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IMPACT OF ADAPTIVE LEARNING ON SENIOR SECONDARY TWO CHEMISTRY STUDENTS' ACHIEVEMENTS AND RETENTION IN JOS EAST LOCAL GOVERNMENT AREA OF PLATEAU STATE, NIGERIA

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ABSTRACT

This study investigated the Impact of Adaptive Learning on Senior Secondary II Chemistry Students' Achievement and Retention in Jos East Local Government Area of Plateau State, Nigeria. The study used Lev Vygotsky's Constructivist Theory (1978) as theoretical framework. The study was guided by four specific objectives. Corresponding research questions and hypotheses were formulated to address these objectives. The study used quasi-experimental research design. The total population of the study comprised 1,200 SS2 Chemistry students drawn from 15 public secondary schools in Jos East. A sample size of 120 students was purposively selected from two comparable public schools—Experimental School, which received the adaptive learning intervention, and Control School, which continued with the lecture method. Pre-test, post-test, and retention test instruments were used to collect quantitative data on student performance. The mean score was used to answer the research questions while the ANCOVA was employed to test the hypotheses. The findings revealed that students taught using adaptive learning strategies significantly outperformed those taught using the traditional lecture method in both academic achievement and knowledge retention. Furthermore, no significant gender differences were observed in the achievement scores of students exposed to adaptive learning, indicating its effectiveness across both male and female students. Also, the study found meaningful differences in performance between the two schools, highlighting the role of instructional methods in shaping learning outcomes. In conclusion, this study provides evidence for the integration of adaptive learning techniques into the secondary school chemistry curriculum. It recommends policy support for digital learning innovations and teacher training to enhance adaptive instructional delivery.

Keywords: Adaptive Learning, Chemistry, Achievement, Retention.

Introduction

Chemistry occupies a central position among science subjects in the secondary school curriculum due to its pivotal role in technological and scientific advancement. It serves as a foundational discipline for students aspiring to pursue careers in various science-based fields such as medicine, pharmacy, agriculture, environmental science, and engineering. Beyond vocational relevance, chemistry equips learners with essential scientific knowledge about the composition, properties, and transformation of matter, which enhances their understanding of the natural world. The study of chemistry also fosters important intellectual abilities such as logical reasoning, analytical thinking, and effective problem-solving skills, which are valuable not only in academics but also in everyday life and national development. however, students' performance in chemistry at the secondary level has remained consistently poor, as revealed by statistical data from public examinations like the West African Senior School Certificate Examination (WASSCE) and the National Examination Council (NECO). This persistent underachievement calls attention to systemic issues in the teaching and learning of chemistry, including factors such as inadequate laboratory resources, teacher competence, and the general perception of the subject as being difficult and abstract (WAEC, 2020; NECO, 2019).

Students' academic achievement in chemistry is significantly shaped by their level of interest and intrinsic motivation toward the subject. Interest serves as a crucial psychological driver that influences how students approach learning—affecting their attitude, engagement in classroom activities, and overall commitment to academic tasks. When students are genuinely interested in chemistry, they are more likely to participate actively in lessons, ask questions, conduct experiments, and seek deeper understanding beyond what is taught. This engagement typically translates into better academic outcomes. However, the reality in many secondary schools reveals a contrary trend, as chemistry is often perceived by students as abstract, complex, and difficult to comprehend.

Gender Differences in Chemistry Achievement and retention gender has long been studied as a factor influencing academic achievement and interest in science subjects, including chemistry. Some research indicates that male students outperform their female counterparts in sciences, often showing more confidence and curiosity. However, other findings argue that this difference is not rooted in ability but rather in societal expectations, gender stereotypes, and unequal learning opportunities. Cultural beliefs that portray science as a male-dominated field often discourage girls from fully participating or developing interest in subjects like chemistry. Additionally, the lack of female role models in science-related fields can limit girls' motivation and self-belief in their scientific abilities (Jegede & Adebayo, 2019; Okeke, 2018; Eze, 2019).

The location of a school—urban or rural—plays a significant role in determining the quality of education students receive and their resulting academic performance. Urban schools tend to have more qualified teachers, better facilities, functional laboratories, and access to educational resources. These advantages foster better learning experiences and can enhance both student achievement and retention in chemistry. Conversely, rural schools often suffer from a lack of infrastructure, insufficient instructional materials, and a shortage of qualified science teachers. Such conditions hinder effective teaching and learning and may contribute to

the disinterest and poor academic performance observed among rural students in chemistry (Owoeye & Yara, 2019; Afolabi, 2019; Adepoju & Fabiyi, 2017).

The senior secondary level is a critical stage in the Nigerian educational system, as it prepares students for higher education and professional careers. However, many students struggle with chemistry at this level, often due to the abstract nature of the subject and the lack of effective teaching strategies (Adeyemi, 2018).

Statement of the Problem

Despite the critical role of chemistry in fostering scientific literacy and technological advancement, students in Nigeria, particularly in Jos East Local Government Area of Plateau State, continue to perform poorly in the subject, as evidenced by consistently low achievement and retention rates Traditional teaching methods, which dominate Nigerian classrooms, often fail to address the diverse learning needs of students, leading to disengagement and a lack of conceptual understanding (Adebayo, 2022; Eze & Ezeudu, 2021). The failure to adopt adaptive learning in the teaching of Chemistry in Jos East LGA of Plateau State have significant implications for students' achievement and retention. Without adaptive learning, students may struggle with a one-size-fits-all approach that doesn't cater for students individual leering needs, potentially hindering their understanding of complex Chemistry concepts. This lack of personalized learning could result in lower academic achievement as students who might require additional support or a different learning pace may not receive it. Without the use of adaptive learning strategies that reinforce concept through tailored feedback and activities, students may have difficulty retaining information long-term, leading to poor retention of critical chemistry knowledge. Consequently, this could impact not only their achievement and retention in exams but also their ability to apply chemistry concept in real-life situations or further education.

Ultimately, not using adaptive learning may perpetuate educational inequalities, where only students who already excel in traditional learning settings benefit from the standard approach, while other continue to fall behind. This study, therefore, seeks to address this gap by investigating the impact of adaptive learning on the achievement and retention of Senior Secondary II (SS2) chemistry students in Jos East, with the aim of providing evidence-based insights into how this innovative approach can be leveraged to improve chemistry education in Nigeria.

Aim and Objectives of the Study

The aim of this study is to investigate the impact of adaptive learning on the achievement and retention of Senior Secondary Il (SS2) chemistry students in Jos East Local Government Area, Plateau State, Nigeria. The specific objectives of the study are:

1. Determine the achievement level of SS2 Chemistry students in Jos East before the treatment.
2. Assess the influence of adaptive learning on the retention of Chemistry concepts among SS2 Chemistry students in Jos East.
3. Investigate the influence of gender on adaptive learning on the achievement male and female SS2 Chemistry students in Jos East.

4. Find the interactive effect of adaptive learning on the retention of male and female Chemistry knowledge between students in School A (adaptive learning) and School B (traditional method), both located in Jos East.

Research Questions

Based on the objectives of this study, the following research questions will be addressed:

1. What is the effect of adaptive learning on the academic achievement of SS2 Chemistry students in Jos East?
2. How does adaptive learning influence the retention of Chemistry concepts among SS2 Chemistry students in Jos East?
3. How does gender influence adaptive learning on the achievement of male and female SS2 Chemistry students in Jos East?
4. What is the difference in retention of male and female Chemistry knowledge between students in School A and School B in Jos East?

Hypotheses

Based on the objectives and research questions, the following hypotheses are formulated for this study:

1. There is no significant difference between the mean achievement scores of students taught using adaptive learning and those taught using the lecture method in Jos East.
2. There is no significant difference between the mean retention scores of students taught using adaptive learning and those taught using the lecture method in Jos East.
3. There is no significant difference between the mean achievement scores of male and female students taught using adaptive learning in Jos East.
4. There is no significant difference in the retention of male and female Chemistry knowledge between students in Experimental and Control School in Jos East.

Theoretical Framework

This study is anchored on Constructivism Theory by Vygotsky (1978) and Piaget (1954), which emphasizes that learners actively construct knowledge through interaction with their environment rather than passively receiving information. The theory highlights that learning is an active, subjective, and context-dependent process shaped by prior knowledge, experiences, and social-cultural factors. In line with this, adaptive learning environments support student-centered approaches by allowing learners to progress at their own pace, explore concepts, and receive personalized feedback. Such approaches enhance engagement, motivation, achievement, and retention, making constructivism a suitable framework for understanding how adaptive learning can positively impact secondary school students' performance in chemistry.

Methodology

This study employed a quasi-experimental research design to investigate the impact of adaptive learning on the achievement and retention of SS2 chemistry students in Jos East Local Government Area, Plateau State, Nigeria. The population comprised 1,200 SS2 chemistry students across 15 public schools, from which a sample of 120 students was selected using the Taro Yamane formula. Two schools were purposively chosen, with intact classes randomly assigned to experimental (adaptive learning) and control (traditional teaching) groups. Data

collection instruments included a researcher-developed Chemistry Achievement Test (CAT) and Retention Test (RT), both validated by experts and pilot-tested for reliability using test-retest methods and Cronbach's alpha. Research assistants were trained to ensure consistency, while ethical considerations such as confidentiality and informed consent were upheld. Both groups took pre-tests, followed by a four-week instructional intervention—adaptive learning through Khan Academy and ChemCollective for the experimental group, and conventional teaching for the control group—after which post-tests and retention tests were administered. Scoring involved awarding points for correct and partially correct responses to capture both achievement and retention levels. Data analysis used mean and standard deviation to answer research questions and Analysis of Covariance (ANCOVA) to test hypotheses regarding differences in achievement and retention across instructional methods, gender, and school type. This methodology ensured rigorous, valid, and reliable findings on the effect of adaptive learning in chemistry education.

Result and Discussion

Results

Research Question 1: What is the effect of adaptive learning on the academic achievement of SS2 Chemistry students in Jos East?

Table 1: Mean Achievement Scores of SS2 Chemistry Students in Experimental and Control Group

Group	N	Pre-Test Mean	SD	Post-Test Mean	SD	Mean Gain
Experimental	62	46.63	9.73	76.68	8.89	30.05
Control	58	47.43	9.17	61.71	9.27	14.28

Source: Field Research, 2025

Table 1 displays the mean scores of SS2 Chemistry students in both the experimental group and the control group before and after the treatment phase of the study. The experimental group ,taught using the adaptive learning approach, had a pre-test mean score of 46.63 (SD = 9.73) and a post-test mean score of 76.68 (SD = 8.89), resulting in a mean gain of 30.05 points. In contrast, the control group, taught using the conventional lecture method, recorded a pre-test mean score of 47.43 (SD = 9.17) and a post-test mean score of 61.71 (SD = 9.27), with a mean gain of 14.28 points. These results suggest that while both groups showed improvement in their academic achievement after instruction, the students in the adaptive learning group (experimental) demonstrated significantly higher gains compared to those in the lecture method group.

Research Question 2: How does adaptive learning influence the retention of Chemistry concepts among SS2 Chemistry students in Jos East?

Table 2: Mean Retention Scores of SS2 Chemistry Students in Experimental and Control Groups

Group	N	Pre Test Mean	SD	Retention Test Mean	SD
Experimental	62	46.63	9.74	72.10	6.90
Control	58	47.43	9.17	57.07	9.27

Source: Field Research, 2025

Table 2 presents the mean scores of students in both the experimental and control groups in the pre-test and retention test conducted two weeks after the treatment. The experimental group, which was exposed to adaptive learning strategies, had a pre-test mean score of 46.63 (SD = 9.74) and a retention mean score of 72.10 (SD = 6.90). On the other hand, the control group, which received instruction through the lecture method, recorded a pre-test mean of 47.43 (SD = 9.17) and a retention mean of 57.07 (SD = 9.27).

Research Question 3: How does gender influence adaptive learning on the achievement of male and female SS2 Chemistry students in Jos East.

Table 3: Mean Achievement Scores of Male and Female Students in the Experimental Group (Adaptive Learning)

Group	N	Pre-Test Mean	SD	Post-Test Mean	SD	Mean Gain
Male	38	46.14	9.23	76.81	8.93	30.67
Female	24	47.36	10.58	76.48	9.01	29.12

Source: Field Research, 2025

Table 3 shows the achievement scores of male and female students within the experimental group who were taught using the adaptive learning method. Male students had a pre-test mean of 46.14 (SD = 9.23) and a post-test mean of 76.81 (SD = 8.93), resulting in a mean gain of 30.67 points. Female students started with a pre-test mean of 47.36 (10.58) and improved to a post-test mean of 76.48 (SD = 9.01), yielding a mean gain of 29.12 points. Although both genders benefited significantly from the adaptive learning approach, male students recorded a slightly higher mean gain than their female counterparts. This suggests that while adaptive learning positively impacted both male and female students' academic achievement, male students in this study experienced marginally greater improvement. However, the difference is not substantial and may not be statistically significant without further inferential analysis.

Research Question 4: What is the difference in retention of male and female Chemistry knowledge between students in School A and School B in Jos East?

Table 4: Mean Retention Scores of Male and Female Students in Experimental and Control School

Group	Gender	N	Post-Test Mean	SD	Retention-Test Mean	SD	Difference Between Achievement & Retention	Percentage
Experimental	Male	38	76.81	8.93	72.16	7.44	4.65	93.95
	Female	24	76.48	9.01	72.00	6.16	4.48	94.14
Control	Male	32	62.24	8.46	57.12	10.36	5.12	91.77
	Female	26	61.00	10.00	57.00	7.81	4.00	93.44

Source: Field Research, 2025

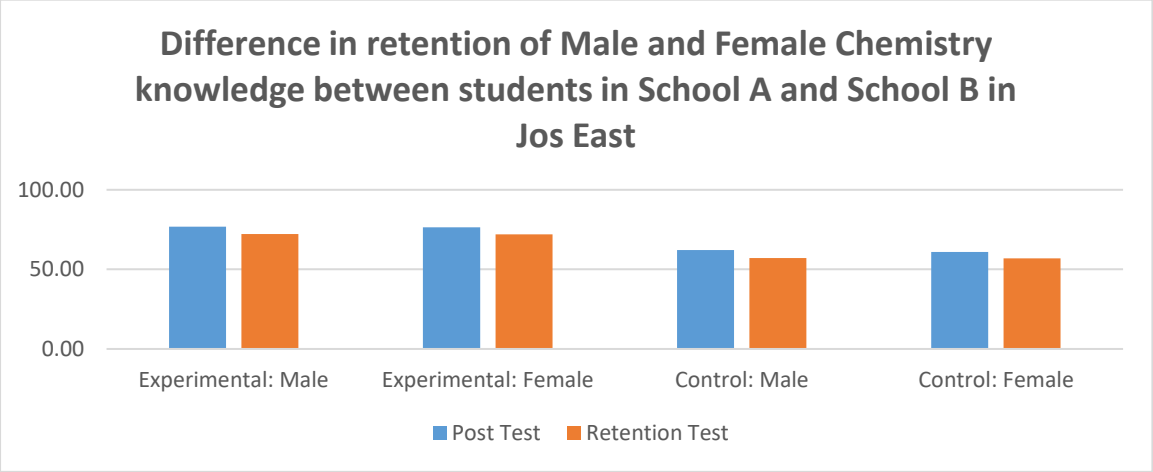

Table 6 compares the academic retention performance of male and female students in Experimental and Control group. In Experimental School where students were taught using adaptive learning techniques, male recorded a post-test mean of 76.81 (SD = 8.93) and a retention mean of 72.16 (SD 7.44), with a minimal difference of 4.65 points between the two tests representing 93.95% retention while female recorded a post-test mean of 76.48 (SD = 9.01) and a retention mean of 72.00 (SD 6.16), with a minimal difference of 4.48 points between the two tests representing 94.14% retention. Conversely, Control group which employed the traditional lecture method, male showed a post-test mean of 62.24 (SD = 10.00) and a retention mean of 57.00 (SD = 7.81), with a wider gap of 5.12 points but with a lesser retention of 91.77% while female showed a post-test mean of 61.00 (SD = 10) and a retention mean of 57.00 (SD = 7.81), with 4.64 points representing a retention of 93.4%.

These results reveal that students in the adaptive learning group (experimental) not only performed better initially in the achievement test but also retained the Chemistry knowledge more effectively over time. The significantly smaller drop in scores for Experimental groups suggests stronger long-term comprehension and retention fostered by adaptive strategies. In

contrast, the control group experienced a steeper decline, indicating that lecture-based instruction may be less effective in sustaining students' understanding of Chemistry concepts. This comparison underscores the potential advantage of adaptive learning in enhancing both immediate academic performance and long-term retention in Chemistry among senior secondary students.

Testing of Hypotheses

Hypothesis 1: There is no significant difference between the mean achievement scores of students taught using adaptive learning and those taught using the lecture method in Jos East.

Table 5: ANCOVA of Mean Achievement Scores

Source of Variance	Sum of Squares (SS)	df	Mean Square (MS)	F	P
Pretest	3121.36	1	3121.36	141.52	0
School	1826.54	1	1826.54	82.76	0
Error	2579.52	117	22.05		
Total	7527.42	119			

Significant at $p < 0.05$

Source: Field Research, 2025

Adjusted Mean Achievement Scores:

Experimental Group: 76.69

Control Group: 61.69

Table 5 shows the comprehensive ANCOVA table for achievement scores (Posttest) which confirms a statistically significant effect of the "School" variable, after controlling for students' initial Pretest scores. The F-statistic of 82.76, with a p-value of less than 0.001, provides strong evidence to reject the null hypothesis. The adjusted mean scores show that students in the Experimental School performed significantly better than those in the Control School.

Hypothesis 2: There is no significant difference between the mean retention scores of students taught using adaptive learning and those taught using the lecture method in Jos East.

Table 6: ANCOVA of Mean Retention Scores

Source of Variance	Sum of Squares (SS)	df	Mean Square (MS)	F	p
Pretest	29.07	1	29.07	0.95	0.33
School	3092.44	1	3092.44	101.11	0
Error	3580.6	117	30.6		
Total	6702.11	119			

*Significant at $p < 0.05$

Source: Field Research, 2025

Adjusted Mean Achievement Scores:

Experimental Group: 72.09

Control Group: 57.08

In Table 6, the comprehensive ANCOVA table for retention scores demonstrates a statistically significant difference between the two schools. The F-statistic of 101.11, with a p-value of less than 0.001, leads to the rejection of the null hypothesis. The adjusted mean scores show that the adaptive learning method (Experimental group) resulted in significantly better retention of knowledge than the lecture method (Control School).

Hypothesis 3: There is no significant difference between the mean achievement scores of male and female students taught using adaptive learning in Jos East.

Table 7: ANCOVA of Mean Achievement Scores of Male and Female Students (Experimental School)

Source of Variance	Sum of Squares (SS)	df	Mean Square (MS)	F	p
Pretest	0.41	1	0.41	0	0.94
Gender	1.53	1	1.53	0.02	0.89
Error	4815.51	59	81.62		
Total	4817.44	61			

*Significant at p > 0.05

Adjusted Mean Achievement Scores:

Male: 76.81

Female: 76.49

Table 7 shows the ANCOVA which shows that there is no statistically significant difference in the achievement scores between male and female students in the Experimental School after controlling for their pretest scores ($F(1,59) = 0.02, p=0.89$). The p-value of 0.89 is much larger than the significance level of 0.05, which means the observed small difference in adjusted means (76.81 for males vs. 76.49 for females) is likely due to chance. Therefore, the null hypothesis is accepted.

Hypothesis 4: There is no significant difference in the retention of male and female Chemistry knowledge between students in Experimental and Control group in Jos East.

Table 8: ANCOVA of Mean Retention Score by School and Gender

Source of Variance	Sum of Squares (SS)	df	Mean Square (MS)	F	p
Pretest	340	1	3.40	0.05	0.82
School	6732.14	1	6732.14	99.24	0.00
Gener	0.73	1	0.73	0.01	0.92
School: Gender	0.01	1	0.01	0.00	0.99
Error	7801.14	115	67.84		
Total	14547.68	119			

*Significant at p < 0.05

Adjusted Mean Achievement Scores:

Experimental Group (Male): 72.15

Experimental Group (Female): 72.01

Control Group (Male): 57.15
Control Group (Female): 56.98

Table 8 presents the ANCOVA results. For the Main Effect of School, the table showed that there is a highly significant difference in retention scores between the Experimental and Control groups after controlling for pretest scores ($F(1, 115) = 99.244$, $p < 0.005$. The adjusted mean retention score for the Experimental group is significantly higher than for the control school, leading to the rejection of this part of the null hypothesis. For the Main Effect of Gender, the table showed that there is no significant difference in the retention score between male and female students after controlling for pretest score ($F(1,115) = 0.01$, $p = 0.92$). The p-value of 0.92 is well above the significance level of 0.05, indicating that gender does not have a significant main effect on retention. For the interaction Effect (School x Gender), the interaction between school and gender is not statistically significant ($F(1,115) = 0.00$, $p = 0.99$). This means that the effect of the learning method (adaptive vs traditional) on retention is consistent for both male and female students. The adaptive learning method benefits both genders similarly in terms of long-term knowledge retention. Therefore, the null hypothesis is partially rejected while there is a significant difference in retention scores between the groups, there is no significant difference between the genders. The benefit of the adaptive learning method on retention is not influenced by gender.

Discussion

The results of this research on the impact of adaptive learning on Senior Secondary Two (SS2) Chemistry students' achievements and retention in Jos East Local Government Area, Plateau State, Nigeria, reveal insightful findings regarding the effectiveness of adaptive learning compared to traditional lecture methods.

The findings from Research Question 1 revealed that adaptive learning significantly improved the academic achievement of SS2 Chemistry students in Jos East compared to the conventional lecture method. Students in the experimental group recorded a mean gain of 30.05 points, which was more than double the mean gain (14.28 points) of their counterparts in the control group. This implies that adaptive learning strategies enhance active participation, individualized instruction, and deeper understanding of Chemistry concepts, leading to better performance. These results are consistent with the findings of Okoye (2019), who reported that students exposed to adaptive learning approaches in science subjects performed significantly better than those taught using traditional lecture methods, as the flexibility of adaptive learning catered to diverse learners' needs and learning paces.

Regarding Research Question 2, the results demonstrated that adaptive learning had a notable effect on retention of Chemistry concepts. Students in the experimental group retained more knowledge (mean = 72.10) compared to the control group (mean = 57.07), two weeks after instruction. This finding suggests that adaptive learning not only promotes short-term academic achievement but also sustains long-term comprehension and retention. The ability of adaptive learning to personalize instruction, offer practice opportunities, and reinforce concepts likely contributed to this superior retention rate. This outcome aligns with the findings of Azevedo (2015), who emphasized that adaptive learning systems enhance knowledge retention because they allow for repeated exposure and tailored reinforcement, which improve cognitive recall over time.

In addressing Research Question 3, results indicated that both male and female students benefited significantly from adaptive learning, with males recording a slightly higher

mean gain (30.67) than females (29.12). Although the difference is marginal, the data suggest that adaptive learning supports academic achievement regardless of gender, making it an equitable teaching strategy. This result corroborates the study by Yusuf and Afolabi (2010), who found that technology-enhanced adaptive learning environments improved student achievement without significant gender disparity, as the approach minimized traditional barriers associated with gender stereotypes in science learning. Thus, adaptive learning appears to promote inclusivity and equal opportunity in Chemistry education.

Finally, with regard to Research Question 4, the findings showed that students in the experimental group retained Chemistry knowledge more effectively than those in the control group, irrespective of gender. Male and female students in the adaptive learning group retained over 93% of their post-test scores, while those in the lecture method group retained slightly lower percentages. This indicates that adaptive learning supports sustained understanding across both genders and different school settings. The results reinforce the conclusion that adaptive learning enhances not only immediate performance but also long-term retention. This finding is in agreement with Nwosu (2017), who reported that adaptive learning strategies promote deeper conceptual understanding, leading to higher levels of retention among secondary school science students compared to conventional teaching methods.

Conclusion

The study concludes that adaptive learning has a significant positive impact on the academic achievement and retention of Chemistry concepts among SS2 students in Jos East. The findings provide strong evidence that adaptive learning method are more effective than traditional lecture methods in fostering better student outcomes, both in terms of immediate academic achievement and long-term retention of subject matter. Moreover, the study emphasizes that adaptive learning is a gender-neutral approach, benefiting both male and female students equally. The effectiveness of adaptive learning was evident regardless of the students' gender, making it an inclusive educational strategy. Additionally, the comparison between the two groups demonstrated the value of adopting modern educational technologies and methods to enhance learning outcomes. This research affirms the potential of adaptive learning in enhancing educational quality, particularly in science subjects like Chemistry. The findings suggest that adopting such techniques in classrooms could significantly improve student learning outcomes across various academic settings.

Recommendations

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

1. Schools and educational authorities in Jos East Local Government Area should consider integrating adaptive learning technologies into their Chemistry curriculum. The significant improvements in student achievement and retention observed in the study highlight the potential benefits of this approach, Schools should invest in adaptive learning and resources to enhance the learning experience of their students.
2. Teachers should be trained in the use of adaptive learning platforms to effectively implement them in the classroom. Professional development programs should focus on how to integrate adaptive learning into Chemistry teaching methods and how to use technology to monitor student progress and tailor instruction to individual needs.

3. While this study found no significant difference in the effectiveness of adaptive learning between male and female students, it would be beneficial for future research to explore other demographic variables, such as socio-economic status and cultural background, to determine if these factors influence the impact of adaptive learning on students' academic outcomes.
4. Policy makers should support the integration of adaptive learning technologies into public schools by providing adequate funding and resources. This support is essential for ensuring that schools, especially in rural and underserved areas, can access the necessary tools to implement adaptive learning effectively.

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