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Analysis of Error Patterns in Mathematics Problem Solving Among Junior Secondary School Students in Minna Metropolis, Niger State, Nigeria

[1]Ahmad, M. U., [2]Zakariyya, A. A., & [3]Ndagara, S. A.
[1&3] Department of Mathematics, Niger State College of Education, Minna, Niger State
[2] Department of Science Education, Ibrahim Badamasi Babagida University Lapai, Niger State

***Corresponding author email:** yamanalkali@gmail.com

Abstract
This study analyses error patterns in mathematics problem solving of junior secondary students in Minna, a Metropolis of Niger State, Nigeria. The population of the study is 650, while the sample size of the study was 180 JSS III Students (82 Male; 98 Female) selected from six (6) schools using a simple random sampling technique. Three research questions and one hypothesis were formulated at 0.05 level of significance to guide the study. An instrument titled Mathematics Diagnostic Test (MDT) was used for data collection and validated by three experts with a reliability coefficient r=0.79. The frequency counts and percentage was used to answer the research questions while chi-square was used to test the null hypothesis. The results revealed that female students recorded the highest frequency count of common error patterns 869, while male students had a frequency count 548. Also, the stated null hypothesis was rejected. This implies gender of junior secondary school students significantly impacts their common error patterns when solving mathematics problems. It was recommended among others: that teachers should identify and discuss students' common error patterns when solving problems, after that teachers should provide appropriate teaching methods to address such issues.

Keywords: Mathematics, Error Patterns, Problem-Solving, Achievement, Students

Introduction

Mathematics is one of the major intellectual subjects taught at primary, junior, and senior secondary school levels, with the primary aim to give a solid foundation for scientific development and prepare them for the next levels of education in Nigeria (Ahmad et al., 2021). Mathematics is the bedrock of science and a solid foundation for any national development and growth. It is an intellectual discipline that takes across all courses, both sciences, arts, and social sciences. And to reckon with in development of any country that wishes to attain scientific, technological, political, and economic developments (Nwoke et al., 2024). It is a subject that provides students with necessary skills, such as critical thinking, creative thinking, logical reasoning, problem-solving, and making vital decisions. Mathematics is an important subject, in their concepts are linked and it is also a pre-requisite for getting admission into tertiary education in Nigeria. A poor foundation in mathematics at any low level of education has negative effects on mathematics learning at future levels since concepts are linked together. That is, concepts, structures, principles, and skills are built from low to high levels (Ahmad et al., 2024). Without a good foundation in mathematics learning, that may lead to learning difficulties and common errors in mathematics problem-solving, which in turn leads to poor achievement in mathematics. It will also hinder learners' ability to perform well in any advanced content in mathematics and limit their academic and career opportunities that require mathematical knowledge and competency.

Good mathematics teachers must be well-informed or aware of the causes of poor performance of each learner in a class for effective teaching/learning in mathematics. This awareness will assist allots to improving the instructional methods and students' learning. Several studies outlined some factors that are attributed to this trend of low achievement in both internal and external examinations (Nwoke et al., 2024). These include Lack of coverage of the curriculum, lack of appropriate instructional materials, poor instructional methods, inadequate mathematics teachers, teachers' attitude towards mathematics, students' attitude towards mathematics and common errors committed in problem-solving. Of all the challenges faced by students which lead to learning difficulties and poor achievement,

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what attracted one to researchers of this study is the common error patterns committed by students due to lack of understanding of mathematical language.

Error analysis (EA) is defined as a diagnostic assessment that assists the teacher in identifying what types of errors a student consistently makes and why (Sheryl, 2018). Furthermore, Cheng (2012) and Brown et al. (2016) viewed, (EA) as a systematic process of reviewing a student's work and then searching for patterns of misunderstanding. Identifying the area of students' specific errors is very crucial and important for students with mathematics learning disabilities and low-performing (Brown et al., 2016; Inekwe, 2017). By pinpointing student's errors, the teacher can easily provide an instructional guide to the student's area of deficiency. Students who have mathematics learning difficulties in the area of conceptual knowledge for several reasons, may have an inability to process information at the same pace as peers, inadequacy in practice, lack of specific feedback during delivery from instructors regarding misunderstanding or non-understanding, mathphobia and difficulties in visual and/or auditory processing (Cheng, 2012). Research in the area of error analysis is not new, several studies have been reported that error analysis has been found a more effective method for identifying patterns of mathematical errors for any student, with or without disabilities, who is facing challenges in mathematics (Riccomini, 2014). EA can assist the mathematics teacher in identifying which steps the student has correctly or not. Also, determine what type(s) of errors a student is making, whether an error is a one-time miscomputation or consistent, misunderstanding of a mathematic concept or procedure. This will give the teacher the opportunity to select an effective teaching method to address the student's misconceptions and to teach the right concept, strategy, or procedure. Determining the type(s) of error patterns committed by a student when solving any mathematical problem refers to identifying error patterns (Brown et al., 2016; Inekwe, 2017) and the model was adopted and modified in the study as contained in the methodology.

Ahmad et al. (2021) opine that despite the importance of mathematics, there has been a lack of improvement in students' achievement in the subject at the final examination yearly. They observed that students face a lot of challenges among others, lack of understanding of mathematical language, which is key to learning and problem-solving. If teachers fail to use proper symbols, terms, concepts and structures when teaching the students, many perceive it wrongly, and misusing mathematical language will entail poor communication. When it occurs, this leads to students in a longer time conceptual error. They observed that students' answer scripts at all levels of mathematics reveal at least eight common types of errors. These include syntactic, semantic, culture inhibition, premature approximation, mechanistic, pragmatic, understanding, and misreading. Common errors in mathematics can be factual, procedural, or conceptual, which may occur for several reasons (Cheng, 2012; Brown et al., 2016). Scholars like Nwoke et al. (2024) submitted that there are various types of errors; visual spatial error, comprehensive error, transformation error, wrong operational error, defective algorithm, and conceptual error. Odor et al. (2023) in another narration listed the following errors, error in encoding, process skill error, transformation error, comprehension error. They also said that when mathematics is taught through teacher-active instruction that involves interaction and constant exercise, learning will be more effective. Inekwe (2017) and Odor et al. (2023) described an error in problem-solving as a wrong process that leads to incorrect answers despite being taught the correct algorithm. To them students of different levels: low, average, and high commit errors in writing the final solution due to computation processes, leading to wrong conclusions. This study focused on five errors based on the report submitted by the Director Test and Measurement Unit on Basic Education Certificate Examination (BECE, 2023). It was confirmed that candidates commit these errors when solving mathematics problems involving fractions, place value, directed numbers, expansion of algebraic expression, and basic operations with more than two operations, resulting in their poor performance. These are conceptual error, computational error, syntactic error, factual error and procedural error.

1. **Conceptual Error:** It is an error committed by students giving a wrong interpretation or misunderstanding the underlying concept. That is to say, lack of understanding of underlying ideas and principles and a recognition of when to use them. This error is then classified into four: wrong usage of the formula, misinterpreting of the concept, misreading of the formula and wrongly writing of mathematics expression. For examples; $10 + 8 = 81$, $87 + 4 = 18$. Also in the case of the word problem student was asked to write out in figure, given that- eight thousand, five hundred thirty-five, the student provided the solution as 8000535. Here the student lacks conceptual knowledge of place value. Conceptual knowledge is an understanding of underlying ideas and principles and a recognition of when to apply them. It also involves understanding the relationships among ideas and principles (Riccomini, 2014).

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2. **Computational Error:** It is an error committed by students after understanding the actual concept but making careless errors in calculation. This may be mistakenly on basic operations or premature approximation. This act will lead to inaccuracy in the solution needed.
3. **Syntactic Error:** An error committed by students on considering the relationship between a symbol and another symbol in a given mathematics expression. For examples; $4^2 = 8$, $-5 + 5 = 10$, $4+7(X-5) = 11+X- 5$
4. **Factual Error:** It is an error as a result of a lack of factual information (e.g., vocabulary, digit identification, place value identification). For instance, $4 + 3 = 8$, $3 \times 4 = 8$, $8 – 5 = 2$, $9 \div 5 = 4$. When a student is given this problem to solve: $457 + 24 = 482$, looking at the answer provided, the solver followed the correct procedures but added the one's column incorrectly. By that act the student has not mastered the basic fact. This error refers to a factual error.
5. **Procedural Error:** It is an error committed due to incorrect performance of steps in the mathematical process (e.g., regrouping, decimal placement). For examples; $23.4 +137=37.1$; $3/9 \times 6/9 =18/9$. Also, $594 + 27 = 5111$, the solver added the ones' column correctly but did not carry over the one tens column. In this case, the student utilized an inaccurate procedure (procedural error).

The primary aim of this study is to analyze error patterns in mathematics problem-solving of junior secondary school students. Additionally, the study will also investigate whether the error patterns have gender disparity. Some researchers have shown in their studies that there is a statistical difference in gender performance in mathematics. For instance, a study by Esuong et al. (2022) revealed that there is a significant mean difference in the academic performance of male and female students in secondary schools. Another study by Nwoke, et al. (2024) reported that there is a significant difference in the errors committed by male and female students. However, research evidence by Ahmad et al. (2023) reported that the impact on academic performance in mathematics is not statistically significant concerning gender, whenever no room is provided for discrimination and stereotypes in the classroom setting. Furthermore, when male and female students are actively engaging in social interaction and motivated. Another study by Odor et al., (2023) reported that the gender of secondary school students does not significantly impact the process errors when solving mathematics problems, especially trigonometry. Thus, there has been little attention on gender disparity in major errors when solving mathematics problems in junior secondary schools. Therefore, there is a need for research work on gender disparity in major errors in mathematics to provide insight for remediation to improve the academic performance of students in junior secondary schools.

Statement of the Problem

Common errors are unavoidable, it is a component of learning and problem-solving in mathematics. Errors and poor performance are being found as major challenges for junior secondary students. Mathematics educators and researchers in mathematics education have made multifarious efforts to remediate errors committed by students to advance their achievement in mathematics, not excluding those with mathematics learning disabilities. This situation of poor performance in the Basic Education Certificate Examination (BECE) has been reported by the Director of, the Test and Measurement unit from 2017 to 2023. It also confirmed that candidates' answer scripts are persistent with common errors when solving problems involving directed numbers, fractions, order of basic operations, expansion and factorization and place value. To the best of our knowledge, no study has been directed to address errors in analysis patterns in mathematics problem-solving among junior secondary students. To close this gap, this study is aimed at analyzing error patterns in mathematics problem-solving of junior secondary students in Minna Metropolis.

Aim and Objectives of the Study

The study is an Errors analysis pattern in mathematics problem solving of junior secondary school students in Minna Metropolis of Niger State. The objectives of this study are to:

1. Identify the types of errors committed by junior secondary school students in mathematics problem-solving.
2. Find out the type of errors committed by male students while solving mathematics problems.
3. Determine the type of errors committed by female students while solving mathematics problems.

Research Questions

The following research questions were asked to guide this study:

1. What types of errors are committed by junior secondary school students while solving mathematics problems?
2. What types of errors are consistently committed by male students while solving mathematics problems?

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3. What types of errors are consistently committed by female students while solving mathematics problems?

Hypothesis

The following null hypothesis is formulated and tested at 0.05 level of significance.

H_{01}: The gender of junior secondary school students does not significantly impact their common error patterns when solving mathematics problems.

Methodology

This study adopted a descriptive survey research design, which was used to characterize by systematic collection, analysis and interpretation of data to describe a phenomenon. The population consisted of 650 JSS III students. A total of 180 JSS III students made up the sample of the study using Cochran's (1963) formula, this was made up of 82 males and 98 females. To identify the common errors involved in solving mathematics problems, the researchers used the Mathematics Diagnostic Test (MDT). The MDT test items were drawn from the BECE examination question papers from 2017- 2023 adopted and modified. The test items consist of 10 essay questions covering directed numbers, place value system, fractions and order of operation. The MDT consists of two sections: section A – Introduction, instruction and bio-data, while, section B – is made up of 10 essay questions. The instrument was validated by three experts from the Federal University of Technology, Minna and the Test and Measurement Unit, Ministry of Basic and Secondary Education, Minna. The reliability of the instrument was established through test-retest and rated as r = 0.79.

The processes of identifying common error patterns committed by students in this study are discussed in phase 1 – 3 below:

Phase 1: the MDT was administered to all students, using pen and paper, showing all their work.

Phase 1I: identifying error patterns, and the five common errors (conceptual, computational, syntactic, factual and procedural).– reviewing the students' solutions, and looking for consistent error patterns.

Phase 1II: determining the number of consistent error patterns in each group.

Data collected were analysed with both descriptive statistics: frequency, and percentage to answer the research questions and inferential statistics; chi-square to test the stated null hypothesis at 0.5 level of significance.

Results

Research One: What types of errors are committed by junior secondary school students in mathematics problem-solving?

The results in Table 1 provide the answer to research question one.

Table 1. Analysis of Common Errors Committed by All Students

Error types	Number of students	Frequency	Percentage (%)
Conceptual	180	257	19.51
Computational	180	190	14.43
Syntactic	180	235	17.84
Factual	180	185	14.05
Procedural	180	450	34.17
Total		**1317**	**100.00**

The result in Table 1 revealed that the highly committed error by students of junior secondary schools was a procedural error with a frequency 450 (34.17%) of 1317, followed by conceptual error with a frequency 257(19.51%). Thirdly, syntactic error with a frequency count 235(17.84%) then computational error with 190 (14.43%). Lastly, factual error out of the five common errors committed had a frequency count 185(14.04%) of 1317.

Research Two: What types of errors are consistently committed by male students while solving mathematics problems?

Table 2 displays the solution to research question two as shown below:

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Table 2. Analysis of Common Errors Committed by Male Students

Error types	Number of students	Frequency	Percentage (%)
Conceptual	82	143	26.10
Computational	82	73	13.32
Syntactic	82	76	13.87
Factual	82	85	15.51
Procedural	82	171	31.20
Total		**548**	**100.00**

It can be observed in Table 2 that the consistently common error committed among the male students was procedural error with the highest frequency count of 171(31.20%) out of 548, followed by conceptual error with 143(26.10%). Factual error stands at the third portion, with a frequency of 85(15,51%) of 548. The fourth and fifth are syntactic errors with a frequency count of 76 (13.87 %) and computational errors had a frequency count of 73 (13.32%) respectively.

Research Question Three: What types of errors are consistently committed by female students while solving mathematics problems?

Results in Table 3 provide a solution to research question three using descriptive statistics.

Table 3. Analysis of Common Errors Committed by Female Students

Error types	Number of students	Frequency	Percentage (%)
Conceptual	98	214	24.63
Computational	98	117	13.41
Syntactic	98	159	18.30
Factual	98	100	11.51
Procedural	98	279	32.11
Total		**869**	**100.00**

Results in Table 3 recorded 32.11% of 100 procedural errors for female students as the highest error committed by them, followed by 24. 63% on conceptual error. Furthermore, 18.30% was recorded on syntactic error as third by ranking order. Lastly, computational and factual errors were recorded at 13.46 % and 11.51% in the fourth and fifth portions respectively.

H_{01}: The gender of junior secondary school students does not significantly impact their common error patterns when solving mathematics problems.

Table 4: Analysis of Chi-square test of Common Error Patterns based on Gender

Variables	N	DF	$\chi^2 Cal$	$\chi^2 Tab$	Decision
Committed Common Error Patterns	180	4	24.02	21.03	Rejected

The result in Table 4, obviously displays that the computed chi-square 24.02 is greater than the critical value 21.02 at Alpha 0.05 level of significance and 4 as the degree of freedom. Hence, we reject the null hypothesis. This implies that the gender of J.S.S III students significantly impacts their common errors when solving mathematics problems.

Discussion

Based on the results in Table 1, the persistently committed error patterns among students when solving mathematics problems from highest to lowest using frequency count are as follows: procedural error 450 (34.17%), conceptual error 257 (19.51%), syntactic error 235 (17.84%), computational error 190 (14.43%) and lastly factual error 185 (14.05). It was also discovered in Tables 2 and 3 with respect to gender disparity that female students had the highest frequency count of common error patterns 869 out of 1317, while male students had a frequency count of 548. In

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order to determine whether the difference is statistically significant, inferential statistics was utilized to test the null hypothesis. Obviously result in Table 4 recorded that the calculated chi-square 24.02 is greater than the critical value 21.03, which implies the stated null hypothesis is rejected. Therefore, the gender of junior secondary school students significantly impacts their common error patterns when solving mathematics problems. This finding confirmed the findings of Nwoke et al. (2024) who reported that there is a significant difference in the error patterns committed by male and female students. Similarly, the study by Esuong et al. (2022) revealed that there is a significant difference in the academic performance of male and female students in secondary schools. But contradicts with findings of Odor et al. (2023) who reported that the gender of secondary schools does not significantly impact the process errors when solving mathematics problems.

Conclusion

This study investigated the error patterns of junior secondary students when solving mathematics problems and their relationship with gender. The results revealed the following error patterns committed based by ranking order from highest to lowest: procedural, conceptual, syntactic, computational and factual errors. Furthermore, female students committed more errors than male students with a frequency count difference of 321. Also, the gender of junior secondary school students significantly impacts their common error patterns when solving mathematics problems.

Recommendations

Against this conclusion, the following recommendations were made:

1. Mathematics teachers should identify and discuss students' common error patterns when solving mathematics problems, after that teachers should provide appropriate teaching methods to address such issues.
2. Mathematics teachers should select effective instructional models to address the students' specific errors. This will assist students in performing the required skills effectively and improve their problem-solving skill
3. s. Curriculum developers should incorporate more problem-solving activities in mathematics education. This can assist students to develop their problem-solving skills and improve their understanding of mathematics concepts, principles and structures.

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