



## Error Analysis as Predictor of Senior Secondary School Students' Academic Achievement in Mathematics

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### Abstract

This study examined how mathematical error types—conceptual, procedural, and computational—predict secondary school students' achievement in mathematics. Using a correlational research design, the study involved 120 students from Abia State. Data were collected with Mathematics Achievement Test (MAT) and an Error Analysis Checklist (EAC). Instrument validity was confirmed by three mathematics education experts and two specialists in measurement and evaluation. Scorer reliability, assessed using Kendall's coefficient of concordance with four scorers, yielded coefficients of 0.82 for the MAT and 0.73 for the EAC. Pearson correlation analysis revealed significant prediction of mathematics achievement by conceptual ( $R^2 = .75$ ), procedural ( $R^2 = .874$ ), and computational errors ( $R^2 = .87$ ) at  $p < 0.05$ . Multiple regression analysis showed that the error types jointly explained 93.3% of the variance in mathematics achievement ( $R^2 = 0.933$ ). The study recommends error analysis, targeted remediation strategies, and teacher capacity-building to enhance students' mathematical performance.

**Keywords:** Computational Errors, Conceptual Errors, Error Analysis, Mathematics Achievement, Procedural Errors,

### Introduction

Mathematics is a fundamental subject in secondary education. It is a critical tool for practical application across diverse fields such as science, engineering, economics, and technology (Hiebert, Carpenter, & Fennema, 2020). Despite its significance, many students encounter persistent difficulties in learning and applying mathematical concepts and procedures. These challenges often manifest in the form of errors—categorized as conceptual, procedural, or computational—which significantly hinder academic achievement (Adams & Forrester, 2021; Booth, Newton, & Twiss-Garrity, 2021).

Error analysis, defined as the systematic identification and classification of students' mistakes during problem-solving, serves as a diagnostic tool for uncovering underlying misconceptions. By examining errors, educators can gain insights into student thinking and adapt instructional strategies to address specific learning gaps. Conceptual errors involve misunderstandings of fundamental mathematical ideas, procedural errors reflect inaccuracies in executing

problem-solving steps, and computational errors pertain to basic arithmetic mistakes (Reys, Lindquist, Lambdin, & Smith, 2022; Siegler, Thompson, & Schneider, 2015).

Contemporary research underscores the potential of error analysis to inform teaching and enhance learning. Rather than viewing errors as mere failures, educators are encouraged to see them as opportunities for promoting deeper understanding and reflective thinking (Tsangaridou, 2022; Schoenfeld, 2021). Structured error analysis can shift the instructional focus from correctness alone to the processes and reasoning behind student responses (Zimmerman & Schunk, 2022).

However, the use of error analysis in classrooms remains limited. Many teachers are not adequately trained to implement diagnostic assessments, and curriculum designs often prioritize final answers over problem-solving processes. Consequently, misconceptions remain unaddressed, affecting students' long-term mathematical proficiency (Holmes & McWhirter, 2020; Pellegrino, Chudowsky, & Glaser,



2021). This study investigates how different types of mathematical errors relate to and predict students' academic achievement in mathematics. It aims to provide empirical evidence that supports the integration of error analysis into routine classroom practice as a strategy for improving learning outcomes.

The study is anchored on Information Processing Theory by Robert Gagné (1974).

This theory conceptualizes learning as a process involving the reception, storage, and retrieval of information. It likens the human mind to a computer system, comprising sensory memory, short-term memory, and long-term memory. Learning occurs when information is effectively encoded and retrieved, while errors arise from breakdowns in these cognitive processes. In the context of this study, students' mathematical errors can be viewed as manifestations of cognitive difficulties during information processing—such as misinterpretation of a problem, incorrect encoding of information, or retrieval errors during computation. Error analysis helps teachers pinpoint where the breakdown occurs and apply targeted instructional interventions, including feedback, repetition, and cognitive scaffolding, to improve processing efficiency and reduce errors. Consequently, students' performance and achievement in mathematics are enhanced.

Previous studies have tried to identify types of errors students commit in mathematics solving process and the effect of such errors in their academic achievement in mathematics. Nwachukwu et al. (2019) investigated error correction techniques and student achievement and reported that error correction improved performance by 33%. Okeke and Anayo (2021) determined the relationship between Error frequency and mathematical anxiety. Findings indicate that higher error frequency correlated positively with increased mathematical anxiety ( $r = 0.55$ ). Obi and Nwoke (2019) investigated the relationship between error frequency and examination performance in mathematics. Result showed a significant negative correlation ( $r = -0.58$ ) between error frequency and examination scores. Ameh et al. (2022) analyzed procedural errors and intervention efficacy and reported that targeted remediation strategies improved student scores by 27%. Similarly, Yusuf et al. (2020) noted that fact errors primarily stemmed from weak foundational knowledge in mathematics. Eze and Okafor (2018) investigated effect of interactive teaching methods on procedural errors using Quasi-experimental design. Findings indicate that interactive teaching reduced procedural

errors by 30%. Usman and Aluko (2019) determined influence of operational errors on conceptual understanding of mathematics. Regression analysis of data indicated that a lack of conceptual understanding significantly contributed to operational errors.

While research has demonstrated the importance of addressing errors for improving mathematical performance, there remains a significant gap in understanding how error analysis can be effectively implemented within the classroom, particularly in secondary school settings. Despite its potential to enhance both teaching and learning, error analysis is often neglected or underused, limiting its effectiveness as a tool for improving academic achievement in mathematics (Adams & Forrester, 2021). It is speculated that students' academic achievement in mathematics has relationship with the type of errors they commit in mathematics solving process and the frequency at which they commit such errors. This is the bedrock of the present study.

This study, therefore, seeks to analyze the types and of errors made by secondary school students in mathematics, exploring their relationship with academic achievement, and examining the extent to which these errors could predict mathematics achievement. By identifying these critical issues, the study aims to provide actionable insights for educators, policymakers, and stakeholders to enhance mathematics instruction and improve student outcomes.

### Research Questions

1. What is the predictive power of conceptual errors on students' academic achievement in mathematics?
2. What is the predictive power of procedural errors on students' academic achievement in mathematics?
3. What is the predictive power of computational errors on students' academic achievement in mathematics?
4. To what extent do conceptual procedural and computational errors predict academic achievement of secondary school students in mathematics?

### Hypotheses

The following hypotheses are formulated and tested at a 0.05 significance level:

1. Conceptual errors do not significantly predict students' academic achievement in mathematics



2. Procedural errors do not significantly predict students' academic achievement in mathematics
3. Computational errors do not significantly predict students' academic achievement in mathematics
4. Conceptual, procedural and computational errors do not significantly predict academic achievement of secondary school students in mathematics

**Methodology**

The study adopted a correlational research design. The population for the study is 1195 senior secondary school two (SS2) students in six government owned secondary schools in Abia state for 2024/2025 session. The sample size of 120 students determined using Taro Yamane formula was drawn using three stage stratified, simple random and disproportionate sampling techniques. The first stage is the sampling of one Local government area from each of the three education zones. The second stage is the sampling of two schools from each of the local government areas giving a total of six secondary schools. The third stage is sampling of 20 students from each of the six schools. This was done to ensure proper representation of students and schools within the state.

Two instruments used to collect data were essay type Mathematics Achievement Test (MAT) and Error Analysis Checklist (EAC). The Mathematics achievement test was constructed by the researchers based on the following topics which the students have been taught: trigonometry, angle of elevation and depression, as well as bearing and distances. A total of 10 essay questions were constructed. Table of specification was used to ensure appropriate sampling of the questions to all content areas and cognitive domains. The other instrument for data collection in the study- Error Analysis Checklist, developed by the researchers, was used to categorize common mathematical errors that students make in Mathematics problem solving process. The errors considered are: Conceptual errors- Misunderstanding mathematical concepts; Procedural errors- Mistakes in following mathematical procedures or steps; Computational errors- Errors in basic arithmetic calculations. Codes of C1, P1 and C2 are assigned to conceptual, procedural and computation errors respectively. The checklist was based on possible errors determined from the solution of the questions.

Three experts in Mathematics education and two from Measurement and Evaluation were given the instruments to review to ensure face and content validity. A pilot test with 20 senior secondary school two students from secondary schools not included in the main study area was conducted. Their responses were scored by four scorers to determine the reliability of the achievement test and error check list. Analysis done using Kendall's coefficient of concordance yielded coefficients of 0.82 and 0.73 for achievement test and error check list respectively

**Data Collection Procedure**

The Mathematics Achievement Test was administered to the sampled students in their respective schools through the help of their mathematics teachers who were properly briefed. Students were given a specific period to complete the test, and their responses in the essay questions were scored by the researchers to identify the types and frequency of errors students made in the test. Errors were categorized according to the checklist. This process was used to obtain the achievement scores of the students as well as the error analysis scores. Data were analyzed using Pearson product moment correlation coefficient and multiple regression analysis.

**Results**

Research question 1 and hypothesis 1

**Table 1** Predictive power of conceptual errors on mathematics achievement

Variables	R	R <sup>2</sup>	Sig, (2-tailed)
Mathematics Achievement	-.866	.75	.000
Conceptual Errors			
N	120		

Note. N = 120. R = Pearson correlation coefficient. R<sup>2</sup> = coefficient of determination.

From table 1, correlation coefficient (R) between mathematics achievement and conceptual error is -0.866, with a Significance (p-value) of .000. The coefficient of determination (R<sup>2</sup>) is .75, which indicates that 75% of achievement in mathematics can be predicted by conceptual error. The p-value (.000) is less than the alpha level of 0.05, therefore the null hypothesis is rejected. Hence conceptual errors significantly predict mathematics achievement.

### Research question 2 and hypothesis 2

**Table 2**

*Predictive power of procedural errors on mathematics achievement*

Variables	R	R <sup>2</sup>	Sig, (2-tailed)
Mathematics Achievement	-.935	.874	.000
Procedural Errors			
N	120		

Note.  $N = 120$ .  $R$  = Pearson correlation coefficient.  $R^2$  = coefficient of determination.

Result from table 2 shows correlation coefficient ( $R$ ) as  $-0.935$  with significance ( $p$ -value) as  $.000$ . The coefficient of determination ( $R^2$ ),  $.874$ , indicates that  $87.4\%$  of achievement in mathematics can be predicted by procedural errors. The significance  $p < .05$ , so the null hypothesis is rejected. Hence procedural errors significantly determine mathematics assessments.

### Research question 3 and hypothesis 3

**Table 3**

*Predictive Power of Computational Errors on Mathematics Achievement*

Variables	R	R <sup>2</sup>	Sig, (2-tailed)
Mathematics Achievement	-.938	.87	.000
Computational Errors			
N	120		

Note.  $N = 120$ .  $R$  = Pearson correlation coefficient.  $R^2$  = coefficient of determination.

Result in table 3 shows that the correlation coefficient ( $R$ ) is  $-0.938$  and the coefficient of determination ( $R^2$ ) is  $.87$ , which indicates that  $87\%$  of achievement in mathematics can be predicted by computational errors.

With a  $p$ -value of  $.000 < .05$ , the null hypothesis is rejected indicating that computational errors significantly predict Mathematics achievement.

### Research question 4 and hypothesis 4

**Table 4: Model Summary and ANOVA for Regression Analysis**

Model	R	R Square	F	Sig.
1	.966 <sup>a</sup>	.933	540.865	.000

Note. Predictors include conceptual, procedural, and computational errors

Table 4 shows that  $R = 0.966$ ,  $R^2 = 0.933$ ,  $F = 540.865$  and Significance ( $p$ -value) =  $.000$ . The indication is that the overall regression model is statistically significant. The  $R^2$  value of  $0.933$  indicates that  $93.3\%$  of the

variance in mathematics achievement can be explained by the combined effect of conceptual, procedural, and computational errors. The high  $F$  value and significant  $p$ -value ( $.000$ ) confirm that the model fits the data well.

**Table 5**

*Multiple Regression Analysis of Error Types Predicting Mathematics Achievement*

Model		Unstandardized Coefficients B	t	Sig.
1	(Constant)	57.509	42.613	.000
	Procedural error scores	-2.081	-8.793	.000
	Computational error score	-2.226	-8.149	.000
	Conceptual error scores	-1.361	-8.282	.000

Note.  $B$  = unstandardized regression coefficient.  $N = 120$ .



Result in Table 5 shows that conceptual, procedural and computational errors have significant negative effects on Mathematics achievement (each variable has negative coefficient and significant p-values). Conceptual error has coefficient of -1.361, t-value of -8.282 and significance level of .000. Also, procedural error has coefficient of -2.081, t-value of -8.793 and significance level of .000. Similarly computational error has coefficient of -2.226, t-value of -8.149 and significance level of .000. Hence, each unit increase in these errors decreases students' scores in mathematics. Therefore, the null hypothesis is rejected. The conclusion is that conceptual, procedural and computational errors significantly predict academic performance in mathematics.

### Discussion of Findings

The study found that conceptual errors significantly predicts 75% of students' academic achievement in mathematics. Conceptual errors often stem from incomplete or incorrect internalization of fundamental concepts, such as misunderstanding the laws of exponents or the nature of trigonometric ratios. The reason could be that when students hold misconceptions at this level, they are likely to misapply mathematical ideas, resulting in systemic errors that will invariably affect their process and accuracy marks. This could lead to poor performance in Mathematics. The finding aligns with previous research (Usman & Aluko, 2019; Hiebert et al., 2020; Booth et al., 2021), which underscores the detrimental impact of weak conceptual understanding on performance. The findings emphasize the need for teachers to prioritize conceptual clarity and to use diagnostic tools like concept mapping, Socratic questioning, and real-life applications to strengthen students' foundational understanding.

Similarly, procedural errors presented as a significant predictor of Mathematics achievement. Procedural errors arise when students understand the concept but incorrectly execute the steps involved in solving a problem—such as failing to follow the order of operations or mishandling algebraic manipulations. The reason for this result could stem from the fact that scoring of Mathematics test involve assignment of method marks at different steps. Loss of method marks due to procedural error leads to loss of accuracy marks which will lead to poor achievement. This result is consistent with studies by Ameh et al. (2022) and Eze and Okafor (2018), which reported that procedural lapses significantly hinder students' performance and

can be addressed effectively through targeted interventions and interactive teaching.

Furthermore, computational errors were found to predict mathematics achievement by 87%. These errors which typically involve basic arithmetic mistakes such as incorrect addition, subtraction, or multiplication will deny students some process and accuracy marks which will lead to poor performance. It often reflect carelessness, anxiety, or weak foundational skills. This outcome is supported by Yusuf et al. (2020), who linked computational errors to poor foundational knowledge. While such errors may appear minor, their cumulative effect in multi-step problems can drastically lower performance. These results highlight the necessity of ensuring mastery of arithmetic skills before advancing to more complex topics. Addressing computational errors may require increased practice, the use of digital drills, error feedback loops, and immediate correction strategies in instruction. It also suggests that continuous reinforcement of basic arithmetic is necessary even at the secondary level.

The regression analysis revealed that conceptual, procedural, and computational errors collectively explained 93.3% ( $R^2 = 0.933$ ) of the variance in students' academic achievement. This is a remarkably high explanatory power, confirming that the frequency and type of mathematical errors are powerful predictors of performance. Interestingly, all three error types were significant predictors ( $p < .05$ ), but with varying coefficients: Conceptual error ( $B = -1.361$ ), Procedural errors ( $B = -2.081$ ) and computational errors ( $B = -2.226$ ) had significant negative effects, confirming their strong detrimental impact. This corroborates the finding of Okeke and Anayo (2021), Obi and Nwoke (2019), Adams and Forrester (2021), Nwachukwu et al (2019) who reported negative influence of conceptual, procedural and computational errors on students' academic achievement in mathematics.

The overall implication is that reducing these errors through intentional teaching practices, formative assessment, and remediation can dramatically improve student achievement. The result strongly supports the integration of error analysis into everyday mathematics instruction as both a diagnostic and formative tool.

### Conclusion

The study provides compelling evidence that mathematical errors—conceptual, procedural and



computational—have a profound effect on students' academic performance. The ability of these errors to predict achievement with high accuracy demonstrates the value of error analysis as both an instructional and assessment tool. Future efforts should prioritize the integration of error analysis into teaching, curriculum, and assessment strategies to enhance learning outcomes and mathematical proficiency among secondary school students.

### Recommendations

Based on the findings of the study, the following recommendations are made:

#### 1. Integrate Structured Error Analysis into Teaching Practice

Teachers should incorporate regular error analysis exercises into mathematics instruction. This involves not only correcting students' mistakes but analyzing the types and sources of errors to provide targeted feedback. This approach will help students develop metacognitive skills and deepen their understanding of mathematical concepts and procedures.

#### 2. Provide Targeted Remediation for Procedural and Computational Errors

Given the strong negative impact of procedural and computational errors on achievement, specific intervention programs should be developed to address these areas. Teachers can use step-by-step guides, error-correction tasks, and peer-assisted learning to help students master the correct procedures and improve arithmetic accuracy.

#### 3. Strengthen Conceptual Understanding through Active Learning

Conceptual errors highlight gaps in students' foundational knowledge. Teachers should employ instructional strategies that promote conceptual learning—such as visual models, real-life applications, and exploratory activities—to help students build a strong understanding of mathematical principles before introducing complex procedures.

#### 4. Train Teachers in Diagnostic and Formative Assessment Techniques

Professional development programs should equip teachers with skills to conduct diagnostic assessments and interpret student errors effectively. Emphasis should be placed on using error patterns to inform instruction, design individualized interventions, and guide continuous learning improvement.

#### 5. Incorporate Error-Based Assessment into School Evaluation Systems

Assessment practices should go beyond grading correct answers to include evaluations of students' error patterns. Schools and examination bodies can adopt formative error-focused assessments as part of internal evaluations to help identify learning gaps early and improve instruction.

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