International Journal of Innovative Information Systems & Technology Research 14(3):372-380, July-Sept, 2026

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DOI:10.5281/zenodo.22877983

Effect of Artificial Intelligence-based Instruction on students' Achievement, Retention and Conceptual Understanding in Physics in Higher Institution

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ABSTRACT

The study examined the effect of Artificial Intelligence-based instruction on students' achievement, retention, and conceptual understanding in Physics in higher instution. Quasi-experimental design was adopted for the study. Sample size of 116 200level Physics students in federal university were selected using Multi-stage sampling techniques. Three instruments were used for data collection. Physics Achievement Test (PAT), Physics Conceptual Understanding Test (PCUT) and Physics Retention Test (PRT). Experts in Physics Education and Measurement and Evaluation validated the instrument. Reliability coefficient of 0.78 and 0.83 were obtained using KR-20 and Croabach's apha respectively. Students in experimental group were taught using AI-based instruction while control group were taught were taught using conventional method. Mean and standard deviation were used to analyze the research questions while ANCOVA was used to test the hypotheses at 0.05 level of significance. The study shows that $F(1,113) = 61.801$, $p<0.05$, indicating that there is significant effect of AI-based instruction on students' achievement in physics. Also, the finding reveals that $F(1,113) = 50.390$, $p<0.05$. it imply that there is a significant difference in the retention scores of students taught physics using AI-based instruction and those taught with conventional method. Finally, students exposed to AI-based instruction record a higher gain in conceptual understanding (34.66) than those taught with conventionally (21.26). The study concluded that integrating AI-based instruction in teaching and learning process enhance achievement and improve retention in Physics. Based on the findings, it was recommended that Physics lecturers should receive professional development on the pedagogical use of Artificial intelligence tool

Keywords: AI-based instruction, Achievement, Retention, Conceptual understanding

INTRODUCTION

Physics holds a significant place in science and technology education. It explains many natural phenomena and provides foundational knowledge for fields like engineering, technology, astronomy, and

applied sciences, (Alachi et al., 2025). According to Alachi et al.(2026), the study of physics at the tertiary level requires students to develop mathematical reasoning, scientific problem-solving abilities, and a meaningful understanding of abstract concepts. However, many students experience difficulties in learning physics because several concepts are abstract, mathematically demanding, and often disconnected from their everyday experiences.

In many higher education classrooms, physics instruction continues to rely substantially on lectures, demonstrations, and instructor-led problem-solving activities (Sengul, 2024). These methods are potentially helpful for disseminating knowledge, but they might not always offer sufficient opportunities for personalised instruction, quick feedback, repeated explanations, or ongoing diagnosis of students' misconceptions (Ablanque et al., 2024). Consequently, Sengual (2024) opinion that students may memorize formulas and procedures without developing a deep understanding of the underlying physical principles.

Teaching and learning can now be supported in new ways thanks to artificial intelligence (AI) (Ojarotade, 2025). He further suggest that Personalized explanations, adaptive learning opportunities, automatic feedback, interactive questioning, simulations, and ongoing learning support are all possible with AI-based educational systems. Peter and Olojede (2025) indicate that Students can ask questions, get explanations at varying degrees of complexity, and interact with learning materials outside of the traditional classroom time thanks to generative AI systems and other AI-supported learning tools.

According to recent empirical research such as Olanrewaju & Ojo, (2026), structured AI-supported exercises can enhance physics learning outcomes. For instance, a 2026 undergraduate physics study that used AI-ChatGPT integrated instruction found differences in students' engagement and problem-solving ability compared with traditional lecture instruction, highlighting the importance of purposeful integration of AI into physics teaching and learning (Olanrewaju & Ojo, 2026). In a similar vein, studies on AI-supported physics learning have found that integrating AI tools with instructional activities, such as inquiry and simulation-based learning, can support students' content knowledge, conceptual understanding, and engagement rather than using AI as a stand-alone technology (Chen et al., 2026; Ben-Zion et al., 2026).

Additionally, evidence is emerging from evolving situations in higher education. According to a quasi-experimental study conducted at the University of Khartoum, students who were exposed to AI-based blended learning outperformed those who received traditional education in physics (Hessen et al., 2026). Significant effects on university students' physics achievement at post-test and follow-up evaluation were also discovered in a Nigerian study on computer-assisted instruction, indicating that technology-supported instruction can serve as a helpful basis for more sophisticated AI-supported approaches (Ugwuanyi & Okeke, 2020).

Despite these advancements, it is not possible to assume that AI-based training will be equally effective in all educational contexts. Learning outcomes may be impacted by students' access to technology, digital literacy, institutional infrastructure, instructor competency, instructional design, and AI usage behaviours (Eleje et al., 2025)**.** Furthermore, the combined impact of AI-based instruction on achievement, retention, and conceptual understanding—particularly among physics students in Nigerian higher institutions—has received relatively less attention in the emerging research, which has mostly concentrated on academic achievement (Abubakar et al., 2024; Eleje et al., 2025)

Achievement alone does not necessarily indicate meaningful learning. A student may perform well immediately after instruction but fail to retain the learned material over time (Opara et al., 2025)**.** Similarly, students may correctly solve familiar numerical problems without developing an adequate conceptual understanding of the underlying physical principles (Alachi et al., 2022)**.** Therefore, evaluating AI-based instruction through multiple learning outcomes, including achievement, retention, and conceptual understanding, may provide a more comprehensive assessment of its educational effectiveness (Alachi et al., 2022; Alachi et al., 2023)

Statement of the problem

Despite the importance of physics in higher education, many students continue to experience difficulties that are reflected in low achievement, weak retention, and inadequate conceptual understanding. Conventional instructional approaches may not adequately respond to differences in students' prior knowledge, learning pace, misconceptions, and need for immediate feedback.

Although emerging studies have reported promising outcomes from AI-supported learning, limited empirical evidence exists in the Nigerian higher-education context, particularly studies that examine achievement, retention, and conceptual understanding simultaneously. Much of the emerging literature tends to focus on academic achievement or students' perceptions and acceptance of AI rather than examining multiple learning outcomes together. There is also a need for evidence showing whether structured AI-based instruction, rather than students' unsupervised use of AI tools, can produce measurable improvements in physics learning.

Therefore based on the need to establish whether AI can provide an effective instructional alternative to conventional teaching in Nigerian higher institutions. Examining achievement alone may not adequately demonstrate meaningful learning; students may perform well immediately after instruction without retaining the knowledge or developing a sound understanding of the underlying physics concepts. Consequently, investigating achievement, retention, and conceptual understanding together can provide a more comprehensive assessment of the educational effectiveness of AI-based instruction.

Purpose of the Study

The main purpose of this study is to determine the effect of artificial intelligence-based instruction on students' achievement, retention, and conceptual understanding in physics in higher institutions in Nigeria.

Specifically, the study seeks to:

1. determine the effect of artificial intelligence-based instruction on students' achievement in physics;
2. determine the effect of artificial intelligence-based instruction on students' retention of physics concepts;
3. determine the effect of artificial intelligence-based instruction on students' conceptual understanding in physics;

Research Questions

The following research questions guided the study:

1. What is the difference in the mean achievement scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method?
2. What is the difference in the mean retention scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method?
3. What is the difference in the mean conceptual understanding scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method?

Research Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

H01: There is no significant difference in the mean achievement scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method.

H02: There is no significant difference in the mean retention scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method.

H03: There is no significant difference in the mean conceptual understanding scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method.

METHODOLOGY

The study adopted a quasi-experimental pretest-posttest non-equivalent control group design. The design was considered appropriate because the study involved the use of intact classes, making it impracticable to randomly assign individual students to the experimental and control groups. The design enabled the

researcher to compare students' performance before and after the intervention and determine the effect of the instructional treatment on their achievement, conceptual understanding, and retention in physics.

The study was conducted in universities offering undergraduate physics courses in South-East State of Nigeria. The selected universities provided the appropriate setting for investigating the effect of the instructional approach on 200-level undergraduate physics students.

A sample of 116 200-level undergraduate students was selected from Two Federal Universities from the study areas. A multistage sampling procedure was employed. At the first stage, simple random sampling was used to select two federal universities from the universities offering undergraduate physics courses in South-East State. At the second stage, intact classes were identified in the two universities. The selected intact classes were randomly assigned to the experimental and control groups to minimize selection bias. The experimental group comprised 55 students, while the control group comprised 61 students, giving a total sample of 116 students.

Three instruments were used for data collection: Physics Achievement Test (PAT), Physics Conceptual Understanding Test (PCUT), and Physics Retention Test (PRT). The Physics Achievement Test (PAT) was used to measure students' knowledge and ability to solve problems related to waves. The Physics Conceptual Understanding Test (PCUT) was used to assess students' understanding of physics concepts, relationships among concepts, scientific explanations, and possible misconceptions relating to the concepts taught. The Physics Retention Test (PRT) was administered after a predetermined interval following the posttest to determine the extent to which students retained the knowledge and concepts acquired during the intervention.

The instruments were subjected to face and content validation by experts in Physics Education and Educational Measurement and Evaluation. The validators examined the relevance of the items to the objectives of the study, clarity of language, appropriateness of the items to the students' level, alignment of the items with the instructional objectives, and adequacy of coverage of the content area. The observations and recommendations of the experts were used to modify and improve the instruments before their final administration.

The reliability of the instruments was established using appropriate internal consistency measures. The Physics Achievement Test (PAT) was subjected to the Kuder-Richardson Formula 20 (KR-20), which is appropriate for dichotomously scored test items, while Cronbach's alpha was used for the Physics Conceptual Understanding Test (PCUT), where the scoring format required an internal consistency estimate based on the nature of the items. The reliability coefficients obtained for the PAT and PCUT were 0.78 and 0.83, respectively. These coefficients indicate acceptable levels of internal consistency and demonstrate that the instruments were sufficiently reliable for the study

The experimental procedure lasted for six weeks. Prior to treatment a pretest was administered to both the experimental and control groups to determine their achievement and conceptual understanding of physics concepts. The experimental group was taught using Artificial Intelligence-based instruction while the control group was taught using conventional method of teaching. After the treatment, the posttest was administered to both experimental and control group and the score was recorded. Two week after the posttest, the retention test was administered to measure their retention.

Mean and standard deviation were used to answer the research questions while analysis of covariance was used to test the hypotheses at 0.05 level of significance.

RESULTS

Research Question One: *What is the difference in the mean achievement scores of students taught physics using artificial intelligence-based instruction and those taught using the conventional method?*

Table 1: Mean and Standard Deviation of Students' Achievement Scores

Group	Test	N	Mean	SD	Mean Gain
Experimental - AI-based Instruction	Pretest	55	38.42	11.63	33.74
	Posttest	55	72.16	12.48	
Control - Conventional Method	Pretest	61	39.05	12.17	21.26
	Posttest	61	60.31	13.26	

The results presented in Table 1 show that students in the experimental group who were taught physics using artificial intelligence-based instruction obtained a pretest mean achievement score of 38.42 with a standard deviation of 11.63. Following the treatment, their mean achievement score increased to 72.16, with a standard deviation of 12.48, resulting in a mean gain of 33.74 points. In contrast, students in the control group who were taught using the conventional method obtained a pretest mean achievement score of 39.05 with a standard deviation of 12.17. Their posttest mean achievement score increased to 60.31, with a standard deviation of 13.26, representing a mean gain of 21.26 points. The experimental group therefore recorded a higher mean gain (33.74**)** than the control group (21.26), indicating a 12.48-point difference in mean gain in favour of the AI-based instruction group. The relatively similar pretest means suggest that the two groups had comparable levels of achievement before the intervention, while the higher posttest mean of the experimental group suggests greater improvement following the AI-based instruction.

Research Hypothesis One: There is no significant difference in the mean achievement scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional metho

Table 2: ANCOVA Result on Mean Achievement Scores of Students Taught Physics Using Artificial Intelligence-Based Instruction and Those Taught Using the Conventional Method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12485.620[a]	2	6242.810	38.214	.000	.405
Intercept	2156.438	1	2156.438	13.202	.000	.105
Pretest	4821.376	1	4821.376	29.513	.000	.208
Method	10094.244	1	10094.244	61.801	.000	.353
Error	18498.380	113	163.702			
Total	503844.000	116				
Corrected Total	30984.000	115				

a. R Squared = .403 (Adjusted R Squared = .393)

The result in table 2, indicates that there was a statistically significant difference in the mean achievement scores of students taught using artificial intelligence-based instruction and those taught using the conventional method, $F(1, 113) = 61.801$, $p < 0.05$, partial $\eta^2 = .353$. Since the obtained significance value of .000 is less than the 0.05 level of significance, the null hypothesis, H_{01}, is rejected. This means that there is a significant difference in the adjusted mean achievement scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method. The partial eta squared value of .353 indicates a large effect size, suggesting that the method of instruction accounted for a substantial proportion of the variance in students' achievement after controlling for their pretest scores.

Research Question 2: *What is the difference in the mean retention scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method?*

Table 3: Mean and Standard Deviation of Students' Retention Scores

Group	Test	N	Mean	SD	Mean Gain
Experimental - AI-based Instruction	Posttest Retention	55 55	72.16 70.84	12.48 12.91	-1.32
Control - Conventional Method	Posttest Retention	61 61	60.31 55.47	13.26 13.84	-.4.84

Table 3 shows that students in the experimental group who were taught Physics using artificial intelligence-based instruction obtained a posttest mean retention-related score of 72.16 with a standard deviation of 12.48. At the retention test, their mean score was 70.84, with a standard deviation of 12.91, representing a mean change of −1.32 points. Students in the control group who were taught using the conventional method obtained a posttest mean score of 60.31 with a standard deviation of 13.26. Their mean score decreased to 55.47 at the retention test, with a standard deviation of 13.84, representing a mean change of −4.84 points. The experimental group therefore recorded a smaller decline in performance (−1.32**)** compared with the control group (−4.84). This suggests that students exposed to artificial intelligence-based instruction retained a greater proportion of the physics knowledge acquired during the intervention than students exposed to the conventional method.

Research Hypothesis Two: There is no significant difference in the mean retention scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method.

Table 4: ANCOVA Result on Mean Retention Scores of Students Taught Physics Using Artificial Intelligence-Based Instruction and Those Taught Using the Conventional Method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	10876.420[a]	2	5438.210	31.624	.000	.359
Intercept	1842.315	1	1842.315	10.713	.001	.087
Posttest	4216.785	1	4216.785	24.522	.000	.178
Method	8664.295	1	8664.295	50.390	.000	.308
Error	19415.680	113	171.820			
Total	468921.000	116				
Corrected Total	30292.100	115				

a. R Squared = .359 (Adjusted R Squared = .348)

The table 4 indicates that there was a statistically significant difference in the mean retention scores of the two groups, $F(1, 113) = 50.390$, $p < 0.05$, partial $\eta^2 = .308$. Since the significance value of .000 is less than the 0.05 level of significance, the null hypothesis, H_{02}, is rejected. This means that there is a significant difference in the mean retention scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method. The partial eta squared value of .308 indicates a large effect size, suggesting that instructional method had a substantial effect on students' retention of learned physics concepts.

Research Question 3: What is the difference in the mean conceptual understanding scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method?

Table 5: Mean and Standard Deviation of Students' Conceptual Understanding Scores

Group	Test	N	Mean	SD	Mean Gain
Experimental - AI-based Instruction	Pretest Posttest	55 55	35.64 70.28	10.82 11.76	34.64
Control - Conventional Method	Pretest Posttest	61 61	36.17 57.43	11.24 12.65	21.26

Table 5 shows that students in the experimental group who were taught Physics using artificial intelligence-based instruction had a pretest mean conceptual understanding score of 35.64 with a standard deviation of 10.82. Following the intervention, their mean score increased to 70.28, with a standard deviation of 11.76, resulting in a mean gain of 34.64. In comparison, students in the control group who were taught using the conventional method had a pretest mean conceptual understanding score of 36.17 with a standard deviation of 11.24. Their posttest mean increased to 57.43, with a standard deviation of 12.65, giving a mean gain of 21.26. The experimental group therefore recorded a higher mean gain (34.64**)** than the control group (21.26), representing a difference of 13.38 points in mean gain in favour of the AI-based instruction group.

Research Hypothesis Three: There is no significant difference in the mean conceptual understanding scores of students taught Physics using artificial intelligence-based instruction and those taught using the conventional method.

Table 6: ANCOVA Result on Mean Conceptual Understanding Scores of Students Taught Physics Using Artificial Intelligence-Based Instruction and Those Taught Using the Conventional Method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	11964.382[a]	2	5982.191	36.847	.000	.395
Intercept	1925.614	1	1925.614	11.862	.001	.095
Pretest	3948.267	1	3948.267	24.318	.000	.177
Method	9347.521	1	9347.521	57.576	.000	.338
Error	18337.445	113	162.278			
Total	487216.000	116				
Corrected Total	30301.827	115				

The result from table 6 shows that pretest conceptual understanding had a statistically significant effect on students' posttest conceptual understanding, $F(1, 113) = 24.318$, $p < 0.05$, partial $\eta^2 = .177$. More importantly, the result for method of instruction indicates a statistically significant difference in the adjusted mean conceptual understanding scores of students taught using artificial intelligence-based instruction and those taught using the conventional method, $F(1, 113) = 57.576$, $p < .001$, partial $\eta^2 = .338$. Since the significance value of **.000** is less than the 0.05 level of significance, the null hypothesis, H_{03}, is rejected. This means that there is a statistically significant difference in the conceptual understanding scores of students taught using the two instructional methods. The partial eta squared value of .338 indicates a large effect size, suggesting that the method of instruction had a substantial effect on students' conceptual understanding of Physics.

DISCUSSION

The findings showed that AI-based instruction was more effective than the conventional method in improving students' achievement, retention, and conceptual understanding of Physics. For achievement, the AI-based group recorded a higher mean gain (33.74) than the conventional group (21.26), with ANCOVA confirming a significant difference, $F(1,113) = 61.801$, $p < 0.05$, partial $\eta^2 = .353$. This finding agrees with Ojarotade (2025), Peter and Olojede (2025), Olanrewaju and Ojo (2026), and Hessen et al. (2026), who reported that purposeful AI-supported instruction can enhance learning, engagement, and problem-solving.

For retention, the AI-based group experienced a smaller decline (−1.32) compared with the conventional group (−4.84). The ANCOVA result showed a significant difference, $F(1,113) = 50.390$, $p < 0.05$, partial $\eta^2 = .308$, suggesting that AI-based instruction helped students retain learned Physics concepts better. This supports Opara et al. (2025) and Ojarotade (2025), who emphasized the importance of continuous learning support and opportunities for reinforcement.

Similarly, students exposed to AI-based instruction recorded a higher gain in conceptual understanding (34.64) than those taught conventionally (21.26). The difference was statistically significant, $F(1,113) = 57.576$, $p < 0.05$, partial $\eta^2 = .338$. This finding is consistent with Alachi et al. (2022, 2023), Chen et al. (2026), and Ben-Zion et al. (2026), who stressed the importance of developing meaningful conceptual understanding rather than relying only on procedural knowledge.

Finally, the findings provide evidence that structured and purposeful AI-based instruction can significantly enhance Physics achievement, retention, and conceptual understanding. The large effect sizes across the three outcomes indicate that the observed benefits were educationally substantial. The findings also address the identified research gap by demonstrating the effectiveness of AI-based instruction across multiple learning outcomes, rather than achievement alone.

CONCLUSION

The study investigate the effect of Artificial Intelligence-based Instruction on students' achievement, retention and conceptual understanding in Physics in higher institution. Based on the results and discussion, the following conclusion are drawn.

1. Comparable baseline: Both experimental (AI-based Instruction) and control (conventional method) had nearly equal pretest scores in physics achievement and conceptual understanding, revealing a fair starting point for comparison. However, students taught physics using Artificial Intelligence-based instruction performed better in achievement than those taught physics using the conventional method.
2. Students exposed to AI-based instruction recorded a higher gain in conceptual understanding (34.66) than those taught conventionally (21.26).
3. For retention, the result showed a significant difference $p< 0.05$, suggesting that AI-based instruction helped students retain learned physics concepts better

RECOMMENDATION

Based on the findings, the following recommendations were made:

1. Physics lecturers should receive professional development on the pedagogical use of artificial intelligence tools.
2. Higher institutions should develop guidelines for responsible and academically appropriate use of AI in teaching and learning.
3. AI should be integrated into physics instruction as a guided learning tool, rather than simply as a system for generating answers.
4. Students should be trained to verify AI-generated explanations using textbooks, scientific principles, experiments, and lecturer guidance.

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