DIAGNOSTIC STUDY OF STUDENTS' ERRORS IN PHYSICS PRACTICALS IN GIWA EDUCATION ZONE, KADUNA STATE, NIGERIA

Hauwa Bako[1],
08085454572
hbako@education.abu.edu.ng
Prof. M.M. Atadoga[2]
08035048267
atadoga2008@gmaail.com
Dr. Mustapha Sani Bichi[3]
08069615779
msbichi@abu.edu.ng
Elizabeth Iwuajoku[4]
08065585552
[1,3,4] Department of Science Education, Faculty of Education, Ahmadu Bello University, Zaria,
[2] Institute of Education, Ahmadu Bello University, Zaria

Abstract

This study investigated the diagnostic study of students' errors in physics practicals in Giwa Education Zone, Kaduna State, Nigeria with two objectives: to identify the frequency and percentage of errors committed by Physics students in practicals, and to determine whether significant differences exist in errors committed among students across different schools in Giwa Education Zone, Kaduna State, Nigeria. A survey research design was adopted. The sample consisted of 256 senior secondary II Physics students selected from four public secondary schools using multi-stage sampling. The instrument used was the Physics Practical Test (PPT), which was validated by three experts and achieved a reliability coefficient of 0.83 using the split-half method. Data were analyzed using descriptive statistics (frequency and percentage) and one-way Analysis of Variance (ANOVA). Results revealed five error types: parallax (15.63%), intercept (26.17%), slope (16.02%), computational (19.53%), and scale errors (22.66%). Intercept error was the most frequent, while parallax error was the least frequent. ANOVA results showed no statistically significant difference in error patterns across schools ($F = 2.447$, $p = 0.101 > 0.05$). The study concludes that intercept and scale errors are the most pressing challenges, and the consistency of error patterns across schools suggests systemic rather than localized causes. Recommendations include explicit instruction in graph-plotting skills, development of standardized diagnostic tools, and implementation of zone-wide remediation programs.

Keywords: Error Identification, Physics Practical, Secondary School Students, Comparative Analysis.

Introduction

Physics, as an empirical science, derives its fundamental laws and principles from systematic observation, measurement, and experimentation. The acquisition of practical skills is therefore not merely peripheral but central to meaningful learning in Physics (Millar, 2010; Abrahams & Reiss, 2012). Practical work serves multiple pedagogical functions: it enhances conceptual understanding, develops manipulative skills, fosters scientific attitudes such as curiosity and intellectual honesty, and prepares students for science-related careers (Hofstein & Kind, 2012; Shana & Abulibdeh, 2020). In Nigeria, the National Policy on Education (Federal Republic of Nigeria, 2013) mandates that Physics instruction at the senior secondary school level should emphasize practical activities, as reflected in the examination syllabus of the West African Examinations Council (WAEC).

Despite this policy emphasis, the implementation of effective practical instruction in Nigerian secondary schools remains profoundly challenging. Antwi et al. (2021) documented that many Physics teachers, constrained by time limitations, inadequate laboratory facilities, large class sizes, and insufficient pedagogical content knowledge, resort to the traditional lecture method, treating practical work as a theoretical exercise or relegating it to last-minute examination preparation. This deficit in authentic practical engagement has dire consequences for students' acquisition of science process skills and their overall academic performance in Physics (Okpala & Onocha, 2015).

The performance of Nigerian secondary school students in Physics, particularly in the practical component of the West African Senior School Certificate Examination (WASSCE), has been a source of sustained concern for educators, policymakers, and examination bodies alike. Analysis of WAEC results from Kaduna State over the decade 2012 to 2021 reveals a troubling pattern. During this period, the percentage of candidates who achieved credit grades (A1-C6) in Physics fluctuated but remained consistently low, with only one year (2014) recording a pass rate above 50 percent. In contrast, failure rates (D7-F9) exceeded 50 percent in nine out of the ten years, peaking at approximately 78.86 percent in 2019 (WAEC Office, Kaduna, 2021).

The WAEC Chief Examiners' Reports (2012–2021) consistently attribute this poor performance to specific, recurring errors committed by candidates in the practical paper. These include: incorrect tabulation of readings, wrong graph plotting (choice of scale, axis labeling), inaccurate determination of slope and intercept, parallax errors in reading instruments, computational mistakes, and failure to state precautions appropriately (Thomas, 2017; WAEC, 2018). Notably, these error patterns persist year after year, suggesting that they are not merely idiosyncratic mistakes but rather systematic deficiencies in students' understanding and execution of practical procedures.

Error analysis, as a diagnostic tool in education, involves the systematic identification, description, and explanation of errors in students' work (Corder, 1981; Abdulkarim, 2011). Unlike simple mistake counting, error analysis seeks to uncover underlying cognitive processes, misconceptions, or skill deficits that generate observable errors. In the context of science practical work, error analysis serves several critical purposes: it reveals the specific areas where instruction has been ineffective, provides empirical data for designing targeted remediation, and enables teachers to adjust their pedagogical strategies to address students' actual learning needs (Falalu, 2015; Okereke, 2018).

Previous studies have documented various error typologies in science education. In Physics specifically, Thomas (2017) categorized errors into systematic measurement errors and random measurement errors. Omosewo and Akanbi (2013) identified operational defective algorithms, random errors, and computational errors among secondary school Physics students in Ilorin, Nigeria. Fatuma and Gude (2015) found that Kenyan secondary school students committed parallax errors more frequently than algorithm errors. More recently, Aderonmu and Nte (2016) diagnosed computational errors as the most prevalent among students solving progressive wave equations. However, a critical gap exists in the literature: most error identification studies have focused on theoretical Physics problem-solving rather than authentic practical task performance. Furthermore, limited research has systematically documented error frequencies across multiple schools within the same educational zone to determine whether error patterns are context-specific or systemic. This gap is particularly pronounced in Northern Nigeria, where cultural, linguistic, and resource factors may uniquely influence students' practical engagement.

Statement of the Problem

Physics practical work is an indispensable component of science education, serving as the primary means through which students develop manipulative skills, scientific inquiry abilities, and empirical understanding of natural phenomena (Hofstein & Kind, 2012; Shana & Abulibdeh, 2020). In Nigeria, the National Policy on Education (Federal Republic of Nigeria, 2013) explicitly recognizes the centrality of practical work by mandating that Physics instruction at the senior secondary level integrate hands-on laboratory activities. Furthermore, the West African Senior School Certificate Examination (WASSCE) allocates a substantial portion of the final grade to practical assessment, underscoring its importance. Despite this recognition, evidence from multiple sources indicates that Nigerian secondary school students consistently perform poorly in the practical component of Physics examinations. Analysis of WAEC results from Kaduna State over the decade 2012 to 2021 reveals that failure rates exceeded 50 percent in nine out of ten years, peaking at approximately 78.86 percent in 2019 (WAEC Office, Kaduna, 2021). The WAEC Chief Examiners' Reports (2012–2021) have consistently identified the root cause: students commit specific, recurring errors including parallax errors, incorrect determination of slope and intercept, inappropriate choice of graph scales, computational inaccuracies, and failure to follow sequential procedures (Thomas, 2017; WAEC, 2018). These error patterns persist year after year, suggesting that current instructional interventions are failing. While several studies have documented errors in science education (Abdulkarim, 2011; Omosewo & Akanbi, 2013; Falalu, 2015; Fatuma & Gude, 2015), most have focused on theoretical problem-solving rather than authentic practical task performance. Moreover, limited research has systematically compared error frequencies across multiple schools to determine whether patterns are context-specific or systemic. In Giwa Education Zone, no prior study has systematically identified errors in Physics practicals or determined whether significant differences exist among schools. Therefore, this study addresses the following problem: What specific errors do senior secondary school Physics students in Giwa

Education Zone commit in practical work, and do these errors differ significantly across schools?

Objectives of the Study

The following objectives guided the study:

The main objective of the study is to investigate the diagnostic study of students' errors in physics practicals in Giwa Education Zone, Kaduna State, Nigeria; specifically, the study sought to:

1. investigate the frequency and percentage of errors committed by Physics students in Physics practical.
2. examine the differences in errors committed in Physics practical among senior secondary school Physics students.

Research Questions

The following research questions were answered:

1. What are the frequency and percentage of errors committed by Physics students in Physics practical?
2. What are the differences in errors committed in Physics practical among senior secondary school Physics students?

Hypothesis

The following null hypothesis was tested at $\alpha \leq 0.05$ level of significance:

There is no significant difference between the errors committed in Physics practical among Physics students.

Methodology

This study adopted a survey research design for the diagnostic phase reported in this article. The survey design is appropriate for research objectives that seek to describe the characteristics of a population, identify the frequency of specific phenomena, and compare these phenomena across different groups (Creswell & Creswell, 2018). The design involved the administration of a practical test to students, followed by systematic analysis of their responses to identify, categorize, and count error types. No treatment or intervention was administered during this phase, as the sole purpose was diagnostic. The study was conducted in Giwa Education Zone, Kaduna State, Nigeria. The target population comprised all Senior Secondary II (SS II) students offering Physics in the seventeen public senior secondary schools within Giwa Education Zone. SS II students were chosen because they have completed one full year of senior secondary Physics instruction and are not yet immersed in examination preparation. According to records from the Giwa Zonal Education Office (2021), the total population was 1,870 students, comprising 1,074 males and 796 females. A multi-stage sampling procedure was employed. First, four schools were randomly selected from the seventeen public schools using simple random sampling (balloting without replacement). Within each selected school, all SS II Physics students in intact classes were included in the sample. This intact class sampling approach is widely used to avoid disrupting normal school routines (Sambo, 2008). The final sample consisted of 256 SS II Physics students, comprising 180 males and 76 females. The instrument used for data collection was the Physics Practical Test (PPT), designed by the researcher. The PPT consisted of two sections. Section A sought demographic information. Section B comprised three practical questions adapted from past WAEC (2018) Physics practical examination papers, covering mechanics (simple pendulum), light (lens and image formation), and electricity (resistance and potentiometer circuits). Students were instructed to attempt any two of the three questions, following standard WAEC procedure. The PPT was specifically designed to elicit the error types identified in WAEC Chief Examiners' Reports: parallax, intercept, slope, computational, and scale errors. The PPT was subjected to content and face validation by three experts: a Professor of Science Education, a Professor of Physics, and an experienced secondary school Physics teacher. The experts assessed the instrument for clarity, appropriateness of language, relevance to the curriculum, and adequacy for eliciting target error types. Based on their feedback, ambiguous terms were revised, and timing was extended from 45 to 60 minutes. A pilot study was conducted at Government Secondary School, Bomo, which was not among the sampled schools. An intact class of 68 SS II Physics students participated. The split-half method was used to determine internal consistency reliability. Scores from odd and even items were correlated using the Pearson Product Moment Correlation Coefficient, adjusted with the Spearman-Brown prophecy formula. The calculated reliability coefficient was 0.83, well above the acceptable threshold of 0.70 (George & Mallery, 2003; Taber, 2018). Following ethical approval and institutional permissions, the PPT was administered to all 256 students as a pre-test under standard examination conditions. Students were seated individually, given 60 minutes, and rotated through apparatus stations as needed. Answer booklets were collected and scored using the validated marking scheme. Each script was scored twice with a two-week interval to ensure intra-rater reliability. For each script, the researcher documented the presence or absence of each error type and the student's school affiliation. Data were analyzed using SPSS version 26.0. Descriptive statistics (frequency counts and percentages) were used to answer Research Question One (frequency and percentage of errors). A one-way Analysis of Variance (ANOVA) was used to test Null Hypothesis One (no significant difference in errors among schools) at an alpha level of 0.05. Assumptions of normality (Shapiro-Wilk test) and homogeneity of variances (Levene's test) were verified prior to analysis.

Results

Research Question One: What are the frequency and percentage of errors committed by Physics students in Physics practical? Analysis of the 256 students' scripts revealed five distinct error types. Table 1 presents the distribution.

Table 1: Types, Frequency, and Percentage of Errors Identified in Physics Practical

Types of Errors	Frequency	Percentage (%)
Parallax Error	40	15.63
Intercept Error	67	26.17
Slope Error	41	16.02
Computational Error	50	19.53
Scale Error	58	22.66
Total	**256**	**100.00**

As shown in table 1, intercept error was the most frequent (26.17%), followed by scale error (22.66%), computational error (19.53%), slope error (16.02%), and parallax error (15.63%). This indicates that students struggle most substantially with graph-related skills.

Research Question Two: What are the differences in errors committed in Physics practical among senior secondary school Physics students?" Table 2 presents error frequencies disaggregated by school.

Table 2: Frequency of Errors Committed Among Schools

School	Parallax	Intercept	Slope	Computational	Scale
School 1	24	26	15	28	16
School 2	27	26	25	29	28
School 3	26	27	20	29	27
School 4	26	28	28	26	29

All four schools exhibited all five error types, indicating no school was free from any error category. Variations were observed but were not large.

Hypothesis one: There is no significant difference between the errors committed in Physics practical among Physics students." A one-way ANOVA was conducted at $\alpha = 0.05$. Table 3 presents the results.

Table 3: Summary of ANOVA Results

Source	Sum of Squares	df	Mean Square	F	Sig. (p-value)	Remark
Between Groups	507.750	3	169.250	2.447	0.101	Not Significant
Within Groups	1106.800	16	69.175			
Total	1614.550	19				

Significant at $p \leq 0.05$ level.

The calculated F-statistic was 2.447 with a p-value of 0.101. Since $p > 0.05$, the null hypothesis is retained. There is no statistically significant difference in the types of errors committed among Physics students across the four schools. Error patterns are consistent across the educational zone.

Discussion of Findings

This study achieved two objectives: identifying error types and frequencies, and determining whether significant differences exist across schools. The finding that intercept error was the most frequent (26.17%) aligns with WAEC Chief Examiners' Reports (2012–2021), which consistently note candidates' difficulties with graph interpretation. Scale error (22.66%) being the second most frequent further emphasizes that graph-plotting skills particularly choosing appropriate scales are poorly developed among students. The persistence of these errors suggests that current instructional methods inadequately address graphical data presentation and interpretation. Computational error (19.53%) ranking third supports the findings of Omosewo and Akanbi (2013), Aderonmu and Nte (2016), and Falalu (2015), who documented mathematical deficiencies as a major contributor to poor Physics performance. Even when students collect correct data, computational mistakes lead to incorrect conclusions about physical relationships. Parallax error, while least frequent (15.63%), remains a concern as it indicates improper measurement techniques.

From the perspective of Piaget's (1977) Cognitive Developmental Theory, these errors manifest cognitive disequilibrium. Students' existing schemas are inadequate for processing the demands of WAEC-level practical tasks, particularly those requiring formal operational reasoning about abstract graphical relationships. Traditional instruction facilitates assimilation (memorizing procedures) but not accommodation (restructuring understanding). The second major finding no significant difference in error patterns across schools ($p = 0.101$) is both instructive and significant. While descriptive variations existed, ANOVA confirmed these were not statistically significant. This finding diverges from Abdulkarim (2011) and Okereke (2018), who found school-based differences in other subjects. The consistency in Giwa Education Zone may be attributable to standardized curriculum, homogeneous teacher preparation, and shared resource constraints across public schools. The implication is that error causes are systemic rather than localized, justifying zone-wide rather than school-specific remediation strategies.

Conclusion

This study identified the major types of errors commonly committed by Physics students during practical work, namely parallax error, intercept error, slope error, computational error, and scale error. Among these, intercept error was found to be the most prevalent, while parallax error occurred least frequently, indicating varying levels of difficulty in students' practical measurement and data interpretation skills. The study further examined whether differences existed in the pattern of errors among students from different schools. The findings revealed no statistically significant difference in the errors committed across the schools. Consequently, the null hypothesis was retained, suggesting that the errors observed are systemic and widespread rather than being limited to specific schools.

Recommendations

Based on the findings and conclusions reached in the study, the following recommendations were made:

1. Physics Teachers: Systematically diagnose student errors before remediation. Devote explicit instructional time to graph-plotting skills, including scale selection, slope and intercept determination, and computational accuracy. Address parallax error through direct instruction on proper measurement techniques.
2. Curriculum Planners: Allocate more curriculum time to graphical skills as explicit learning objectives rather than implicit prerequisites. Develop standardized diagnostic tools aligned with the five identified error types.
3. Educational Administrators: Implement a zone-wide remediation program rather than school-specific interventions, as errors are consistent across schools. Provide mandatory professional development workshops for all Physics teachers on error diagnosis and remediation.
4. Future Researchers**:** Conduct qualitative studies to investigate root causes of errors. Replicate this study in other zones and states to test generalizability. Design and evaluate remediation packages targeting the five identified error types.

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