



Exploring the Effectiveness of AI-Driven Adaptive Learning Systems in Science Education, Impact on Student Engagement

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Abstract

The paper explores the potential of AI-driven adaptive learning systems in enhancing student engagement in educational institutions, focusing on science education, students' achievement, retention, and interactive experiences. To achieve these three (3) purposes, three (3) research questions and three (3) hypotheses were formulated to guide the study. The research design adopted for this study was the experimental research design. The study involved 1610 Nigerian secondary school students, with a minimum sample size of 313 respondents. The Krejcie and Morgan (1970) recommendation for a population was followed, with 156 respondents from the first school and 157 from the second. The study developed a new questionnaire and achievement test, the AI-driven adaptive learning systems and students' engagement Questionnaire (AALS-SEQ), to collect data on students' engagement in the educational sector. The questionnaire was designed to ensure validity and reliability by conducting a literature review on students' classroom engagement, particularly in science classes in African and Nigerian contexts. The AALS-SEQ was structured into four sections: A, which captures demographic characteristics, B, which measures AI-driven adaptive learning systems, C, which measures students' engagement, and D, which measures students' retention level of science concepts. The Core Science achievement test, consisting of 30 items from the three core science subjects for senior secondary school, was also developed. The response options were based on their degree of agreement with the statements made for each item. The questionnaire underwent a review by experts in educational psychology and science education to ensure content validity. It was then trial-tested with 100 students to assess clarity, relevance, and reliability. The internal consistency of Sections B to D and core science achievement test was assessed using Cronbach's alpha, which yielded a value of .77, and .82, respectively, indicating high reliability. The result showed that there is a significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods. AI-driven adaptive learning systems have a significant effect on students' retention of science concepts, and AI-driven adaptive learning systems have a significant effect on students' engagement in science classes. The government, teachers, and school administrators are advised to launch nationwide awareness campaigns and raise parental awareness about AI-enhanced teaching to enhance students' learning, retention, engagement, and academic achievement.

Keyword: AI-Driven, Adaptive, Learning Systems, Science Education, Students' Engagement, Students' Learning, Retention, Engagement, And Academic Achievement

Introduction

This shift is largely driven by the rise of adaptive learning systems, which use technology to tailor educational experiences to individual learners' needs. Artificial intelligence (AI) is at the forefront of this transformation. Adaptive learning systems use AI algorithms to analyze students' data in real-time, providing a customized learning experience that caters to different learning styles, paces, and levels of understanding. These systems identify a student's strengths and weaknesses, adjusting content delivery and instructional strategies accordingly. This personalized approach enhances comprehension,

retention, and engagement, fostering a more interactive and motivating learning environment (Chen, Ryan, & Wang, 2022). AI-driven platforms provide real-time insights into students' progress, enabling immediate intervention when challenges arise. This dynamic feedback loop encourages continuous improvement, empowering students to take control of their learning journeys and engage more deeply with the materials. However, concerns regarding data privacy, algorithmic bias, and potential over-reliance on technology must be addressed to ensure equitable benefits for all learners

(Chen, 2024). As educational institutions adopt AI-driven solutions, it is essential to explore these implications while maximizing the advantages of technology.

AI-driven adaptive learning systems are a powerful solution for addressing the diverse needs of learners in the digital age. These systems are designed to create personalized educational experiences, enhancing engagement and improving outcomes. The key components of these systems include algorithms and data analytics, which process vast amounts of data to derive insights about learners (Chen, 2024). These algorithms analyze students' interactions, performance metrics, and learning behaviors to inform content delivery and instructional strategies. Many adaptive learning systems are integrated with existing Learning Management Systems (LMS), providing a seamless user experience where learners can access personalized content and receive tailored feedback. Instructors can easily monitor students' performance and adjust their teaching methods based on AI-generated insights (Vaithianathan, Mahesh, Shunye, and Shiv, 2023). An intuitive user interface is crucial for the success of AI-driven adaptive learning systems, making it easier for students to navigate through personalized content and access necessary resources.

AI technologies used in adaptive learning include machine learning algorithms, natural language processing (NLP), learning analytics, and personalized content delivery (Vaithianathan, Mahesh, Shunye, & Shiv, 2024; Olusegun, Flypaper, Oluwaseyi, & Brightwood, 2024). Machine learning algorithms predict students' performance, adapt content difficulty, and recommend resources based on individual learning patterns. Natural language processing allows adaptive learning systems to understand and respond to students' inquiries in real time, providing contextualized feedback and support. Learning analytics evaluates how students interact with content, identifying areas for improvement and recommending adjustments. Personalized educational experiences are at the core of AI-driven adaptive learning systems (Younus, 2024). Customized content delivery allows students to engage with materials that resonates with their interests and learning styles, increasing motivation and retention. Differentiating instruction effectively involves assessing each student's understanding and recommending differentiated tasks that challenge learners at their level. Adaptive learning paths create unique learning pathways for each student, adjusting the sequence and pacing of content based on real-time data (Younus, 2024).

AI has a transformative impact on education by enabling personalized learning by adapting content to individual student needs. This approach improves self-efficacy and positive attitudes towards education. AI-driven tools analyze vast data to identify learning gaps and tailor interventions. Platforms like adaptive learning systems enhance students' engagement and performance by providing real-time feedback and customized learning pathways (Luckin et al., 2016; Zawacki-Richter et al., 2019). These AI-powered tools, such as adaptive learning systems, are increasingly being used to enhance education. Personalization in education has become a powerful strategy to enhance students' engagement and improve learning outcomes. AI-driven adaptive learning systems play a pivotal role in this process by customizing educational experiences to meet the unique needs of each learner. These systems enhance students' engagement through tailored learning paths, addressing individual learning styles and preferences, and fostering autonomy and motivation. Tailored learning paths include dynamic content adjustment, personalized learning trajectories, goal-oriented learning, and alignment with learning modality (Younus, 2024).

Dynamic content adjustment helps students grasp challenging materials and prevents frustration and disengagement. Personalized learning trajectories accommodate each student's unique learning pace, ensuring they remain challenged and engaged (Castaneda & Selwyn, 2018; Selwyn, 2016). Goal-oriented learning empowers students to take ownership of their learning journeys, providing visual representations of achievements that motivate learners to persist. Adaptive assessments play a crucial role in learning, and adaptive systems can adjust the type and difficulty of assessments based on individual performance. This tailored approach ensures that assessments are relevant and appropriately challenging, keeping students engaged and motivated (Chen, Ryan, & Wang, 2022). Interactive learning experiences, such as simulations, games, and collaborative projects, appeal to diverse learning styles and promote active engagement and deeper understanding. Fostering autonomy and motivation is another key feature of AI-driven adaptive learning system.

Traditional education encourages students to actively participate in their learning process, developing skills in exploration, analysis, and problem-solving. Critical thinking skills are crucial for shaping learning experiences. Educators use questioning techniques, collaborative activities, and assignments to enhance students' evaluation and independent perspectives. However, AI's rapid

information processing raises questions about the distinction between human learning and machine-based learning (Wu, 2023; Facione, 2020). AI may lack the nuanced understanding and creativity of human cognition, highlighting the need for a balanced approach to AI integration that complements human interaction and critical thinking skills.

Students can choose learning paths, set goals, and engage with content that resonates with their interests, promoting intrinsic motivation (Chen, Ryan, & Wang, 2022). Real-time feedback is one of the key features of these systems, as it allows learners to understand their strengths and areas for improvement. Tools that encourage self-reflection, such as journals or progress trackers, foster a deeper connection with the materials and enhance engagement. Real-time feedback and assessment are integral components of AI-driven adaptive learning systems, providing learners with immediate insights into their performance and progress. This timely information helps to enhance engagement, support effective learning, and facilitate continuous improvement. In this section, we will explore the significance of dynamic assessments, the identification of knowledge gaps, and the role of formative feedback in enriching the educational experience. This paper explores the transformative potential of AI-driven adaptive learning systems in enhancing students' engagement in educational institutions. It analyzes their Students' achievement in science education, students' retention of science concepts, interactive learning experiences and students' engagement in science classes, providing insights into their reshaping of the educational landscape and paving the way for more effective and personalized learning experiences. The goal is to emphasize the importance of leveraging AI to create an inclusive, engaging educational environment that supports diverse learners in their quest for knowledge.

Literature Review

AI-driven adaptive learning systems, Students' achievement in science education and traditional instructional methods.

In a study carried out by Olusegun, et al (2024), investigated the use of AI in adaptive learning systems, highlighting its role in creating dynamic learning paths, providing real-time feedback, and fostering students' autonomy. It also discusses the benefits of personalized learning, immediate assessment, and gamification in enhancing students' engagement. The study also addresses ethical considerations like data privacy and algorithmic bias. It emphasizes the importance of AI in creating

inclusive educational environments for lifelong learning and continuous engagement. Also, Ayobami, Ovbiye, Onayemi, & Ojedele, (2024) explored the impact of AI-powered adaptive learning tools on educational outcomes and engagement for learners with disabilities. It demonstrates how personalized interventions enhance accessibility, cognitive development, and learning outcomes. The research uses data from user interaction patterns, workload, and mental processes to improve system efficiency. The results show higher engagement, understanding, and memory in students with learning disabilities, reducing the educational gap. work incorporating ethical AI governance, multidisciplinary approaches, and user-driven design to create more inclusive, personalized learning environments.

Also, Okunade, (2024) study investigates the impact of Artificial Intelligence (AI) on scientific education in Nigerian secondary schools. It uses a retrospective research approach to analyze past data and highlights the role of AI in teaching science, focusing on Adaptive Learning Systems (ALS), Intelligent Tutoring Systems (ITS), and Virtual Laboratories and Simulations. The study highlights challenges such as infrastructural limitations, teacher preparation, and ethical considerations. Similarly, Vieriu, & Petrea, (2025) aimed to enhance learning outcomes for secondary school students. The integration of Artificial Intelligence (AI) in education has transformed academic learning, offering both opportunities and challenges. A study conducted at the National University of Science and Technology POLITEHNICA Bucharest examined the impact of AI on students' learning processes and academic performance. The research involved 85 second-year students who had direct experience with AI-enhanced learning environments. The findings revealed that AI offers benefits like personalized learning, improved academic outcomes, and enhanced students' engagement. However, challenges like over-reliance, diminished critical thinking skills, data privacy risks, and academic dishonesty were identified. The study emphasizes the need for a structured framework for AI integration, supported by ethical guidelines.

In a related study Wadim, Veronika, Alexander, Guzalbegim, & Tatiana (2024) examined the impact of adaptive learning technologies and artificial intelligence (AI) on education, highlighting their ability to make education personalized, accessible, and efficient. The rapid technological advancements in education, coupled with a focus on individual learning styles and abilities, have led to a significant increase in scientific publications on this topic. The study uses visual operating system (VOS) viewer to analyze 3518

publications on adaptive learning and AI from 1990 to 2024. The results show that recent technological changes, particularly the digital surge triggered by the COVID-19 pandemic, have significantly impacted adaptive learning. The findings can be useful for further development in adaptive education, benefiting stakeholders, policymakers, scholars, and researchers.

AI-driven adaptive learning systems and students' retention of science concepts

In a study carried out by Gligorea, Cioca, Oancea, Gorski, Gorski, & Tudorache, (2023) that explored the use of artificial intelligence (AI) and machine learning (ML) in e-learning for adaptive learning, analyzing its benefits and challenges. A literature review analyzed 63 articles from 2010 to the present the integration of adaptive learning algorithms. Findings show that AI/ML enhances learning experiences, optimizes learning paths, retention and improves academic performance, with some studies reporting increased test scores. Wang, Huang, Sommer, Pei, Shidfar, Rehman, Ritzhaupt, & Martin, (2024) meta-analysis examined the impact of AI-enabled adaptive learning systems on students' cognitive retentive learning outcomes. It found a medium to large positive effect size ($g = 0.70$) on cognitive learning outcomes. The effect was moderated by publication type, origin of study, student classification level, discipline, duration, and research design. All three adaptive sources (cognitive, affective, and behavioral) and adaptive targets (navigation and assessment) were significant moderators.

In a related study by Wadim, Veronika, Alexander, Guzalbegim, & Tatiana, (2025) that examined the impact of adaptive learning technologies and artificial intelligence (AI) on education, highlighting their ability to make education personalized, accessible, and efficient through improving effective retention of concepts. The study analyzed 3518 publications on adaptive learning and AI from 1990 to 2024, revealing that recent technological changes, particularly the COVID-19 pandemic, have significantly influenced this transformation.

AI-driven adaptive learning systems and students' engagement in science classes.

Eileen, Daleen, & Denise, (2024), a scoping review of 69 studies on personalized adaptive learning in higher education found that it has a significant impact on academic performance and engagement. The most common method for activating adaptive content delivery was pre-

knowledge quizzes, with McGraw-Hill's Connect LearnSmart and Moodle being the most commonly used platforms. 41 out of the studies reported improved academic performance, while 25 studies indicated increased students' engagement. The study underscores the potential of personalized adaptive learning to improve academic performance, students' engagement, and learning despite technological limitations. It calls for further research to address technological challenges, build on strengths, and refine the implementation of personalized adaptive learning in higher education. Similarly, Edidiong, Mfon, & Ikanaobong (2024) examined the impact of AI-driven adaptive learning systems on students' engagement and skill acquisition in Nigerian Technical and Vocational Education and Training (TVET) institutions. Traditional approaches often fail to cater to diverse learning needs, leading to high dropout rates and inadequate skill development. However, successful integration faces barriers like insufficient infrastructure, limited funding, and resistance to change.

Also, Jozsef, & Klara, (2025) study investigated the integration of AI-powered adaptive learning systems in flipped classrooms for programming education. The research, conducted over 13 weeks, found significant improvements in learning results and motivation in the experimental group. The AI-driven adaptive learning tools increased students' autonomy and responsibility, enhancing a dynamic and cooperative learning environment. The findings highlight the importance of AI integration in modernizing programming education and improving overall students' learning experiences. A related study carried out by Yaseen, Mohammad, Ashal, Abusaimeh, Ali, & Sharabati, (2025) explored the impact of adaptive learning technologies, personalized feedback, and interactive AI tools on students' engagement across 500 students across various faculties. It examines how these tools influence students' motivation and participation, and how digital literacy can either accelerate or impede their effectiveness. Results show that more adaptive technologies and interactive AI tools improve students' engagement, and students with higher digital literacy are more involved with these tools.

The research paper on AI-driven adaptive learning systems in Nigeria is limited due to a lack of focus on the country's educational context, implementation challenges, data privacy and security, algorithmic bias, scalability and sustainability, teacher support and training, and the impact on learning outcomes.

Purpose of the study

This paper explores the transformative potential of AI-driven adaptive learning systems in enhancing students' engagement in educational institutions. It specifically emphasizes students' achievement in science education, students' retention of science concepts, interactive learning experiences and students' engagement in science classes, providing insights into their reshaping of the educational landscape and paving the way for more effective and personalized learning experiences.

Objective of the study

1. What impact do AI-driven adaptive learning systems have on students' achievement in science education compared to traditional instructional methods?
2. What impact do AI-driven adaptive learning systems have on students' retention of science concepts?
3. How do AI-driven adaptive learning systems influence students' engagement in science classes?

Hypotheses

1. There is no significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.
2. AI-driven adaptive learning systems have no significant effect on students' retention of science concepts.
3. AI-driven adaptive learning systems have no significant effect on students' engagement in science classes.

Methodology

Research philosophy and design

This study's research philosophy is positivism, which assumes that reality is objective, measurable, and independent of the researcher's subjective interpretation. Following this research philosophy, an experimental research design was adopted. An Experimental research design is a systematic method for observing the effect of independent variables on dependent variables, aiming to establish a cause-and-effect relationship for testing hypotheses and validating theories. This paper explores the transformative potential of AI-driven adaptive learning systems in enhancing students' engagement in educational institutions. The researcher collected data about these variables from students at a specific point in time without manipulation.

Study participants

This study's population comprised 1610 secondary school students (names masked for security reasons). The eligibility criteria were that the respondent be a student in Nigeria. To this view, a verified and approved sampling technique must be used to select a sample size that can represent the group population. The Krejcie and Morgan (1970) recommendation for a population and the best sample size will be used. About this recommendation, the population of 1610 will have a sample size of 313. Thus, a sample size of 313 respondents was considered the minimum requirement. This sample involves two secondary schools in the Calabar South Local Government Area of Cross River State. In this study sample of 156 was selected from the first school (78 in the experimental group, while 78 in the control group), while the second school had 157 (79 in the experimental group, while 78 in the control group). A simple random sampling technique was used to select the participants for this study. Selection was based on the total number of schools in Calabar South available in the state to give each school an equal socioeconomic status represented in the same proportion as the population.

Instrument for data collection

Given the lack of instruments with robust psychometric properties relevant to the context of this study, we developed a new questionnaire and an achievement test entitled AI-driven adaptive learning systems and students' engagement Questionnaire (AALS-SEQ) and core science achievement test. The AALS-SEQ was meticulously designed to systematically collect data on students' engagement within the educational sector. The development of the AI-driven adaptive learning systems and students' engagement Questionnaire (AALS-SEQ) involved several critical steps to ensure its validity and reliability. First, an extensive literature review was conducted to understand existing research on students' classroom engagement, especially in science class, particularly within the African and Nigerian contexts. The AALS-SEQ was structured into four main sections. Section A captures the demographic characteristics of the respondents, including age, unique serial number, gender, class of study, class size, and science subject of best interest. Section B consists of 6 items designed to measure AI-driven adaptive learning systems on a modified four-point Likert scale (1 = not at all, 2 = rarely, 3 = sometimes, 4 = always). Section C consists of 6 items designed to measure student engagement and is organised on a modified four-point Likert scale (1 = not at all, 2 = rarely, 3 = sometimes, 4 = always).

Section D consists of 6 items designed to measure students' retention level of science concepts in terms of a modified four-point Likert scale (1 = not at all, 2 = rarely, 3 = sometimes, 4 = always). The Core Science achievement test consist of 30 items each from the three core science subjects for senior secondary school. That is 10 per subject, this is also an objective test item with options ranging from A-D. The response options were based on their degree of agreement with the statements made for each item.

Validity and Reliability

The questionnaire underwent an initial review conducted by a panel of three subject matter experts specializing in educational psychology and science education to ensure content validity. Their feedback was instrumental in refining the items, ensuring they were culturally appropriate and comprehensively covered the necessary dimensions. Subsequently, AI-driven adaptive learning systems and Students' Engagement Questionnaire (AALS-SEQ) and core science achievement test were pilot-tested with a sample of 100 students to evaluate the clarity, relevance, and reliability of the items. The aim was to identify any ambiguities, misunderstandings, or difficulties with the items. The feedback received from the trial test was used to refine and improve the questionnaire. Areas such as language clarity, item relevance, cultural appropriateness, comprehensive coverage, and item simplicity were addressed based on the feedback received. These iterative revisions ensured that the final version of the questionnaire was well-suited for the study's objectives and the target population. Subsequently, a panel of three psychometric experts scrutinized the final version of the questionnaire to evaluate its face validity. The internal consistency of Sections B to D and core science achievement test was assessed using Cronbach's alpha, which yielded a value of .77, and .82 respectively indicating high reliability.

Ethical considerations

The Nigerian Code of Health Research Ethics allowed for survey-based studies without ethical approval. Participants had the freedom to leave at any time, were informed about the study's goals, risks, and rewards, and there was no mental or bodily injury. No pressure or coercion was used, and all data was kept private, anonymized, and participant names were not disclosed.

Data collection and analysis procedures

The data collection for this study involved the physical administration of printed questionnaires. The data collection will be done in two phases. First,

a pre-test will be administered to all the selected sample. Then a treatment (instructions using AI-driven adaptive learning systems) will be given to 50% of the selected sample while the other where taught 50% (traditional method of instruction example like lecturing method). After two weeks the second administration of the instrument was done. The result of both administrations was compared using the unique serial number assigned to each student. The research team, accompanied by two research assistants, visited each school, where the specified number of questionnaire copies was distributed and subsequently collected upon completion. Responses were subjected to scoring on a scale ranging from 1 to 4, where a score of 1 denoted not at all and 4 indicated always for positively framed statements; negatively worded items were reverse-scored and for core science achievement test for every wrong answer is given 0 and for every right answer is given 1. The scored data underwent meticulous preparation to ensure completeness, accuracy, and consistency, devoid of missing data, outliers, or attrition. Descriptive statistics were computed to summarize the data, including the mean and standard deviation. In contrast, inferential statistics such as analysis of covariance analysis was utilized.

Results

Research Question one

What impact do AI-driven adaptive learning systems have on students' achievement in science education compared to traditional instructional methods? The experimental group (AI-driven adaptive learning systems) showed a significant impact on the students' achievement compared to the control group (traditional instructional methods). Specifically, the mean students' achievement in the experimental group increased by 0.63 in the experimental group, while the control group showed an increase of 1.09. These findings suggest that the AI-driven adaptive learning system was effective in improving students' achievement in students. The significant difference between the experimental and control groups indicates that the intervention had a positive impact on students' achievement. The 1.09 increase in students' achievement in the experimental group is significant, suggesting that the intervention may be a valuable tool for improving students' achievement in this population. These results support the growing body of evidence that AI-driven adaptive learning systems can be effective in improving students' achievement.

Research Question Two

What impact do AI-driven adaptive learning systems have on students' retention of science concepts? The experimental group (AI-driven adaptive learning systems) showed a significant impact on the students' retention of science concepts compared to the control group (traditional instructional methods). Specifically, the mean students' retention of science concepts in the experimental group increased by -0.13 in the experimental group, while the control group showed an increase of 0.76. These findings suggest that the AI-driven adaptive learning system was effective in improving students' retention of science concepts in students. The significant difference between the experimental and control groups indicates that the intervention had a positive impact on students' retention of science concepts. The 0.76 increase in students' retention of science concepts in the experimental group is significant, suggesting that the intervention may be a valuable tool for improving students' retention of science concepts in this population. These results support the growing body of evidence that AI-driven adaptive learning systems can be effective in improving students' retention of science concepts.

Research Question Three

How do AI-driven adaptive learning systems influence students' engagement in science classes? The experimental group (AI-driven adaptive learning systems) showed a significant impact on the students' engagement in science classes compared to the control group (traditional instructional methods). Specifically, the mean students' engagement in science classes in the experimental group increased by -0.01 in the experimental group, while the control group showed an increase of 0.43. These findings suggest that the AI-driven adaptive learning system was effective in improving students' engagement in science classes. The significant difference between the experimental and control groups indicates that the intervention had a positive impact on students' engagement in science classes. The 0.43 increase in students' engagement in science classes in the experimental group is significant, suggesting that the intervention may be a valuable tool for improving students' engagement in science classes in this population. These results support the growing body of evidence that AI-driven adaptive learning systems can be effective in improving students' engagement in science classes.

Table 1: Table showing the impact of AI-driven adaptive learning systems students' academic performance, retention of science concept and engagement in science classes

Variables	Groups	N	Mean	Std. Deviation
Academic performance (pretest)	Control	157	9.96	2.02
	Experimental	156	20.08	2.28
Academic performance (posttest)	Control	157	10.09	1.96
	Experimental	156	21.17	2.36
Retention (pretest)	Control	157	10.18	2.04
	Experimental	156	20.30	2.40
Retention (posttest)	Control	157	10.05	2.39
	Experimental	156	21.06	2.34
Engagement (pretest)	Control	157	9.90	2.32
	Experimental	156	19.76	2.30
Engagement (posttest)	Control	157	9.89	2.42
	Experimental	156	20.19	2.36

Hypotheses One

There is no significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.

The hypothesis was tested with analysis of covariance (ANCOVA). The results are shown in

Table 2. From the analysis in Table 2, the null hypothesis was rejected. Hence, AI-driven adaptive learning systems has a significant influence on the achievement score of science education in the study area. The result further revealed that there was a main effect of AI-driven adaptive learning systems ($F=371.228$, $p>.05$), on achievement scores of

science students in the study area. Based on these results, the null hypothesis states that there is no significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods at .000 was rejected. The result, therefore, indicated that there is significant effect on students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.

To determine the amount of effect on students' achievement in science education between

AI-driven adaptive learning systems and traditional instructional methods science students, a Fisher Least Squares Post-Hoc test was conducted, as observed in Table 3. It can be seen from Table 2 that those who were taught with AI-driven adaptive learning systems had more achievement scores than those who were taught with traditional instructional methods (mean difference = 8.677, $p < .05$). All the differences between the various groups were significant at .05 level of significance.

Table 2: Summary of ANCOVA for effect on students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	5535.716 ^a	2	2767.858	1085.757	.000
Intercept	1343.912	1	1343.912	527.181	.000
Groups	946.350	1	946.350	371.228	.000
Pre test	1.068	1	1.068	.419	.518
Error	790.265	310	2.549		
Total	9489.000	313			
Corrected Total	6325.981	312			

a. R Squared = .875 (Adjusted R Squared = .874)

Table 3: Fisher Least Post-Hoc Multiple comparison on for effect on student achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. ^b
Traditional teaching method	AI-driven adaptive learning systems	-8.677*	.450	.000
AI-driven adaptive learning systems	Traditional teaching method	8.677*	.450	.000

Hypothesis two

AI-driven adaptive learning systems have no significant effect on students' retention of science concepts.

The hypothesis was tested with analysis of covariance (ANCOVA). The results are shown in Table 4. From the analysis in Table 4, the null hypothesis was rejected. Hence, AI-driven adaptive learning systems has a significant effect on the students' retention of science concepts in the study area. The result further revealed that there was a main effect of AI-driven adaptive learning systems ($F=470.250$, $p>.05$), on students' retention of science concepts in the study area. Based on these results, the

null hypothesis states that there is no significant effect on students' retention of science concepts between AI-driven adaptive learning systems and traditional instructional methods at .000 was rejected. The result, therefore, indicated that AI-driven adaptive learning systems have a significant effect on students' retention of science concepts.

To determine the extent to which AI-driven adaptive learning systems effect on students' retention of science concepts. AI-driven adaptive learning systems and traditional instructional methods science students were used, and a Fisher Least Squares Post-Hoc test was conducted, as observed in Table 5. It can be seen from Table 5 that

those who were taught with AI-driven adaptive learning systems had more students' retention of science concepts than those who were taught with traditional instructional methods (mean difference =

9.729, $p < .05$). All the differences between the various groups were significant at the .05 level of significance.

Table 4: Summary of ANCOVA for the effect of AI-driven adaptive learning systems on student retention of science concepts.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	5792.001 ^a	2	2896.000	1138.368	.000
Intercept	1639.132	1	1639.132	644.315	.000
Groups	1196.312	1	1196.312	470.250	.000
Pre	19.583	1	19.583	7.698	.006
Error	788.638	310	2.544		
Total	95413.000	313			
Corrected Total	6580.639	312			

a. R Squared = .880 (Adjusted R Squared = .879)

Table 5: Fisher Least Post-Hoc Multiple comparison on effect of AI-driven adaptive learning systems on student retention of science concepts between AI-driven adaptive learning systems and traditional instructional methods.

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. ^b
Traditional teaching method	AI-driven adaptive learning systems	-9.729*	.449	.000
AI-driven adaptive learning systems	Traditional teaching method	9.729*	.449	.000

Hypothesis three

AI-driven adaptive learning systems have no significant effect on students' engagement in science classes

The hypothesis was tested with analysis of covariance (ANCOVA). The results are shown in Table 6. From the analysis in Table 6, the null hypothesis was rejected. Hence, AI-driven adaptive learning systems has a significant effect on the students' engagement in science classes in the study area. The result further revealed that there was a main effect of AI-driven adaptive learning systems ($F=405.781$, $p>.05$), on students' engagement in science classes in the study area. Based on these results, the null hypothesis states that there is no significant effect on students' engagement in science classes between AI-driven adaptive learning systems and traditional instructional methods at .000 was

rejected. The result, therefore, indicated that AI-driven adaptive learning systems have a significant effect on students' engagement in science classes.

To determine the extent to which AI-driven adaptive learning systems effect on students' engagement in science classes. AI-driven adaptive learning systems and traditional instructional methods science students were used, and a Fisher Least Squares Post-Hoc test was conducted, as observed in Table 7. It can be seen from Table 7 that those who were taught with AI-driven adaptive learning systems had more students' engagement in science classes than those who were taught with traditional instructional methods (mean difference = 8.297, $p < .05$). All the differences between the various groups were significant at the .05 level of significance.

Table 6: Summary of ANCOVA for the effect of AI-driven adaptive learning systems, which has no significant effect on students' engagement in science classes

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	6093.755 ^a	2	3046.877	1469.151	.000
Intercept	1033.886	1	1033.886	498.522	.000
Groups	841.550	1	841.550	405.781	.000
Students engagement	3.994	1	3.994	1.926	.004
Error	642.910	310	2.074		
Total	90849.000	313			
Corrected Total	6736.665	312			

a. R Squared = .905 (Adjusted R Squared = .904)

Table 7: Fisher Least Post-Hoc Multiple comparison on the effect of AI-driven adaptive learning systems has no significant effect on students' engagement in science classes

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig. ^b
Traditional teaching method	AI-driven adaptive learning systems	-8.297*	.412	.000
AI-driven adaptive learning systems	Traditional teaching method	8.297*	.412	.000

Summary of result findings

1. The result showed a significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods.
2. The result showed that AI-driven adaptive learning systems have a significant effect on students' retention of science concepts.
3. The result showed that AI-driven adaptive learning systems have a significant effect on students' engagement in science classes

Discussion of Findings

There is no significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods. The result showed a significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods. The findings agree with the findings of Ayobami et al. (2024), who found that AI-powered adaptive learning tools improve educational outcomes and engagement for learners with disabilities. They found that personalized interventions enhance accessibility, cognitive development, and learning outcomes. Kunade (2024) studied the impact of AI on scientific education in Nigerian secondary schools, focusing on Adaptive Learning Systems (ALS), Intelligent Tutoring

Systems (ITS), and Virtual Laboratories and Simulations. However, challenges such as infrastructural limitations, teacher preparation, and ethical considerations were identified. Vieriu & Petrea (2025) aimed to enhance learning outcomes for secondary school students, highlighting the benefits of AI in improving academic performance. The study found that AI offers personalized learning, improved academic outcomes, and enhanced students' engagement. However, challenges like over-reliance, diminished critical thinking skills, data privacy risks, and academic dishonesty were identified. Wadim et al. (2024) analyzed 3518 publications on adaptive learning and AI from 1990 to 2024, highlighting the significant impact of recent technological changes, particularly the digital surge triggered by the COVID-19 pandemic. These results appear to be significant because it AI helped to improve students' engagement. This is because AI adaptive learning system is necessary to help improve learning outcomes.

AI-driven adaptive learning systems have no significant effect on students' retention of science concepts. The result showed that AI-driven adaptive learning systems have a significant effect on students' retention of science concepts. The findings agree with the findings of the study by Gligorea, Cioca, Oancea, Gorski, Gorski, & Tudorache (2023) and Wang, Huang, Sommer, Pei, Shidfar, Rehman, Ritzhaupt, &

Martin (2024) that found that the integration of artificial intelligence and machine learning in e-learning enhances learning experiences, optimizes learning paths, improves academic performance, and increases test scores. A meta-analysis by Wadim, Veronika, Alexander, Guzalbegim, & Tatiana (2025) also highlighted the impact of adaptive learning technologies and AI on education, highlighting their ability to make education personalized, accessible, and efficient. The study analyzed 3518 publications from 1990 to 2024, revealing that recent technological changes, particularly the COVID-19 pandemic, have significantly influenced this transformation. AI is a more practical means of learning, especially science concepts; therefore, an AI learning system assist the experimental group to understand the concept very well.

AI-driven adaptive learning systems have no significant effect on students' engagement in science classes. The result showed that AI-driven adaptive learning systems have a significant effect on students' engagement in science classes. The findings agree with the findings of Edidiong, Mfon, & Ikanaobong (2024) that studied the impact of AI-driven adaptive learning systems on students' engagement and skill acquisition in Nigerian TVET institutions. Traditional approaches often fail to cater to diverse learning needs, leading to high dropout rates and inadequate skill development. Successful integration faces barriers like insufficient infrastructure, limited funding, and resistance to change. Jozsef, & Klara (2025) found significant improvements in learning results and motivation in flipped classrooms for programming education, highlighting the importance of AI integration in modernizing programming education. Yaseen, Mohammad, Ashal, Abusaimah, Ali, & Sharabati (2025) explored the impact of adaptive learning technologies, personalized feedback, and interactive AI tools on students' engagement across 500 students, finding that more adaptive technologies and interactive AI tools improve students' engagement. This result is like this because the AI adaptive system assisted the experimental group to be more engaged, this is because AI itself is self-engaging platform.

Conclusion

The findings above lead to the following conclusion which were made thus: The result showed that there is a significant effect of students' achievement in science education between AI-driven adaptive learning systems and traditional instructional methods. Also, AI-driven adaptive learning systems have a significant effect on students' retention of science concepts. In the same vain AI-

driven adaptive learning systems have a significant effect on students' engagement in science classes. This is to say that the more teachers use AI the more improve the achievement performance, retention, engagement and overall academic achievement. This can be achieved by teachers including the use of AI into the teaching process, especially in science subjects.

Recommendation

It was recommended that government, teachers and school administrators create nationwide awareness campaigns and increasing parents' knowledge via national and social media platforms the importance of teaching with AI assistant no matter what the subject is, this is to forester students effective learning, retention, engagement and over roll academic achievement.

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