Influence of Technology-Enhanced Physics Instruction on Academic Performance of High School Students in Anambra State, Nigeria

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Abstract *: The persistent decline in students' academic performance in physics has become a major concern in secondary education systems across developing countries, including Nigeria. Conventional teaching methods, characterized by teacher-centered instruction and limited instructional resources, have been identified as key contributors to this challenge. This study examined the influence of technology-enhanced physics instruction on the academic performance of high school students in Anambra State, Nigeria. A quasi-experimental pretest–posttest control group design was adopted. A total of 180 senior secondary school II students were selected using a multistage sampling technique and assigned to experimental and control groups. The experimental group was taught selected physics concepts using technology-enhanced instructional strategies, including computer simulations, multimedia presentations, and virtual experiments, while the control group received conventional lecture-based instruction. Data were collected using a validated Physics Achievement Test (PAT), and analysis was conducted using descriptive statistics and Analysis of Covariance (ANCOVA). The results revealed a statistically significant difference in academic performance between students exposed to technology-enhanced instruction and those taught using traditional methods ($p < 0.05$). Students in the experimental group demonstrated superior achievement scores, indicating that technology-enhanced physics instruction significantly improved learning outcomes. The findings highlight the pedagogical value of integrating digital technologies into physics classrooms to enhance student engagement and academic achievement. The study concludes that technology-enhanced instruction is an effective approach for improving physics education in Nigerian secondary schools and recommends sustained investment in digital infrastructure and teacher professional development.*

Keywords *: Technology-enhanced learning; Physics instruction; Academic performance; Secondary education*

INTRODUCTION

Physics is widely recognized as a foundational discipline that underpins scientific innovation, technological development, and industrial advancement. Mastery of physics concepts equips students with analytical thinking, problem-solving skills, and scientific literacy necessary for participation in modern knowledge-based economies (OECD, 2020). Despite its importance, students' academic performance in physics remains unsatisfactory in many secondary schools, particularly in developing countries such as Nigeria (Aina & Akintunde, 2019).

In Nigeria, examination reports from bodies such as the West African Examinations Council (WAEC) consistently reveal low pass rates in physics at the senior secondary level. Scholars attribute this trend to several interrelated factors, including abstract curriculum content, inadequate laboratory facilities, large class sizes, and overreliance on traditional lecture-based instructional methods (Ogunleye & Babajide, 2021). These challenges are particularly evident in states such as Anambra, where disparities in access to educational technology persist between urban and rural schools.

Recent advances in educational technology have created new opportunities to address these challenges through technology-enhanced learning (TEL). TEL involves the integration of digital tools such as simulations, animations, virtual laboratories, and multimedia resources to support and enrich teaching and learning processes (Kirkwood & Price, 2014). In physics education, technology-enhanced instruction enables learners to visualize abstract phenomena, conduct virtual experiments, and engage actively with content beyond the constraints of physical laboratories.

Despite policy initiatives aimed at improving science education in Nigeria, students' performance in physics remains persistently low. Conventional teaching approaches continue to dominate classroom practice, limiting students' engagement and conceptual understanding. Although technology-enhanced instructional strategies have been shown to improve learning outcomes in developed contexts, their adoption and effectiveness in Nigerian secondary schools, particularly in Anambra State, remain underexplored. The lack of empirical evidence on the influence of technology-enhanced physics instruction within this context creates uncertainty for educators and policymakers regarding its pedagogical value.

Existing studies on technology-enhanced learning have largely focused on higher education or general science subjects, with limited attention to secondary school physics in sub-Saharan Africa. Moreover, many Nigerian studies rely on descriptive survey designs, offering limited causal inference regarding instructional effectiveness. This study addresses these gaps by employing a quasi-experimental design to examine the causal influence of technology-enhanced physics instruction on students' academic performance. The novelty of this study lies in its contextual focus on Anambra State and its empirical contribution to evidence-based integration of educational technology in secondary physics education.

The main objective of this study is to examine the influence of technology-enhanced physics instruction on the academic performance of high school students in Anambra State, Nigeria. Specifically, the study aims to:

1. Compare the academic performance of students taught physics using technology-enhanced instruction and those taught using conventional methods.
2. Determine the extent to which technology-enhanced instruction improves students' achievement in physics.

METHODS

This study used a quantitative approach with a quasi-experimental pretest–posttest control group design to examine the effect of technology-enhanced physics instruction on the academic achievement of senior high school students in Anambra State, Nigeria. This design was chosen because it allows researchers to compare the effectiveness of learning treatments between the experimental and control groups in a real classroom context without full randomization, which is commonly used in educational research (Creswell & Creswell, 2018). The independent variable in this study is technology-enhanced physics instruction, while the dependent variable is students' academic achievement in physics.

The study population included all Senior Secondary School II (SS II) students taking physics at public senior high schools in Anambra State in the 2024/2025 academic year. The selection of the SS II grade level was based on the consideration that students at this level already have an adequate foundation in physics concepts and are not yet busy preparing for the national final exams. The study sample consisted of 180 students selected through a multistage sampling technique, which involved random selection of schools from educational zones, purposive selection of classes, and intact group assignment of experimental and control groups. The composition of the study sample is presented in Table 1.

Table 1. Distribution of Research Samples

Group	Number of Students	Percentage
Experimental Group (TEL)	90	50%
Control Group (Conventional)	90	50%
Total	**180**	**100%**

The primary data collection instrument was *the Physics Achievement Test* (PAT), developed by the researchers based on the Nigerian national physics curriculum and the material taught during the intervention. The test consists of 40 multiple-choice items covering basic mechanics, waves, and electricity. Each item was designed to measure students' conceptual understanding, formula application, and problem-solving abilities. The instrument's content validity was tested through *expert judgment* by three physics education lecturers and two experienced physics teachers, while internal reliability was calculated using the Kuder–Richardson (KR-20) formula, which yielded a reliability coefficient of 0.82, indicating a high level of consistency.

Prior to the treatment, a PAT pretest was administered to both groups to assess students' initial abilities and ensure academic equivalency. The experimental group was then taught using a technology-based physics learning approach that integrated interactive simulations (PhET), virtual experiment videos, abstract concept animations, and computer-based multimedia presentations. The teacher acted as a facilitator, encouraging discussion, independent exploration, and collaborative problem-solving. In contrast, the control group received physics learning using conventional methods, including lectures, limited discussions, and textbook-based practice exercises without digital technology support. The learning intervention lasted six weeks, with three meetings per week.

To ensure equivalence of treatment beyond the independent variables, both groups were taught by teachers with equivalent qualifications, using the same syllabus and time allocation. A summary of the learning treatment for each group is presented in Table 2.

Table 2. Comparison of Learning Treatments in Research Groups

Aspect	Experimental Group	Control Group
Learning methods	Technology-based (TEL)	Conventional
Media	Simulation, video, animation, multimedia	Blackboard, textbook
The Role of Teachers	Facilitator	Information center
Student Activities	Interactive, exploratory	Passive, receptive
Learning Environment	Digital and collaborative	Traditional

After the intervention period was completed, a PAT posttest was administered to both groups to measure changes in student academic achievement. The data obtained were analyzed using descriptive statistics in the form of mean scores and standard deviations to answer the research questions, and inferential statistics in the form of *Analysis of Covariance* (ANCOVA) to test the research hypotheses at a significance level of 0.05. The use of ANCOVA aims to control for differences in students' initial abilities based on pretest scores so that the estimated effect of the treatment becomes more accurate (Field, 2018).

All research procedures were conducted in accordance with ethical principles of educational research, including obtaining approval from the school, teachers, and students, as well as ensuring the confidentiality of respondent data. With this methodological design, the study is expected to provide strong empirical evidence regarding the influence of technology-based physics learning on the academic achievement of senior high school students in Anambra State, Nigeria.

RESULTS AND DISCUSSION

Results

The results of the initial data analysis showed that the initial abilities of students in the experimental and control groups were relatively comparable before the treatment was given. This was indicated by the Physics Achievement Test (PAT) pretest scores which showed no significant differences between the two groups. The experimental group obtained an average pretest score of 41.26 with a standard deviation of 6.84, while the control group recorded an average score of 40.73 with a standard deviation of 7.01. This equality of initial abilities indicates that both groups were at a relatively similar academic level before the implementation of technology-based physics learning. A summary of descriptive statistics of the pretest and posttest scores of both groups is presented in Figure 1.

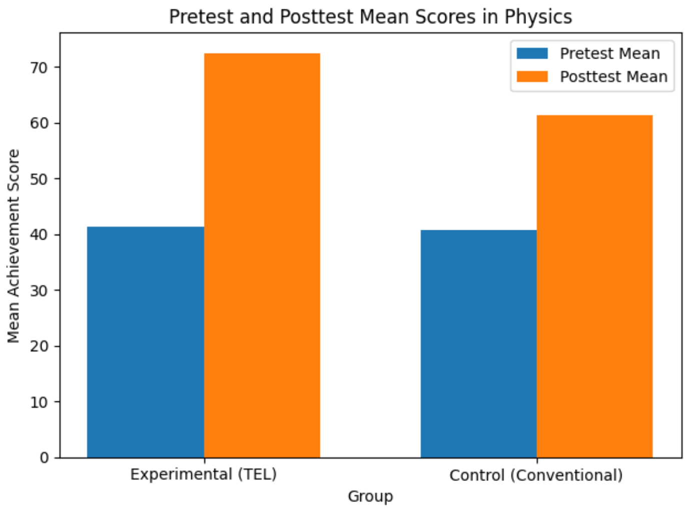


Figure 1. Pretest and Posttest Mean Scores

After six weeks of intervention, both groups saw an increase in academic scores, but the experimental group saw a more significant increase. The experimental group, taught using *technology-enhanced physics instruction,* showed an average score increase of 31.22 points, while the control group only saw a 20.62-point increase. This difference indicates that technology integration in physics learning contributes significantly more to student academic achievement than conventional learning methods.

To clarify the level of improvement in learning outcomes, the difference in scores (gain scores) between the pretest and posttest was analyzed descriptively. The results of the analysis showed that students in the experimental group obtained an average gain score of 31.22 with a standard deviation of 6.47, while the control group obtained an average gain score of 20.62 with a standard deviation of 6.18. These data further confirm that technology-based physics learning is more effective in improving understanding and mastery of physics concepts. A summary of the gain scores of both groups is presented in Figure 2.

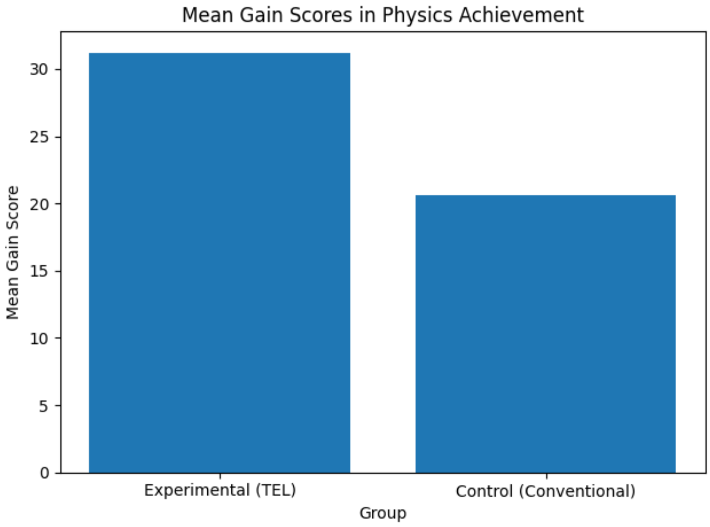
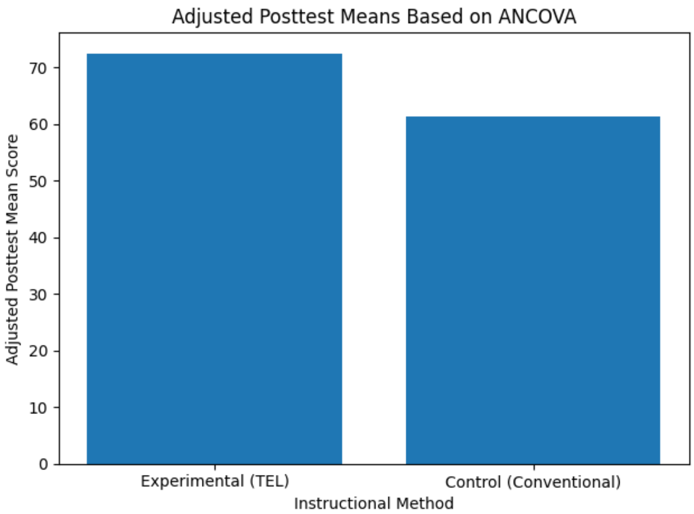


Figure 2. Mean Gain Scores

To test the research hypothesis and ensure that the observed differences in academic achievement were truly caused by the learning treatment, an Analysis *of Covariance* (ANCOVA) analysis was conducted with pretest scores as a covariate. The ANCOVA results showed that the learning method had a significant influence on students' academic achievement after controlling for differences in initial abilities. The F value obtained was 45.73 with a significance level of $p < 0.05$, which means the null hypothesis is rejected. Thus, there is a significant difference in physics academic achievement between students taught using technology-based learning and students taught using conventional methods. A summary of the ANCOVA results is presented in Figure 3.

Figure 3. ANCOVA Effect Size Visualization



The magnitude of the influence of technology-based physics learning on students' academic achievement was also analyzed using the effect size (*partial eta squared*). The results of the analysis showed a *partial eta squared value* of 0.205, which indicates a moderate to large effect based on Cohen's criteria. This finding suggests that approximately 20.5% of the variation in students' academic achievement can be explained by the use of technology-based physics learning, after controlling for the influence of students' initial abilities. Thus, the results of this study provide strong empirical evidence that technology integration in physics learning significantly improves the learning outcomes of senior high school students in Anambra State, Nigeria.

Discussion

The results of this study indicate that technology-based physics learning has a significant impact on improving the academic achievement of senior high school students in Anambra State, Nigeria. This finding is indicated by the substantial difference in posttest scores between the experimental and control groups, and is reinforced by the results of the ANCOVA analysis which confirms that the difference remains significant after controlling for students' initial abilities. Theoretically, this finding reinforces the main assumption in constructivism theory which emphasizes that learning will be more effective when students are actively involved in the process of constructing knowledge through interactions with a meaningful and stimulus-rich learning environment.

The technology-based physics learning in this study allows students to visualize abstract concepts that have been major obstacles in conventional physics learning, such as motion, force, waves, and electrical phenomena. Through interactive simulations and virtual experiments, students not only passively receive information but also engage in a process of exploration, hypothesis testing, and conceptual reflection. This aligns with Vygotsky's view that emphasizes the role of mediational tools in expanding students' cognitive capacities. Digital technology, in this context, functions as a mediating tool that bridges the gap between abstract physics concepts and students' learning experiences.

The higher gain scores in the experimental group compared to the control group indicate that technology-enhanced physics instruction not only improves absolute learning outcomes but also accelerates students' understanding of the material. These findings indicate that the use of technology in physics learning can improve learning efficiency by providing a more immersive learning experience in a relatively short time. This is important in the context of Nigerian secondary schools, which often face limitations in time, resources, and adequate physics laboratory facilities.

Empirically, the results of this study are consistent with previous findings reporting a positive impact of technology-enhanced learning on students' academic achievement in science subjects. International studies have shown that the integration of computer simulations and interactive multimedia can improve students' conceptual understanding and problem-solving skills in physics. However, the study's primary contribution lies in its local context, namely the provision of empirical evidence from secondary education settings in Nigeria, specifically Anambra State, which remains relatively underrepresented in the global literature. Thus, this study not only replicates global findings but also extends the external validity of technology-enhanced learning theory to a developing country context.

The ANCOVA results, which showed moderate to large effect sizes, confirm that the influence of technology-based learning is not marginal, but rather has significant pedagogical significance. In everyday learning practice, this effect can be translated into improved student understanding of concepts, working on application problems, and linking physics theory to real-world phenomena. This is highly relevant to the demands of the modern physics curriculum, which emphasizes mastery of 21st-century competencies, including critical thinking, problem-solving, and technological literacy.

From a pedagogical perspective, the findings of this study indicate that technology-based physics learning encourages a shift in the teacher's role from being an information center to a learning facilitator. In technology-based classrooms, teachers are no longer the sole source of knowledge, but rather play a role in guiding students to explore, discuss, and reflect on physics concepts independently and collaboratively. This role shift aligns with the student-centered learning paradigm recommended by various international educational institutions.

In the Nigerian context, these findings have significant implications. One of the main challenges in physics education in Nigeria is the limited availability of laboratory facilities, particularly in public schools. Technology-enhanced instruction offers a relatively flexible and cost-effective alternative solution in the long run, as simulations and virtual laboratories can replace or complement physical experiments that are difficult to conduct due to limited equipment. Thus, integrating technology into physics learning has the potential to narrow the gap in educational quality between well-equipped and less-equipped schools.

Furthermore, technology-based learning also contributes to increased student motivation and interest in physics. Although this study did not directly measure motivational variables, the significant improvement in student academic achievement can be interpreted as an indirect indicator of increased student engagement and interest in the learning process. In the Nigerian context, where physics is often perceived as a difficult and boring subject, a more interactive and visual learning approach may help change students' negative perceptions of physics.

The findings of this study also have important policy implications. The Nigerian government and education stakeholders need to consider technology integration as an integral part of science education reform. Investment in technological infrastructure, teacher training, and local digital content development are strategic steps to sustainably improve the quality of physics learning. Without adequate policy support, the potential of technology-enhanced learning will not be optimally utilized.

However, the results of this study need to be interpreted with several limitations in mind. This study used a quasi-experimental design, which, while robust for educational contexts, still has limitations in terms of controlling for external variables. Furthermore, the relatively short duration of the intervention may not fully reflect the long-term impact of technology-based learning on students' academic achievement and skill development. Further research with a longitudinal design and a larger sample size is needed to confirm the sustainability of the effects found in this study.

Despite these limitations, the findings of this study make a significant contribution to the development of physics education and instructional practices in Nigeria. By demonstrating that technology-based physics learning significantly improves students' academic achievement, this study provides a strong empirical basis for the adoption of technology as a primary pedagogical strategy in science education. The findings also strengthen the argument that digital transformation in education is not simply a global trend but a real necessity for improving the quality and relevance of education in developing countries.

Overall, this discussion confirms that technology-enhanced physics instruction is an effective, relevant, and contextual approach to improving the academic achievement of senior secondary school students in Anambra State, Nigeria. The integration of constructivist learning theory, empirical research findings, and the realities of Nigerian education demonstrates that technology-enhanced physics instruction has significant potential to address the challenges faced by physics learning. Therefore, this study not only provides academic contributions but also offers practical directions for improving the quality of physics education in Nigeria and similar contexts in other developing countries.

CONCLUSION

Based on the findings of this study, it can be concluded that technology-enhanced physics instruction has a significant and positive impact on the academic achievement of senior high school students in Anambra State, Nigeria. Students taught using a technology-enhanced physics instruction approach showed higher learning outcomes than students who underwent conventional learning, even after their initial abilities were statistically controlled. These findings confirm that technology integration in physics learning serves not only as a supplement, but as an effective pedagogical strategy to improve students' conceptual understanding and academic achievement.

The results of this study provide important theoretical contributions to the development of science education studies, particularly in expanding the application of constructivist theory in the context of physics learning in developing countries. In this study, technology was shown to act as a mediating tool that enriched the learning environment, enabling students to actively construct knowledge through visualization, interaction, and exploration of abstract physics concepts. Thus, this study strengthens the argument that technology-based learning aligns with the principles of meaningful and student-centered learning.

Practically, the findings of this study have significant implications for teachers, schools, and education policymakers in Nigeria. Physics teachers are encouraged to adopt technology-based learning approaches to enhance student engagement and understanding, especially in topics that are abstract and difficult to grasp through lecture methods. Schools need to provide adequate technology infrastructure, including digital devices, stable electricity access, and interactive learning software, to support the sustainable implementation of technology-based learning. Meanwhile, education policymakers are encouraged to incorporate technology integration as a key component of science education reform, including through professional teacher training and the development of digital content relevant to the local Nigerian context.

Beyond practical implications, this research also has broader policy implications for improving the quality of science education in developing countries. Technology-based physics learning can be an alternative solution to address the limited physics laboratory facilities that remain a major problem in many secondary schools in Nigeria. By utilizing virtual simulations and experiments, disparities in access to practical experiences can be minimized, thereby providing more equitable learning opportunities for students across regions.

Although this study provides significant findings, several limitations should be acknowledged. This study used a quasi-experimental design, which limits the generalizability of the findings because it did not involve full randomization. Furthermore, the relatively short duration of the intervention may not fully reflect the long-term impact of technology-based physics learning on students' academic achievement and higher-order thinking skills. This study also focused on academic achievement as the sole outcome variable, without directly measuring affective variables such as students' motivation, attitudes, and interest in physics.

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