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TRIGTASTROPHE: ANALYSIS OF THE PROCESS ERRORS SENIOR SECONDARY STUDENTS COMMIT IN SOLVING TRIGONOMETRIC PROBLEMS

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ABSTRACT

Introduction: Mistakes made while solving Mathematical problems can provide insight into their difficulties in learning Mathematics. Identifying frequently occurring mistakes can be an essential tool for teachers to assess their students' proficiency in Mathematics.

Purpose: This study was designed to examine the extent to which process errors are made by Nigerian secondary school students while solving trigonometric problems.

Methodology: A descriptive survey research design was adopted. Data was collected from 300 respondents selected from a population of 7304 SS3 students using purposive sampling. The Trigonometry Diagnostic Test (TDT) was used to collect data upon validation by experts in Mathematics education and measurement and evaluation. The TDT had a high internal consistency and a reliability coefficient of 0.89. The collected data were analysed using frequency counts, percentages, and the Chi-square test of independence.

Results: The study identified that most Nigerians senior secondary school students made errors in reading, transformation, process skills, and encoding while solving trigonometric problems, whereas comprehension errors were relatively rare. The findings indicated that students' gender and school location did not significantly influence the process errors made while solving trigonometric problems.

Conclusion: The study suggests that Mathematics teachers need to be aware of the different types of errors made by their students in trigonometric problem-solving and develop appropriate programmes to address gaps or disparities.

Recommendation: Based on the findings, it is recommended that Mathematics teachers should design more practical and activity-based trigonometry programs to reduce errors.

Keywords: Gender, female, male, rural, school location, urban.

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PUBLIC INTEREST STATEMENT

This study have important implications for addressing educational inequalities and ensuring all students have equal opportunities to learn and succeed in mathematics regardless of gender or location. By identifying these errors the errors students commit when solving trigonometric problems, educators and curriculum developers can develop targeted interventions to help students improve their problem-solving skills and mathematics performance. The study also provides valuable insights into the strengths and weaknesses of the mathematics education system in Obubra Local Government Area of Cross River State, Nigeria, which can inform policy decisions and resource allocation.

INTRODUCTION

Mathematics is crucial in advancing science and technology, which justifies its mandatory inclusion in Nigeria's primary and secondary school curriculum. However, despite its significance, considerable evidence indicates that numerous secondary school students do not excel in mathematics. For instance, studies have reported that students' performance in Mathematics has generally been poor and sometimes fluctuated over the years (Bassey et al., 2020; Esuong et al., 2022; Okigbo & Ejikeme, 2017; Owan, 2020; Owan et al. 2020; Owan, Duruamaku-dim, et al., 2019; Owan, Etudor-Eyo, et al., 2019). Okigbo and Ezeanyi (2020) assert that mathematics significantly affects academic progress. One major aspect of Mathematics that students tend to fail the most is trigonometry.

Trigonometry studies anything about the functions of sine, cosine and tangent. Several studies have highlighted the importance of trigonometry as a foundational subject in algebra and geometry (Sarac, 2017; Zulfa, 2020). Developing a strong understanding of trigonometry has been found to enhance students' cognitive abilities (Sulistyaningsih, 2021) and foster critical thinking skills by promoting reasoning and proof skills (Phonapichat, 2014). However, it is among the most challenging topics for many secondary school students who struggle to pass (Usman, 2017). The students' poor performance in trigonometry is concerning and requires immediate attention. Orhun (2013) discovered that students struggled to grasp trigonometry concepts and made mistakes. Teacher-centred and memorisation-based teaching methods only provide temporary knowledge and are not retained by students in the long term. Moreover, Delice (2012) reported that most students misconceive trigonometric concepts, perceiving them as difficult. For this reason, many of them dislike it (Challenger, 2009).

Nevertheless, the WAEC Chief Examiners' Report from 2015 to 2019 confirmed that candidates commit process errors when solving trigonometric problems involving Pythagoras' Theorem, Sine Rule, Cosine Rule, elevation and depression, resulting in their abysmal performance. Inekwe (2017) describes an error in problem-solving as a wrong process that leads to an incorrect solution despite being taught the correct process. Some studies, have identified specific process errors students make when solving trigonometry problems using the "Newman Error Analysis" such as reading, comprehension, transformation, process skill and encoding errors (Newman, 1977; Sapire et al., 2016; Usman; 2017; Rahmawati & Permata, 2018).

According to Singh et al. (2010), reading errors (RE) are mistakes students make when they struggle to comprehend the words or symbols in the questions. Comprehension errors (CE), on the other hand, arise when pupils have a firm grasp on reading comprehension but lack a firm grasp on the underlying difficulties being tested (Singh et al., 2010). Transformation errors (TE) occur when there is a mistake in the mathematical modelling or when the issue is improperly transformed into a mathematical form (Dewi & Kartini, 2021). Students with low abilities make transformation errors frequently (Halim & Rasidah, 2019; Rahmawati & Permata, 2018), which results from students' inability to understand the method to be used. Process skills errors (PSE) are mistakes in solving a problem (Jha, 2012; Singh et al., 2010). Other studies (e.g., Rahmawati & Permata, 2018; Utami, 2016) have supported that calculation mistakes cause process skills errors. Errors in encoding (EE) refer to errors students make when they obtain incorrect answers despite correctly completing the problem-solving process (Singh et al., 2010). Students across different ability levels (low, medium, and high) commonly make mistakes in writing the final answer due to incorrect calculation processes, leading to incorrect conclusions (Darmawan et al., 2018; Wahidah et al., 2017).

The main focus of this study was on the process errors that students make when solving trigonometric problems. These errors are not limited to computational mistakes but include errors in mathematical thinking, answers, and incorrect or unsupported strategies (Barlow et al., 2018). The research conducted by Sofiyah (2018) revealed that high-skilled mathematics students commonly commit errors in proving trigonometric identities due to improper procedures and skill hierarchy issues. Similarly, Usman (2017) reported that transformation and process skill errors are the most prevalent errors students commit in solving trigonometry problems. Students' weaknesses in basic arithmetic operations were found to be the main cause of errors in solving trigonometric problems (Usman, 2017). Sirajo (2015) found no significant uniformity in student's errors when solving trigonometric problems across different institutions.

However, it is not a common practice to use error analysis in teaching mathematics in the classroom (Rushton, 2018). Typically, teachers demonstrate correctly worked examples as models for students to imitate without giving them enough practice in exercises and strategies. Orhun (2004) attributed students' errors in trigonometry to the teaching method used by teachers. The scholar noted that when trigonometry is taught through a teacher-active method that involves constantly memorising ready-made knowledge and repeating it, students learn trigonometry more effectively. The primary objective of this research was to detect the process errors that senior secondary school students make while solving mathematics trigonometry problems. Additionally, the study aimed to investigate whether the process errors committed by students when solving trigonometry problems in mathematics vary with their gender and school location.

Studies have shown significant gender differences in mathematics achievement among students. For instance, studies have reported significant mean differences in the academic performance of male and female students in secondary schools (e.g., Kazembe & Sithole, 2010) in favour of males (Esuong et al., 2022; Okereke & Onwukwe, 2011) and females (Marshall, 2008). Additionally, Ghazvini and Khajehpour (2011) showed gender differences in the strategies used by male and female students in mathematics, with boys using concentration, information processing, and selecting main ideas strategies more and achieving better grades. However, a long list of studies found no significant difference in performance between males and females (Ajai & Imoko, 2015; Akanmu & Bala, 2022; Annetta et al., 2009; Joiner et al., 2011; Kola & Taiwo, 2013; Oludipe, 2012; Omenka & Kurumeh, 2013; Owolabi, 2014; Papastergiou, 2009). A study conducted by Baah-Korang et al. (2015) found no significant difference based on sex in mixed-sex schools; however, in single-sex schools, girls outperformed boys in elective mathematics. However, Gaisman's (2015) study found no significant differences in performance between boys and girls in basic math, but boys tended to perform better at the high school level. Similarly, Marshall (2008) categorised gender-based types of errors in mathematics, where girls were found to be more prone to errors caused by confusion of meaning or applying irrelevant rules, while boys were more susceptible to errors in translation. However, there has been limited research on gender differences in process errors when solving trigonometry problems. Thus, more research is needed to understand the role of gender in Mathematics performance and process errors, which could provide insights for interventions to improve math performance for all students.

Several studies have highlighted the impact of school location on students' academic achievement, with some reporting significant differences between urban and rural schools (Kemjika, 2009; Ogunleye & Adepoju, 2011). According to Kemjika (2009) and Ogunleye and Adepoju (2011), a school's location may influence learners' academic progress. It has been reported that students in urban schools outperformed those in rural schools in mathematical and fundamental science, with a greater failure rate in rural schools (Ahiaba & Igweonwu, 2013; Bassey et al., 2010; Nwogu, 2010). However, some studies' findings contradict these findings by revealing no significant gap in the mean performance scores of students in urban and rural schools who learned mathematics (Kolawale & Popoola, 2011; Macmillan, 2012; Ntibi & Edoho, 2017; Taiwo & James, 2015). Consequently, Titus et al. (2016) reported a lack of agreement in the literature regarding the impact of school location on academic performance. Some studies have suggested that urban students perform better than those in rural areas, while others have argued that rural students perform better despite facing more challenges. Meanwhile, some studies have not found a significant difference in academic performance between the two groups. This highlights the need for further research to clarify the issue. While previous studies have focused on overall academic achievement, there is a knowledge gap regarding the relationship between school location and the specific process errors students make when solving trigonometric problems, which the present study aims to address. It is crucial to address the gaps in the literature to enable us identify and address educational inequalities that may arise from the location of a school. This, in turn, ensures that all students, regardless of their location, have equal opportunities to learn and succeed in their academic pursuits.

STATEMENT OF THE PROBLEM

Errors are an inevitable part of learning, even in mathematics. Deviating from the real solution, errors have been a constant issue for students, with their poor performance in mathematics being a cause for concern. In particular, the poor performance of students in trigonometry has been a concern for Mathematics educators, parents, and governments. This poor performance is evident in the senior secondary school certificate examinations. WAEC Chief Examiners' Reports from 2015 to 2019 confirm that candidates frequently make process errors when solving problems in Pythagoras' Theorem, Sine Rule, Cosine Rule, elevation, and depression. As a result, the researchers conducted a study to investigate the types and frequency of errors committed by senior secondary school students in mathematics, focusing on classifying them based on gender and school location.

PURPOSE OF THE STUDY

Specifically, the study assessed:

1. The process errors students commit in solving trigonometry problems in mathematics generally and with regard to gender;
2. The process errors students commit in solving trigonometry problems in mathematics based on school location.

RESEARCH QUESTIONS

The study was based on the following set of research questions:

1. To what extent are process errors committed by students in solving trigonometric problems in mathematics generally and with regard to gender?
2. To what extent do secondary school students commit process errors in solving trigonometric mathematics problems based on their school's location?

HYPOTHESES

The following hypotheses guided the study.

1. The gender of secondary school students does not significantly impact their process errors when solving trigonometric Mathematics problems.
2. The location of the school attended by secondary school students does not significantly impact the process errors they make when solving trigonometric problems in mathematics.

METHODS

Research Design

The research design utilised in this study was a descriptive survey. It is a design that involves describing events without manipulating what is observed (Bassey & Owan, 2023). According to Abonyi et al. (2006), this research design is ideal for collecting data from a small sample of a larger population to systematically describe and interpret characteristic features and facts about existing things without manipulation. In this study, the descriptive survey design was deemed appropriate since it involved gathering data from a small sample of students without manipulating any variable. This design was well-suited to identify and test hypotheses regarding errors made in solving trigonometry problems among secondary school students in mathematics.

Population and Sample

The population for this study consisted of all public senior secondary school students from the 16 public secondary schools in Obubra Local Government Area of Cross River State. Based on data obtained from the Obubra Local Government Education Authority, the population comprised 7,304 students, of which 3,554 were male and 3,750 were female. To obtain the sample, the study employed two sampling methods. The first method was simple random sampling, which involved randomly selecting six public secondary schools from the 16 available in the area. This was done by writing the names of all the schools on separate pieces of paper, mixing them up in a container, and choosing one at random without replacement. The process was repeated until six schools were chosen. This method ensured that each school had an equal chance of being selected and that the sample was unbiased. The second sampling method used was purposive sampling, which involved selecting all available students from the six public secondary schools Obtaining a representative sample of students from the selected schools was important. The total number of students selected from the six schools was 100, with an equal number of male and female students. The study's sample included 300 senior secondary school students (males = 150; females = 150) in SSS3 from the six selected public secondary schools. Table 1 provides the sample details.

Table 1: Sample distribution of senior secondary school students from selected public schools inCross River State

School	Location	Male	Female	Total
A	Urban	27	30	57
B	Urban	25	23	50
C	Urban	28	20	49
D	Rural	20	22	42
E	Rural	27	30	57
F	Rural	22	23	45
Total		**150**	**150**	**300**

Instrument for Data Collection

To explore the process errors involved in solving trigonometry problems in mathematics, the researchers utilised the Trigonometry Diagnostic Test (TDT). The TDT is composed of two parts, I and II. Part I collects personal data such as school location and gender, while Part II comprises six essay questions in mathematics. These questions were

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adapted and modified from previous WAEC exams from different years, all within the mathematics curriculum in senior secondary schools. An example of a question in the instrument is *Given that Sin (A+B)= Sin A Cos B + Cos A Sin B without using mathematical tables or calculator, evaluate sin* $105^0 = 60^0 + 45^0$. The TDT was subjected to both face and content validation. Three experts in measurement and evaluation and mathematics education reviewed and made necessary corrections to the instrument. To measure the TDT's reliability, the researchers used Kendall's W coefficient of concordance, deemed appropriate since the test was essay-type scored by different teachers across five scripts. The researchers obtained Kendall's inter-rater reliability (W) estimate of 0.89, indicating high reliability.

Procedure for Data Collection

To initiate the study, the researchers obtained an introductory letter from Ebonyi State University Post Graduate School, which enabled them to acquire a research permit from the State Ministry of Education in the Ikom Zone. Following approval from the ministry, the researchers were granted a three-month research permit. A copy of the permit was submitted to the Executive Secretary Education Authority in Obubra, and an introductory letter was sent to all the principals of the schools sampled in the study to inform them of the research purpose and details. The researchers also visited all the selected schools in Obubra before the actual study date to minimise the Hawthorne effect. To identify the process errors committed by the students, the researchers employed mathematics teachers from different schools to administer the Trigonometry Diagnostic Test (TDT). Using pen and paper, students showed all their workings, and the five process errors (reading, comprehension, transformation, process skill, and encoding errors) were identified in each student's TDT item. The frequency of these errors was determined and grouped based on gender and school location.

Procedure for Data Analysis

Data collected were analysed using both descriptive and inferential statistics. Computing frequency counts, and percentages were used to answer the research questions, while the Chi-square (X2) test was used for hypotheses testing at a significant level of 0.05. In making a decision, the null hypothesis is rejected if the probability value is equal to or less than the significant value of 0.05 ($p < 0.05$). However, the null hypothesis is accepted if the probability value exceeds 0.05 ($p > 0.05$).

RESULTS

Research Question 1: To what extent are process errors committed by students in solving trigonometric problems in Mathematics generally and with regard to gender?

Table 2: Process errors committed by students when solving trigonometric problems

S/N	Process Errors	Male		Female		Total	
		Freq.	%	Freq.	%	Freq.	%
1	Reading	23	16.10	39	23.01	62	19.9
2	Comprehension	7	4. 89	17	10.03	24	7.7
3	Transformation	31	21.67	27	15.93	58	18.6
4	Process skill	42	29.36	44	25.96	86	27.6
5	Encoding	40	27.96	42	24.78	82	26.2
	Total	**143**		**169**		**312**	

According to Table 2, the error type that occurred most frequently was process skill errors, with 86 (27.6%) instances, followed by encoding errors, with 82 (26.2%) instances. The third most common type of error was reading errors, with 62 (19.9%) instances, followed by transformation errors with 58 (18.6%) instances, and finally, comprehension errors with only 24 (7.7%) instances. These findings suggest that the most common errors made by students when solving trigonometry problems were related to reading, transformation, process skills, and encoding. In contrast, errors related to comprehension were relatively infrequent.

Regarding gender differences, Table 3 reveals that male students had higher frequency counts than their female counterparts in transformation errors (31 vs 27) and process skill errors (42 vs 44). However, female students had higher frequency counts than male students in reading errors (39 vs 23), comprehension errors (17 vs 7) and encoding errors (42 vs 40). Overall, male students had a total frequency count of 143 (46%), while female students had a total frequency count of 169 (54%). Therefore, the study suggests that female students committed a slightly higher frequency of process errors than male students.

Research Question 2: To what extent do secondary school students commit process errors in solving trigonometric mathematics problems based on their school's location?

Table 3: Process errors committed by urban and rural school students when solving trigonometric problems

S/N	Process Errors	Urban		Rural		Total	
		Freq.	%	Freq.	%	Freq.	%
1	Reading	32	19.8	30	20.00	62	19.9
2	Comprehension	13	8.0	11	7.30	24	7.69
3	Transformation	31	19.1	27	18.00	58	18.6
4	Process skill	44	27.2	42	28.00	86	27.6
5	Encoding	42	25.9	40	26.70	82	26.2
	Total	**162**		**150**		**312**	

Table 3 displays the analysis of process errors among urban and rural students. The results reveal that urban students had higher frequency counts in all process error types than their rural counterparts. Specifically, urban students had more process skill errors (44), encoding errors (42), transformation errors (32), reading errors (32), and comprehension errors (13) compared to their rural counterparts, with frequency counts of 42, 40, 30, 27, and 11, respectively. Moreover, urban students had a total frequency count of 162, representing 50.4% of the sample, while rural students had a frequency count of 150, representing 46.6%. The percentage difference between the two groups was 8.4%, indicating that urban students had slightly higher frequency counts of process errors than their rural counterparts. The analysis demonstrates that urban and rural students' most common errors were reading, transformation, process skills, and encoding, while comprehension errors were less common.

Hypothesis 1: The gender of secondary school students does not significantly impact their process errors when solving trigonometric Mathematics problems.

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Table 4: Chi-square test of the process errors committed by senior secondary school students based on gender

Gender	Reading	Comprehension	Transformation	Process skill	Encoding	X^2_{cal}	Alpha	X^2_{crit}	Decision
Male	Oi=23 Ei=28.4	Oi=7 Ei=11	Oi=31 Ei=26.6	Oi=42 Ei=39.4	Oi=40 Ei=37.6	7.61	.05	11.07	NS
Female	Oi=39 Ei=33.6	Oi=17 Ei=13	Oi=27 Ei=31.4	Oi=44 Ei=46.6	Oi=42 Ei=44.4				

Note: Oi = Observes frequency. Ei = Expected frequency; NS = Not Significant

Table 4 shows that the calculated Chi-square value of 7.61 is less than the critical Chi-square value of 11.0 at the .05 level of significance with 4 degrees of freedom. Following this result, the null hypothesis, earlier formulated, was upheld. This implies that the gender of secondary school students does not significantly impact the process errors they make when solving trigonometric problems in mathematics. Therefore, the observed gender differences earlier reported in Table 2 are attributable to chance.

Hypothesis 2: The location of the school attended by secondary school students does not significantly impact the process errors they make when solving trigonometric problems in mathematics.

Table 5: Chi-square test of the process errors committed by senior secondary school students based on school location

School Location	Reading	Comprehension	Transformation	Process skill	Encoding	X^2_{cal}	Alpha	X^2_{crit}	Decision
Urban	Oi =32 Ei=32.2	Oi =13 Ei=12.5	Oi =31 Ei=30.1	Oi =44 Ei=44.6	42 Ei=42.6	0.14	0.05	11.07	NS
Rural	Oi =30 Ei=29.8	Oi =27 Ei=27.9	Oi =27 Ei=27.9	Oi =42 Ei=41.4	Oi =40 Ei=39.4				

Note: Oi = Observes frequency; Ei = Expected frequency; NS = Not significant

Table 5 shows that the calculated Chi-Square is 0.14, whereas the critical Chi-square is 11.07. At the .05 level of significance and 5 degrees of freedom, the results indicate that the calculated value of the Chi-square is less than the critical value. Consequently, we failed to reject the null hypothesis due to a lack of support from the statistical evidence gathered. This implies that the location of the school attended by secondary school students does not significantly impact the process errors they make when solving trigonometric problems in mathematics.

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DISCUSSION

Process errors committed by students when solving trigonometric problems

In this study, the process errors made by students in trigonometry were identified through diagnostic tests, and five different types of process errors were observed with varying frequencies. Students' most common process errors were reading, transformation, process skills, and encoding errors. These findings are consistent with the observations made by other researchers (such as Adule, 2018; Gilbert & Calvert, 2003; Inekwe, 2017) that process errors are common in mathematics and physics. The findings highlight students' common process errors in trigonometry and provide important implications for teaching and learning mathematics. Identifying reading, transformation, process skill, encoding, and comprehension errors provide teachers and educators with insights into the areas where students are likely to struggle the most when solving trigonometry problems. One important implication is the need for teachers to provide adequate instruction on the basic trigonometric concepts to avoid process skill errors, which were identified as the most frequent error committed. Teachers should also emphasise the importance of careful reading and understanding of the problem, as reading and comprehension errors were identified as common errors. The findings suggest that students need more support in modelling mathematics and transforming problems into mathematical forms to avoid transformation errors. Teachers should provide good examples and practice opportunities for students to develop modelling and transformation skills. Lastly, encoding errors can be reduced by emphasising the importance of accurate calculation and unit conversions. Teachers should also provide feedback on student's work to help them identify and correct any encoding errors they make.

Process errors in solving trigonometric problems based on students' gender

This study revealed that process errors that secondary school students commit in solving trigonometric problems do not depend significantly on Gender. However, female students committed slightly more errors than their male counterparts, with a percentage difference of 8.4%. This result implies that female students are not significantly different from males in the degree to which they commit errors when solving trigonometric problems. This result aligns with Okigbo's (2021) result, which showed no significant difference in the frequency of the process errors committed by SS3 male and female students. Similarly, the result supports previous studies (e.g., Kola & Taiwo, 2013; Oludipe, 2012), which found no significant difference between male and female students in their Mathematics performance. However, the result contradicts many studies (e.g., Ariyo, 2016; Okereke & Onwukwe, 2011; Yara, 2009), which found a significant difference between males and females regarding their mathematics performance.

Nevertheless, the finding of this study that gender does not significantly affect the frequency of process errors in solving trigonometric problems among secondary school students is important for educators, policymakers, and researchers. This implies that male and female students are equally prone to committing process errors in trigonometry. Therefore, teachers and curriculum designers should not base their teaching strategies and instructional materials on gender differences. The result also suggests that teachers should adopt teaching methods that help students understand trigonometry's basic concepts and principles, regardless of gender. Teachers should also emphasise the importance of carefully paying attention to details and reading instructions to avoid errors. Moreover, educators should provide more opportunities for students to practice problem-solving, which could help reduce transformation, process skills, and encoding errors. The finding of this study is also relevant to policymakers as it highlights the need for gender-inclusive policies in education. Gender biases and stereotypes could affect the way teachers and policymakers perceive the abilities and potentials of male and female students. This result emphasises the importance of promoting gender equality in education and providing equal opportunities for male and female students to achieve their full potential. Researchers should investigate other factors influencing process errors in trigonometry among secondary school students, such as prior knowledge, motivation, and learning style. Moreover, future studies should explore the effectiveness of different teaching strategies and instructional materials in reducing process errors in trigonometry and if there are any gender differences in the effectiveness of these strategies.

School Location and Process Errors of Students in Solving Trigonometric Problems

This study found that the frequency of process errors senior secondary school students committed when solving trigonometric problems did not depend significantly on school location. However, urban students made more errors on average than rural students. The errors made by urban students were mostly related to reading, transformation, process skills, and encoding, while rural students also struggled with these types of errors. However, comprehension errors were low for both groups, indicating that they understood the given problems. This finding supports the results of Anghileri (2011), who found that when solving trigonometry problems, students tend to make more reading, transformation, process, skill, and encoding errors than comprehension errors. In line with Gur's (2009) view, the study's result indicates that the process errors made by students in learning trigonometry can provide feedback to teachers to assess their teaching and correct the students' mistakes accordingly. The result is consistent with several previous studies (e.g., Alkhadrawi, 2015; Ezeudu & Obi, 2013; Ezeudu, 2014; Kolawale & Popoola, 2011) suggesting that location has no significant impact on students' Mathematics performance. However, the finding contradicts other studies (e.g., Igboegwu & Okonkwo, 2012; Yara, 2009) that reported a significant difference in Mathematics achievement between urban and rural schools. Despite the disagreements, the findings suggest that teachers should focus on helping students improve their ability to read and interpret math problems, choose appropriate mathematical methods, perform math processes correctly, and write final answers accurately. Additionally, the results suggest that the school's location does not significantly impact student performance in Mathematics, which is consistent with previous research. However, the findings contradict other studies that have found significant differences in students' mathematics achievement between urban and rural schools.

CONCLUSION

This study examined the process errors senior secondary school students committed when solving trigonometric problems and their relationship with gender and school location. Modified Newman Error Hierarchy was used in classifying students' errors. The results showed no significant difference in the frequency of process errors committed by male and female students. School location had no statistically significant relationship with the frequency of process errors committed by students. However, on average, urban students made more errors than rural students, and both groups struggled with similar errors related to reading, transformation, process skills, and encoding. Comprehension errors were low for both groups, indicating that they understood the given problems. The findings provide valuable insights for mathematics teachers in designing effective teaching methods to improve students' problem-solving skills. The findings of this study suggest that Mathematics teachers need to pay attention to the different types of errors made by their students in trigonometry problem-solving and design appropriate programmes to address any gaps or disparities. The study indicates that teachers should engage in meaningful teaching of trigonometry, not only to teach the content of trigonometry courses but take cognisance of the ability and maturity of the students. Overall, this study contributes to the ongoing discussion on factors affecting students' performance in mathematics. Further research is needed to investigate other factors influencing students' performance in solving trigonometric problems.

RECOMMENDATIONS

Based on the conclusion drawn from this study, the following recommendations were made:

1. Teachers should consider their students' process errors when solving trigonometric problems. They should identify common errors and provide targeted instructions to address them.
2. Teachers should design instructional activities to help students develop reading, transformation, process, and and encoding skills when solving trigonometric problems. This will help students to perform these skills effectively and improve their problem-solving ability.
3. Curriculum developers should consider incorporating more problem-solving activities in mathematics education. This can help students to develop their problem-solving skills, improve their understanding of mathematical concepts and help them avoid common process errors when solving trigonometric problems.
4. Future studies should explore other factors influencing process errors when solving trigonometric problems, such as teacher experience, teaching methods, and students' motivation. This will help to develop more effective interventions that address the underlying causes of process errors and improve students' problem-solving abilities in trigonometry and other aspects of Mathematics.

Conflict Of Interest: The authors declare that there is no conflict of interest

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Disclaimer Statement: The views expressed in this article are solely those of the authors and do not necessarily reflect the official policy or position of their affiliated institutions.

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Authorship and Level of Contribution
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