



EFFICACY OF SCIENCE PROCESS APPROACH IN REMEDIATING PHYSICS PRACTICAL ERRORS AMONG SECONDARY SCHOOL STUDENTS IN KADUNA STATE, NIGERIA

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Abstract

This study examined the effect of the Science Process Approach (SAPA) on remediating errors in Physics practical among secondary school students in Giwa Education Zone, Kaduna State, Nigeria, and further assessed its impact on male and female students' performance. A quasi-experimental pretest-posttest control group design was employed. The sample consisted of 256 SSII Physics students (180 males, 76 females) selected through simple random sampling from four public secondary schools. The experimental group was taught using SAPA, while the control group was taught using the conventional lecture method over six weeks. The instrument for data collection was the Physics Practical Test (PPT), which had a reliability coefficient of 0.83. Two research questions and two null hypotheses guided the study. Data were analyzed using descriptive statistics (mean, standard deviation) and independent t-tests at a significance level of $p \leq 0.05$. Results revealed that students exposed to SAPA performed significantly better (mean = 43.23) than those exposed to the conventional method (mean = 30.87), with a mean difference of 12.36



($t = 2.83$, $p = 0.01$). Regarding gender, male students (mean = 53.37) and female students (mean = 53.19) showed no significant difference in performance ($t = 0.57$, $p = 0.95$). The study concludes that SAPA is an effective strategy for improving students' performance in Physics practicals and is gender-friendly. Recommendations include the adoption of SAPA by Physics teachers and the integration of activity-based, process-oriented methods into teacher training programs.

Keywords: Science Process Approach, Physics practical, error remediation, academic performance

Introduction

Physics occupies a unique and indispensable position in the scientific and technological advancement of any nation. As a fundamental science, Physics provides the foundational principles that underpin engineering, medicine, information technology, and virtually all applied sciences (Josiah, 2018). The subject deals with the study of matter, energy, and their interactions, and its laws, formulae, and facts are established through experimental investigations involving practical activities (Daniel & Lasisi, 2019). Recognizing its importance, the Federal Republic of Nigeria (FRN, 2013) designated Physics as one of the core science subjects that every science student must study at the senior secondary school level, as stipulated in the National Policy on Education.

The teaching of Physics at the secondary school level aims not only to impart theoretical knowledge but also to develop practical skills, scientific attitudes, and problem-solving abilities in students (Adeyemo, 2016). Through practical work, students are expected to acquire essential science process skills such as observing, measuring, classifying, inferring, predicting, interpreting data, controlling variables, and experimenting (NARST, 2018). These skills are crucial for scientific inquiry and for preparing students for careers in science and technology. According to Shehu (2016), Physics enables students to acquire problem-solving and decision-making skills that help them respond to societal challenges including industrial changes, climate change, health

issues, and economic development. Despite the recognized importance of Physics and the emphasis on practical work in the curriculum, student performance in Physics practicals at the senior secondary school level in Nigeria has remained persistently poor over the years. Reports from the West African Examination Council (WAEC) Chief Examiners spanning from 2012 to 2021 consistently indicate that candidates who offer Physics perform poorly in practical-based assessments (WAEC, 2012-2021). The Chief Examiners' reports have highlighted specific errors committed by students in Physics practical papers, including wrong graph plotting, wrong interpretation of graphs, parallax error, intercept error, slope error, computational error, and scale error (WAEC, 2018; Thomas, 2017). These errors have been identified as major contributors to the low performance of students in Physics examinations. The magnitude of this problem is evident in the performance data from Kaduna State. WAEC examination results for Physics students in Kaduna State between 2012 and 2021 reveal that in most years, over sixty percent of candidates failed the subject, with failure rates reaching as high as 78.86 percent in 2019 (WAEC Office, Kaduna, 2021). This trend is deeply concerning to educators, policymakers, and stakeholders in science education, as it threatens the nation's ability to produce sufficient qualified scientists, engineers, and technologists.

Several factors have been attributed to this poor performance. Researchers have identified the predominant use of



inappropriate teaching methods as a primary cause (Atadoga & Lakpini, 2013; Onyeka, Nneka, & Augusta, 2018). Specifically, the lecture method, which is a teacher-centered approach where students passively receive information, remains the dominant instructional strategy in many Nigerian secondary schools (Ali & Akubue, 2020). The lecture method, while efficient for covering large amounts of content, does not actively engage students in the learning process, discourages initiative and curiosity, and fails to provide opportunities for students to develop practical skills (Achugbu & Anulika, 2020). Other contributing factors include inadequate laboratory facilities, insufficient qualified Physics teachers, poor student attitudes toward the subject, and the abstract nature of many Physics concepts (Josiah, 2018; Okekere, 2018).

In response to these challenges, researchers have explored alternative instructional strategies that are more student-centered and activity-oriented. Among these is the Science Process Approach (SAPA), which focuses on the development of fundamental and integrated science process skills that scientists employ in their investigations (Ibrahim, 2020; Ogeniyi, 2015). The American Association for the Advancement of Science (AAAS) identified fourteen process skills, hierarchically arranged from basic skills (observing, classifying, communicating, and measuring) to integrated skills (interpreting data, controlling variables, hypothesizing, and experimenting) (Akinbola & Afolabi, 2010). Unlike the lecture method, SAPA directly involves students as active participants in the teaching-learning process, enabling them to take responsibility for their learning and to construct their own knowledge through hands-on activities (Aksela, 2017; Ezeliora, 2020).

The theoretical underpinning of this study is Piaget's (1977) Cognitive Developmental Theory. Piaget posited that cognitive development occurs through the interaction of innate capacities and environmental events, and that children pass through a series of developmental stages. Central to this theory are the concepts of schema, which are cognitive structures that enable transition from one cognitive level to another; assimilation, which is taking in new information into existing schemas; accommodation, which is altering existing schemas in light of new knowledge; and equilibration, which is striking a balance between assimilation and accommodation. In the context of Physics practicals, when a student's existing schema cannot explain new observations or tasks, the student experiences disequilibrium, which often manifests as errors or misconceptions. The Science Process Approach, by actively engaging students in hands-on activities and guiding them through the process of scientific inquiry, facilitates accommodation and equilibration, thereby reducing errors and enhancing learning.

Numerous studies have demonstrated the effectiveness of process-oriented teaching strategies. Falalu (2015) identified errors in Physics and developed a remediation package using problem-solving methods, finding that the remediation was effective in reducing error frequency and improving academic achievement. Ogeniyi (2015) investigated the impact of process approach on chemistry students and found that students exposed to the process approach performed significantly better than those taught with lecture methods, with higher retention of learning. Asabe and Yusuf (2016) reported similar results with pre-service chemistry teachers, where those exposed to science process skills approach achieved significantly better than their counterparts



taught with lecture methods. Gültekin and Altun (2022) examined the impact of activities based on scientific process skills on problem-solving skills and found significant improvements in the experimental group.

However, despite these promising findings, much of the existing research on SAPA has focused on general academic achievement or theoretical understanding, with relatively limited attention to the specific application of SAPA for remediating identified errors in Physics practicals. Furthermore, while error analysis studies have been conducted in various disciplines, such as Abdulkarim (2011) in Geography, Agaba (2014) in Biology, and Falalu (2015) in Physics theory, few studies have systematically identified specific practical errors (parallax, intercept, slope, computational, and scale errors) and then deliberately applied SAPA as a remediation strategy to address those errors. Another important dimension of this study is the consideration of gender. Gender differences in science performance have been a subject of ongoing debate. Some researchers have reported that male students perform better than female students in Physics, attributing this to spatial ability differences, societal stereotypes, or differential treatment in the classroom (Fatuma & Gude, 2015; Omosewe & Akanbi, 2013; Yang & Chen, 2018). For instance, Fatuma and Gude (2015) found that female students committed more parallax errors while male students committed more algorithm errors. Researchers have found no significant gender differences when activity-based, student-centered methods are employed (Bichi, 2002; Okereke, 2018; Thomas, 2017; Usman, 2010). This suggests that instructional method may be a moderating variable in gender-performance relationships. Therefore, examining whether SAPA produces differential effects on male and female students is an important

contribution to the literature. The present study is, therefore, situated at the intersection of three critical areas in science education: the persistent problem of errors in Physics practicals as documented by WAEC, the need for effective instructional strategies to remediate these errors, and the question of whether such strategies benefit male and female students equally.

Objectives of the Study

The following objectives are formulated to guide the study which are to:

- i. ~~find out~~ determine the effect of Science Process Approach in remediating errors committed in Physics practical among Physics students in Kaduna State.
- ii. determine the influence of gender in remediating errors committed in Physics practical when students are exposed Science Process Approach in Kaduna State.

Research Questions

The following research questions were formulated and answered in the study:

1. What is the difference between the mean performance scores of Physics students exposed to Science Process Approach and those exposed to conventional method?
2. What is the difference between the mean performance mean of male and female Physics students exposed to Science Process Approach?

Null Hypotheses

The following null hypotheses were tested at a significance level of $p \leq 0.05$:

H₀₁: There is no significant difference between the mean performance scores of Physics students exposed to Science Process Approach and those exposed to conventional method in Kaduna State.



H₀₂: There is no significant difference between the mean performance scores of male and female Physics students exposed to Science Process Approach in Kaduna State.

Methodology

This study adopted a quasi-experimental research design involving a pretest and posttest for both experimental and control groups. This design was considered appropriate because it allowed the researcher to determine the effect of the Science Process Approach on students' performance in Physics practicals while comparing it with the conventional method. The target population of this study comprised all senior secondary school two (SSII) students offering Physics in the seventeen public senior secondary schools in Giwa Education Zone, Kaduna State, Nigeria. According to records obtained from the Giwa Zonal Education Office (2021), the total population of SSII Physics students in the zone was one thousand eight hundred and seventy (1,870), consisting of one thousand and seventy-four (1,074) male students and seven hundred and ninety-six (796) female students. The sample for this study consisted of two hundred and fifty-six (256) SSII Physics students drawn from the population of one thousand eight hundred and seventy students. A multi-stage sampling procedure was employed. In the first stage, simple random sampling using the draw-from-the-hat method without replacement was used to select four schools from the seventeen public senior secondary schools in the zone. In the second stage, a pretest was administered to all SSII Physics students in the four selected schools to determine the comparability of their academic ability levels. The pretest scores were subjected to Analysis of Variance (ANOVA), which revealed the existence of significant differences among three of the schools. Consequently, these three schools were subjected to Scheffe's post-hoc test, and

the results showed no significant difference between two of the schools. These two schools were therefore randomly assigned to the experimental group and the control group. The experimental group consisted of one hundred students (fifty-nine males and forty-one females) from one school, while the control group consisted of one hundred and fifty-six students (one hundred and twenty-one males and thirty-five females) from the other school. The sample size of two hundred and fifty-six students was considered adequate for this study as it exceeded the minimum of thirty participants per group recommended by the Central Limit Theorem for experimental research (Tuckman, 1975; Sambo, 2008). The instrument used for data collection in this study was the Physics Practical Test (PPT), which was developed by the researcher based on the WAEC Physics practical question papers and the revised 2014 National Physics Curriculum. The PPT consisted of two sections.

Section A was designed to collect demographic information from the respondents, including their gender, class, school name, and age. Section B contained three practical questions adapted from WAEC (2018) Physics practical question papers. The three questions covered three major areas of Physics: mechanics (using a simple pendulum to determine acceleration due to gravity), light (using a lens to determine focal length and magnification), and electricity (using a metre bridge to determine resistance). Each question required students to perform actual experiments, record observations, perform calculations, plot graphs, determine slopes and intercepts, draw conclusions, and state precautions. Students were instructed to attempt any two of the three questions within a period of one hour. The Physics Practical Test (PPT) was subjected to content and face validation by three experts.



A pilot study was conducted to determine the reliability coefficient of the Physics Practical Test (PPT) and to ascertain the appropriateness of the time allocation, the facility and discrimination indices of the test items, and the overall quality of the instrument. The PPT was administered once to these sixty-eight students. The split-half method was used to determine the reliability of the instrument. In this method, the test items were divided into two halves (odd and even numbers), and the scores from each half were correlated using the Pearson Product Moment Correlation Coefficient (PPMC). The reliability coefficient obtained was 0.83, which was considered high enough to indicate that the instrument was reliable for data collection. A reliability coefficient of 0.80 or above is generally considered acceptable for educational research instruments.

The treatment for this study lasted for six weeks. During this period, the researcher served as the instructor for both the experimental and control groups. The experimental group was taught using the Science Process Approach (SAPA), while the control group was taught using the conventional method. Both groups were taught the same Physics practical topics, which included reflection of light, refraction

of light waves, electricity (resistance and Ohm's law), equilibrium of forces, and simple pendulum. The researcher administered the same Physics Practical Test (PPT) to both the experimental and control groups. The researcher collected the answer booklets at the end of the session and marked them using the same standardized marking scheme. All the scores from posttest were entered into the Statistical Package for Social Sciences (SPSS) version 26.0 for analysis.

The data collected from the administration of the Physics Practical Test (PPT) were analyzed using both descriptive and inferential statistical tools. Descriptive statistics, specifically mean and standard deviation were used to answer the research questions. For the inferential analysis, the null hypotheses were tested using the independent samples t-test at a significance level of $p \leq 0.05$.

Results

Research Question One: What is the difference between the mean performance scores of Physics students exposed to Science Process Approach and those exposed to conventional method in Kaduna State?

To answer this question, the posttest mean scores of the experimental and control groups were compared using descriptive statistics of mean and standard deviation.

Table 1: Summary of Mean and Standard Deviation of Posttest Performance Scores of Experimental and Control Groups

Group	N	Mean	Std. Deviation	Mean Difference
Experimental (SAPA)	100	43.23	3.81	12.36
Control (Lecture)	156	30.87	5.98	

Table 1 shows that students in the experimental group (exposed to SAPA) had a mean performance score of 43.23, while students in the control group (exposed to conventional method) had a mean score of

30.87. The mean difference of 12.36 is in favor of the experimental group. This indicates that students taught using the Science Process Approach performed better

than those taught using the conventional method.

Null hypothesis one: There is no significant difference between the mean performance scores of Physics students exposed to Science

Process Approach and those exposed to conventional method. To test this hypothesis, an independent t-test was conducted at $p \leq 0.05$. The results are presented in Table 2.

Table 2: Summary of t-test Analysis of Mean Performance Scores of Experimental and Control Groups

Group	N	Mean	Std. Deviation	df	t-cal	p-value	Remark
Experimental	100	43.23	3.81	71	2.83	0.01	Significant
Control	156	30.87	5.98				

Significant at $p \leq 0.05$ level

Table 2 reveals that the calculated t-value was 2.83 with a p-value of 0.01 at 71 degrees of freedom. Since the p-value (0.01) is less than the 0.05 level of significance, the null hypothesis is rejected. This means there is a significant difference between the performance of students taught with Science Process Approach and those taught with the conventional method. Therefore, the Science Process Approach is more effective in

improving students' performance in Physics practicals.

Research Question Two: What is the difference between the mean performance scores of male and female Physics students exposed to Science Process Approach in Kaduna State?

To answer this question, posttest mean scores of male and female students within the experimental group were compared. The results are presented in Table 3.

Table 3: Summary of Mean and Standard Deviation of Posttest Scores of Male and Female Students in the Experimental Group

Gender	N	Mean	Std. Deviation	Mean Difference
Male	59	53.37	9.51	0.18
Female	41	53.19	14.49	

Table 3 shows that male students exposed to SAPA had a mean performance score of 53.37, while female students exposed to the same approach had a mean score of 53.19. The mean difference of 0.18 is negligible, indicating that both male and female students performed similarly when taught using the Science Process Approach.

Null Hypothesis Two: *There is no significant difference between the mean performance scores of male and female Physics students exposed to Science Process Approach.*

To test this hypothesis, an independent t-test was conducted at $p \leq 0.05$. The results are presented in Table 4.

**Table 4: Summary of t-test Analysis of Performance Mean Scores of Male and Female Students in the Experimental Group**

Gender	N	Mean	Std. Deviation	df	t-cal	p-value	Remark
Male	59	53.37	9.51	65	0.57	0.95	Not Significant
Female	41	53.19	14.49				

Not significant at $p > 0.05$

Table 4 reveals that the calculated t-value was 0.57 with a p-value of 0.95 at 65 degrees of freedom. Since the p-value (0.95) is greater than the 0.05 level of significance, the null hypothesis is retained. This means there is no significant difference between the performance of male and female students exposed to the Science Process Approach. Thus, SAPA is gender-friendly and equally effective for both sexes.

Discussion

The results revealed that students taught using the Science Process Approach (experimental group) performed significantly better than those taught using the conventional lecture method. This finding aligns with previous research. Ibrahim (2020) found that primary school pupils exposed to SAPA achieved significantly higher scores in Basic Science and Technology than those taught with conventional methods. Similarly, Ogeniyi (2015) reported that chemistry students taught using SAPA showed better academic achievement and retention compared to those taught with lecture methods. Asabe and Yusuf (2016) also found that pre-service chemistry teachers exposed to science process skills approach performed significantly better than their counterparts taught with lecture methods.

The superior performance of the experimental group can be attributed to the active, student-centered nature of SAPA. In the SAPA classroom, students were directly involved in hands-on activities, collaborative learning, and self-assessment. They

observed, measured, classified data, made predictions, interpreted results, and conducted experiments all of which align with Piaget's (1977) cognitive development theory, which emphasizes that learning occurs through active construction of knowledge rather than passive reception.

The conventional method used in the control group positioned students as passive recipients of information. This teacher-centered approach discourages initiative, curiosity, and creativity (Achugbu & Anulika, 2020), and does not provide opportunities for students to practice the process skills essential for Physics practicals. This finding is consistent with Falalu (2015), who reported an inverse relationship between error frequency and academic achievement as errors increased, performance decreased. By actively engaging students in the learning process, SAPA reduced the frequency of errors and consequently improved performance.

The findings also showed no significant difference between the performance of male and female students exposed to SAPA. This indicates that the Science Process Approach is gender-friendly and equally effective for both sexes. This result supports the findings of Thomas (2017), who concluded that gender is not a major issue in Physics practical works when students are properly taught how to obtain accurate results and minimize errors. Similarly, Okereke (2018) found no significant gender differences in errors committed when using demonstration teaching methods. Usman (2010) also



reported no gender differences in Integrated Science practical activities when using activity-based instruction. Bichi (2002) found no significant difference between male and female students' achievement when using problem-solving instructional strategies. However, this finding contradicts some earlier studies. Fatuma and Gude (2015) reported that female students committed more parallax errors while male students committed more algorithm errors. Omosewe and Akanbi (2013) found that male students had significantly higher error frequencies. Falalu (2015) reported that female students performed poorly compared to males due to the abstract nature of Physics.

Conclusion

Based on the findings of this study, the following conclusions are drawn: The Science Process Approach (SAPA) is significantly more effective than the conventional lecture method for improving students' performance in Physics practicals. Students taught using SAPA demonstrated higher academic achievement and made fewer errors compared to those taught with traditional methods. The Science Process Approach is gender-friendly. There is no significant difference between the performance of male and female students taught using SAPA. The approach provides equal learning opportunities and benefits for both sexes. Therefore, the persistent poor performance of students in Physics practicals, particularly the common errors reported by WAEC, can be addressed through the adoption of the Science Process Approach.

Recommendations

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

1. **Physics teachers** in senior secondary schools should adopt the Science

Process Approach for teaching Physics practicals. This will help reduce common errors (parallax, intercept, slope, computational, and scale errors) and improve students' overall performance.

2. **Schools and education authorities** should organize workshops, in-service training, and seminars to train Physics teachers on the effective implementation of the Science Process Approach.
3. **Curriculum planners** should consider integrating the Science Process Approach into the senior secondary school Physics curriculum as an alternative or complement to existing teaching methods.
4. **Teacher training institutions** should emphasize process-oriented, activity-based teaching strategies in their programs to prepare future teachers who are competent in methods like SAPA.

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