes and insights.

III. RESULTS AND DISCUSSION

A. Quantitative Phase of the Study

Table 1. Respondents' Perception of Their Ability to Identify Errors

Type of Errors	*Mean*	*SD*	*Verbal Interpretation*
Factual	3.26	0.34	Strongly Agree
Procedural	3.23	0.38	Agree
Conceptual	3.28	0.36	Strongly Agree
Careless	3.29	0.39	Strongly Agree
Overall	3.27	0.35	Strongly Agree

The table shows the overall mean score was 3.27, which can be verbally interpreted as "Strongly Agree." This indicates that respondents generally perceived themselves as capable of recognizing errors in terms of factual, procedural, conceptual and careless errors. These findings highlight a general strength in identifying obvious errors, such as incorrect numbers or symbols used in calculations, as well as addressing deeper conceptual misunderstandings that arise from gaps in error analysis tasks.

It also highlights that among the errors, the respondent generally felt confident in identifying errors that arise from inattention or oversight, usually due to a brief lapse in focus rather than a lack of understanding, with a mean score of 3.29. This indicates that they are particularly skilled at identifying errors that require minimal effort or attention to address, such as misreading the problem and sloppy handwriting leading to misinterpretation.

As noted in the study by Abdullah et al. (2015), careless errors often arise from factors such as negligence in accurately transcribing information from the question, reliance on guesswork, and a general lack of attention to detail. Since respondents often make these same mistakes themselves, they are more familiar with them, making these errors easier to recognize during error analysis tasks.

Moreover, the respondents revealed the lowest mean score of 3.23, indicating that they generally feel slightly less confident in their ability to identify errors in the sequence or execution of steps required to solve problems during the error analysis approach. This suggests that respondents found it more challenging to identify gaps or incorrect calculations in mathematical procedures than to recognize errors resulting from a lack of understanding or application of the correct mathematical concepts.

This finding is further reflected in error analysis tasks, where respondents demonstrate the ability to detect missing steps in problem-solving, such as skipped operations or incomplete procedures. These errors are often visible and stem from the improper application of mathematical rules, as highlighted by Andriani et al. (2021). Moreover, this outcome confirms the findings of Mathaba et al. (2024), which found that understanding the correct order of mathematical steps is a common procedural error among the respondents.

Table 2. Pre-test and Post-test Scores of the Respondents' Critical Thinking Skills in terms of Interpretation

Mean Score	*Pre-test*		*Post-test*		*Proficiency Level*
	F	%	F	%	
3.00 – 4.00			13	37.14	Extending
2.00 – 2.99			9	25.71	Proficient
1.00 – 1.99	7	20	10	28.57	Developing
0.00 – 0.99	28	80	3	8.57	Emerging
Total	35	100	35	100	

It can be derived from Table 5 that, in the pre-test, most respondents (28 out of 35, or 80%) were at the Emerging level, where they struggled to interpret errors and often provided little or no explanation of the step-by-step process. This demonstrated a limited understanding of why the given solutions were incorrect and why the described process must be followed. Only 20% (7 respondents) achieved the "Developing" level, where the explanation of the correct process was unclear or incomplete. Moreover, no respondents is attaining higher proficiency levels, indicating a partial understanding of the errors. Instead of fully grasping the underlying concepts, they tended to fix only the obvious mistakes, missing the deeper issues that led to the given errors.

Following the use of the error analysis approach, respondent performance improved, with 37.14% reaching the Extending level, demonstrating the ability to interpret errors by providing thorough and clear explanations of the correct process. They could not only interpret what went wrong but also understand the reason behind the errors. In addition, 25.71% were classified as Proficient level, indicating a clear explanation of the correct process and the capacity to make appropriate corrections. Meanwhile, 28.57% remained at the "Developing" level, and 8.57% remained at the "Emerging" level, showing growth but still occasionally misinterpreting errors where they cannot provide or there is little explanation of the correct procedure to apply on the given error analysis task.

Table 3. Pre-test and Post-test Scores of the Respondents' Critical Thinking Skills in terms of analysis

Mean Score	Pre-test		Post-test		Proficiency Level
	F	%	F	%	
3.00 – 4.00			11	31.43	Extending
2.00 – 2.99			11	31.43	Proficient
1.00 – 1.99	5	14.29	12	34.29	Developing
0.00 – 0.99	30	85.71	1	2.86	Emerging
Total	35	100.00	35	100	

The data in Table 3 highlight the progression of the respondents' skills in identifying errors before and after the implementation of the error analysis approach. The pre-test results reveal that the majority of the respondents (85.71%) were at the Emerging level, meaning they identified few or no errors. They struggled to pinpoint errors and lacked an understanding of what went wrong with the given problem. Meanwhile, 14.29% were at the Developing level, recognizing some errors but missing the important ones.

After the implementation of the error analysis approach, the results highlight progress in respondents' critical thinking skills in analysis. Nearly all respondents advanced to higher proficiency levels, with equal proportions (31.43%) attaining Proficient and Extending levels. This suggests that the respondents identified most or all the errors correctly and have developed the ability to break down the incorrect solution to locate the specific mistake and provide reasonable explanations. Furthermore, the respondents no longer viewed errors as simple miscalculations but analyzed them step by step to ensure correction. On the other hand, 34.29% remained at the Developing level, and 2.86% were still at the Emerging level, indicating that some respondents still made errors.

This emphasizes how error analysis encouraged students to think critically and assess errors more deeply than just identifying them at the surface level. The respondents learned to analyze solutions and identify the cause of errors. By thoroughly examining faulty work, the respondents improved their conceptual grasp and their capacity to identify errors.

Ultimately, the findings demonstrate that error analysis changes the way students learn mathematics by moving them from passive problem-solving to active analytical participation, which guarantees increased precision, and depth in their mathematical skills.

Table 4. Pre-test and Post-test Scores of the Respondents' Critical Thinking Skills in terms of Evaluation

Mean Score	Pre-test		Post-test		Proficiency Level
	F	%	F	%	
3.00 – 4.00			13	37.14	Extending
2.00 – 2.99			10	28.57	Proficient
1.00 – 1.99	8	22.86	12	34.29	Developing
0.00 – 0.99	27	77.14			Emerging
Total	35	100	35	100	

Table 4 reveals an improvement in respondent performance from the pre-test to the post-test. Initially, a majority (77.14%) of the 3Five respondents were at the Emerging level, indicating a limited ability to correct errors. These respondents mostly overlooked errors or lacked the reasoning needed to evaluate whether each step of their calculation was correct and what needed to be corrected. A reminder at the Developing level, showing that only some errors were corrected, indicates the ability to review the errors but struggles to correct the steps to arrive at the final answers fully.

However, the post-test shows that after utilizing the error analysis approach, 37.14% of the respondents reached the Extending level, where they accurately corrected all the errors. Demonstrating the ability to evaluate each step of the problem-solving process and justify answers. An additional 28.57% achieved the Proficient level, able to identify and correct most of the errors, which also shows that the respondent can provide reasonable explanations for the errors that have been corrected. The Developing level increased to 34.29%, while no respondents remained at the "Emerging" level.

The post-test results highlight the importance of error analysis in developing respondents' critical thinking skills, particularly in evaluation. This implies that the respondents can evaluate each step of the calculation to ensure that operations align with the problem description. Moreover, assesses whether the correct method has been applied and verifies the final answers.

This finding supports Marlett (2024), who suggests that error analysis helps respondents critically assess their mistakes, deepen their understanding of concepts, and enhance their evaluation and problem-solving skills. Similarly, in broader educational contexts, error analysis promotes metacognitive skills, enabling respondents to reflect on their thought processes and improve their evaluation skills (Torregoza & Aliazas, 2024).

The following is an example of a respondent's answer, demonstrating their critical thinking skills in evaluation using the error analysis approach. This demonstrates a thorough understanding of both the problem-solving process and the application of correct mathematical operations to arrive at the accurate answer.

Table 5. Pre-test and Post-test Scores of the Respondents' Critical Thinking Skills in terms of Inference

Mean Score	Pre-test		Post-test		Proficiency Level
	F	%	F	%	
3.00 – 4.00			14	40.00	Extending
2.00 – 2.99			9	25.71	Proficient
1.00 – 1.99	8	22.86	8	22.86	Developing
0.00 – 0.99	27	77.14	4	11.43	Emerging
Total	35	100	35	100.00	

Table 5 reveals that 77.14% of respondents were at the Emerging level in the pre-test, where little to no reasoning was evident regarding why the error was committed. This suggests challenges in drawing logical conclusions based on the provided information. Meanwhile, 22.86% of respondents were categorized as Developing, demonstrating some ability to make inferences, though their explanations lacked depth and clarity.

Consequently, a positive shift in the respondent's post-test performance highlights the effectiveness of the error analysis approach. While a portion of respondents (22.86%) remained at the Developing level, a notable 40% of respondents reached the Extending level, demonstrating excellent reasoning and logical thinking in the error analysis. This suggests that the respondent improved their ability to make well-supported inferences and connect them to avoid repeating the same mistake in the future.

Furthermore, 25.71% attained the Proficient level, demonstrating the ability to make sound reasoning and logical thinking in most parts of the incorrect solution. This indicates that, after utilizing the error analysis approach, most respondents can not only identify and analyze errors but also apply logical reasoning to justify the errors and prevent them from happening again.

The data highlights a considerable improvement in the overall critical thinking skills of the respondents, particularly in their ability to draw logical conclusions and identify where errors arise in the error analysis task. This helps respondents critically assess their reasoning, trace their steps back, and infer the root cause of the mistake.

Table 6. Test of Difference between the Pre-test and Post-test Scores of the Respondents before and after the utilization of Error Analysis Approach

Mathematical Thinking Skills	Critical	Mean	SD	t	Df	Sig. (2-tailed)	Interpretation
Interpretation	Pre-test	2.20	1.39	-14.055	34	0.000	Significant
	Post Test	7.94	2.82				
Analysis	Pre-test	1.29	1.74	-15.742	34	0.000	Significant
	Post Test	8.06	2.70				
Evaluation	Pre-test	2.40	1.94	-15.010	34	0.000	Significant
	Post Test	8.31	2.49				
Inference	Pre-test	1.23	1.83	-13.786	34	0.000	Significant
	Post Test	7.60	3.16				

The table illustrates the test of difference between the pre-test and post-test scores in Mathematical Critical Thinking Skills before and after the utilization of the Error Analysis approach. The results reveal significant differences across all four components of Critical Thinking Skills: Interpretation (p=0.000), analysis (p=0.000), Evaluation (p=0.000), and Inference (p=0.000). Since the p-values are all less than the critical value of 0.05, the null hypothesis is rejected. This indicates that the post-test scores show substantial improvement compared to the pre-test scores. Based on these findings, the error analysis approach is shown to have a positive impact on fostering growth in mathematical critical thinking.

These findings align with prior studies highlighting the effectiveness of error analysis in promoting critical thinking skills. For instance, Rushton (2018) demonstrated that incorporating error analysis into teaching practices fosters deeper mathematical comprehension and reflective thinking. Similarly, Umam and Susandi (2022) emphasize the importance of error analysis as a tool for enhancing respondents' ability to accurately interpret problems, systematically analyze solutions, evaluate their reasoning, and infer effective problem-solving strategies. These studies reinforce the conclusion that the Error Analysis Approach is a valuable pedagogical strategy for improving critical thinking skills in mathematics.

B. Qualitative Phase of the Study

The thematic analysis of the study illustrates how error analysis fosters critical thinking skills, transforming the way respondents approach problem-solving and has revealed four clustered meanings. These are as follows: developed analytical thinking skills, reflective thinking and self-correction, strengthened problem-solving efficiency and enhanced understanding and conceptual clarity.

Respondents shared that identifying and reflecting on their mistakes helped them understand concepts more clearly, analyze problems more thoroughly, and become more mindful of the steps they take in solving equations. This process encouraged them to slow down, observe, and think critically before answering. As a result, their awareness, focus, and ability to reason improved. These insights revealed that the error analysis approach does more than just correct mistakes; it also plays a vital role in enriching respondents' critical thinking skills. Through analysis of errors and reflection on the mistake, the respondents became more proactive in improving their problem-solving efficiency and instilled the habit of reflective thinking.

Overall, the qualitative findings revealed that the error analysis approach in mathematics class was a meaningful experience that positively influenced their learning and mental processes. Error analysis not only supported their academic growth but also strengthened important mental habits by encouraging analytical reasoning, reflection, efficiency, and conceptual understanding. This approach empowered respondents to approach problems with confidence, precision, and deeper comprehension.

As mentioned by Marzano (2017) and Aliazas et al. (2023), examining errors enables students to gain a deeper understanding of content by reflecting on their own reasoning and evaluating the logic behind the information presented to them.

IV. CONCLUSIONS

The study concludes that utilizing an error analysis approach significantly improves the critical thinking skills of students, as evidenced by the difference between the pre-test and post-test scores of the respondents.

This highlights the importance of incorporating structured error analysis tasks into an instructional approach to facilitate a deeper understanding of the lesson. While the research achieved its objectives, limitations such as the short duration of implementation and the sample size should be considered in future studies. Expanding the scope and duration could yield additional insights into its long-term benefits and applicability in other mathematical topics.

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