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Effect of Artificial Intelligence Enhanced Learning on Secondary School Students' Achievement in Chemistry

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Abstract*—This experimental study investigated the effects of Artificial Intelligence (AI)–enhanced learning outcomes on senior secondary school students' achievement in chemistry , in Ila-Orangun Local Government Area of Osun State. The researchers adopted a quasi-experimental design. The population of the study was Senior Secondary School class 1 (SSS1) students. A sample of 40 students was selected from two schools. 20 students were randomly selected from each school to form one experimental group and a control group. The experimental group received AI-enhanced learning instruction, and the control group received traditional instruction. The instrument used in data collection was titled Chemistry Achievement Test (CAT). The reliability coefficient was determined by the split-half method to establish the internal consistency of the instrument, and a 0.78 coefficient was obtained. Null hypotheses were formulated and tested at 0.05 level of significance to guide the study. Statistical tools such as mean, standard deviation, and Analysis of Covariance (ANCOVA) at 0.05 level of significance were used for data analysis. The result revealed that students in the experimental group had a significantly higher difference in the mean achievement scores in chemistry compared to those in the control group. The findings suggest that AI-enhanced learning can be an effective approach to improving students' understanding and achievement in chemistry. It was then recommended, among others, that teachers should include artificial intelligence in teaching methodology content and make provision to train both teachers and students in the use of artificial intelligence in teaching and learning.

Keywords*— Artificial intelligence, Enhanced, Learning, Achievement

I. INTRODUCTION

Chemistry education plays a crucial role in shaping students' scientific understanding in Nigeria. Traditional pedagogical approaches often fail to engage students, leading to disinterest and difficulty in grasping essential topics in chemistry. This disconnect between students and the subject matter has significant implications for their overall academic performance and their future careers in science fields. Nzenwi (2023) posited that scientific knowledge in high schools often lacks coherence, resulting in students relying heavily on rote memorization without truly understanding the subject matter. This lack of quality learning experiences hinders students' progress, resulting in poor performance and disinterest in learning chemistry. Students memorize formulas and definitions without comprehending their applications, which prevents them from developing critical thinking skills and a genuine interest in the subject. Considering these findings, there is a growing need for innovative solutions, such as the integration of Artificial Intelligence (AI) technologies, to enhance teaching and learning outcomes in Nigeria's education system, especially in secondary schools.

In a 2024 webinar hosted by Pearson, Joel Caughran and Chris Hess from the University of Georgia highlighted the benefits of AI in chemistry education, noting its role in demystifying complex chemical concepts and improving academic performance. They discussed how AI can provide good learning experiences, adapting to the needs of individual students and making difficult concepts more accessible. The 2024 AI+ Educational Summit on advancing human learning with artificial intelligence technologies emphasized the importance of integrating AI in academia, particularly in chemistry education. Educators are encouraged to familiarize themselves with AI applications and integrate them into their teaching strategies to significantly enhance student understanding and performance. Smith (2024) demonstrated that AI algorithms in writing lesson materials deliver content tailored to individual learning patterns, improving students' learning experiences and boosting their performance. According to Rosell and Norvig (2016), AI mirrors human cognition but operates within machines, particularly computers. It encompasses areas such as machine learning (ML), which enables computers to learn from data, and natural language processing,

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which aids them in comprehending and generating human speech.

Amanda Bickerstaff, co-founder and CEO of Artificial Intelligence for Education (2024) explained that Generative AI tools like ChatGPT could significantly impact teaching. A group of 931 educators from various tertiary institutions has completed a comprehensive 13-week AI training program, supported by the Tertiary Education Trust Fund (TETFund), to equip these educators on how to integrate AI tools into teaching and research for a transformative impact on education standards and practices. This study aims to confirm the transformative ability on the 'Effect of AI-enhanced learning on secondary school students' achievement in chemistry', in contrast to traditional methods.

II. STATEMENT OF THE PROBLEM

In an ideal educational setting, secondary school students would develop a high level of interest in chemistry, coupled with appropriate technological and computational knowledge. This foundation would not only prepare them for examinations but also enable them to have a vivid understanding of complex concepts in chemistry. However, the current reality diverges from this ideal. According to Joint Admissions and Matriculation Board (JAMB) Registrar, Prof. Ishaq Oloyede, over 1.9 million secondary school students from 36 states and the Federal Capital Territory took the Unified Tertiary Matriculation Examination. Only a small fraction of students achieved high scores, with 18,401 scoring 300 and above, 77,070 scoring 250 and above, and 439,974 scoring 200 and above. Alarmingly, 1,402,490 students fell short of the ideal benchmark of 200 out of 400. This raises important questions about the effectiveness of current teaching methodologies and materials. These statistics highlight a pressing need to reassess and innovate the educational approaches employed in Nigerian secondary schools.

Traditional pedagogical approaches, characterized by conventional instruction and rote memorization, fail to effectively engage students in chemistry. While literature has addressed enhanced learning through various models, it often overlooks the concerns surrounding AI. This oversight has significant consequences. Students struggle to grasp certain chemistry concepts, leading to a shortage of proficient chemistry professionals. Amanda Bickerstaff, CEO of Artificial Intelligence for Education (2024), explains, "Schools have not been better for a long time, and embracing AI can help solve the problem." Furthermore, individuals who neglect to learn about AI and its workings may risk being displaced by people who can better utilize them to delegate tasks and simplify concepts suitable to student's needs, as explained by Professor Karim Lakhani, of Harvard Business School (2023). This study aims to examine the effectiveness of AI-enhanced learning on secondary school students' achievement in chemistry, compared to traditional methods in secondary school chemistry education.

III. OBJECTIVES OF THE STUDY

The objective of this study is to determine the profile of the participants in terms of gender, investigate the mean difference in the achievement score and to determine the mean difference in the gender scores of the students exposed to the AI method (using ChatGPT in lesson note preparation) and those exposed to the conventional lecture method.

Research Questions

The following research questions were raised to guide the study.

1. What is the profile of the respondents in terms of gender?
2. What is the difference in mean achievement of students taught chemistry using artificial intelligence technologies and those taught using conventional lecture method?
3. What is the difference in the mean achievement of male and female students taught chemistry using artificial intelligence technologies and those taught using conventional lecture method?

Research Hypotheses

The following null hypothesis were formulated and tested at 0.05 level of significance.

Ho_1: There is no significant primary effect of therapy (AI) on students' academic performance (before and post-test scores) in Chemistry.

Ho_2: There is no significant main effect of gender on students' academic achievement (pre and post-tests scores) in Chemistry.

Ho_3: There is no significant interaction effect of treatment (AI and CLM) and gender on students' academic achievement (pre and post-tests scores) in Chemistry.

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IV. METHODOLOGY

For this study, a quasi-experimental study using 2x2 fractional design with control, experimental, post-test, and pre-test phases was employed. All of the Senior Secondary Schools class one (SSS 1) in Ila Local Government Area, Osun State, in Nigeria made up the population.

The sample comprised 40 respondents, with SSS1 students from two intact classes selected from two schools that were chosen. These students, typically, are in the foundational stage of their chemistry education, which make them ideal group for this intervention

The instructional packages that were used for this study consists of six-unit plans developed on the six topics that were used for the experimental group. The topic consists of; Structure of Atom, Atoms and their representation in symbols, Characteristics and Nature of Matter, Atoms and Molecules, Electronic Configuration, and Chemical Combination that was taught for six weeks.

The instrument that the researcher used for the study was self-constructed instrument titled: Chemistry Achievement Test (CAT). It consisted of two sections A and B. Section A consisted of respondents bio-data which include name, class and gender. Section B consisted of 40 multiple choice question items with A-D options.

The CAT instrument's reliability coefficient was determined by the Split-half method to establish the internal consistence and 0.78 value was obtained. Mean, standard deviation and Analysis of Covariant (ANCOVA) at 0.05level of significance were used for data analysis.

The experimental procedure was designed to systematically evaluate the effect of AI-enhanced learning tools on students' chemistry achievement. Permission was granted by principals of both sampled schools. The research commenced and both experimental and control groups underwent a pretest to assess their baseline knowledge. The experimental group received instruction using AI-enhanced lesson for six week period while the control group was taught using the conventional lecture method for the same 6-week period. After the 6-week instructional period, both groups took a posttest identical to the pretest.

The data collected were analyzed using both descriptive and inferential statistical approach. Mean, standard deviation, and frequency distribution are used to summarize key characteristics of the participants, including their demographic data and achievement scores in chemistry. To test the hypotheses, Analysis of Covariance (ANCOVA) is applied to effectively adjust for any initial differences in pretest scores between the control and experimental groups. With the control of the initial disparities, it allows for a more precise comparison of posttest scores, isolating the effects of the independent variables (AI-enhanced learning and gender). By providing insight into both the main effects of the independent variables and their interaction effects, the analysis comprehensively captures both general trends and specific statistical relationships, enabling a well-rounded interpretation of how AI-enhanced learning affects students' chemistry achievement.

V. RESULTS

The effect of artificial intelligence technologies on senior secondary school students' academic advancement toward Chemistry in Osun state was explored in this study. The study also included gender as a moderator variable. The presentations were divided into figures, charts, and tables based on the research questions and hypotheses.

Research Question 1: What is the gender distribution of the respondents?

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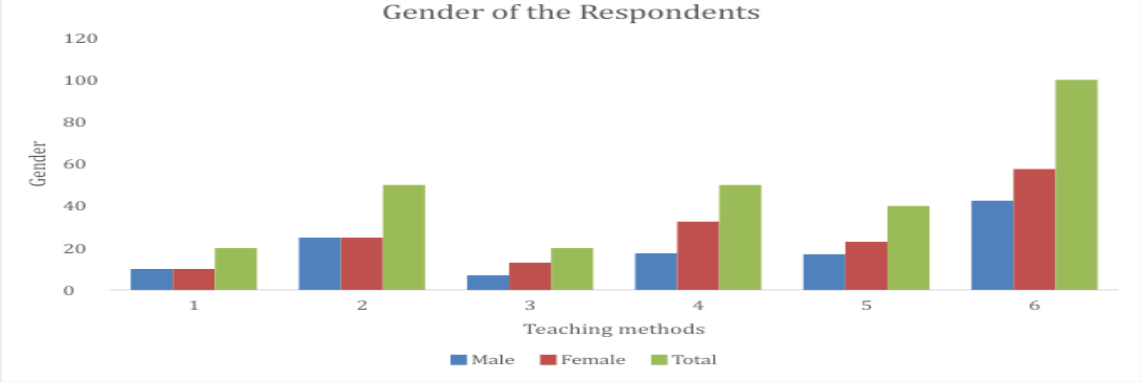

Figure 1: Bar chart showing the gender of the respondents.

The statistics shown in Figure 1 demonstrate that there are forty (40) respondents, out of which 20 (50.0%) belong to the experimental group and 20 (50.0%) are in the control group. The bulk of respondents (57.5%) are female, with 17 (42.5%) being male. Both sexes participated in the study.

Research Question 2: What is the difference in mean achievement of students taught chemistry using artificial intelligence technologies and those taught using conventional lecture method?

Table 1: Mean and standard deviation of performance of students in Chemistry achievement test for artificial intelligence

Treatment	N	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
Artificial-Intelligence	20	15.75	3.878	21.60	3.251	5.85
Conventional lecture method	20	9.75	1.832	11.50	2.743	1.75

Table 1 above shown, the mean and standard deviation of mean students' achievement for the pre-test and post-test of students exposed to artificial intelligence technologies and those who were exposed to the conventional lecture method. It was observed that the pre-test mean for the two categories were 15.75and 9.75 respectively. The table also shows that the post-test mean of the achievement of students exposed to artificial intelligence technologies and those exposed to the conventional lecture method had a mean achievement of 21.60 and 11.50. It was observed that the mean gain, between pre-test and the post-test mean of the experimental groups was 5.85. The experimental groups shown a 5.85 mean gain between pre-test and post-test. The mean gain was larger than the control group's (1.75). Results showed that the experimental group outperformed the control group.

Research Question 3: What is the difference in the mean achievement of male and female students taught chemistry using artificial intelligence technologies and those taught using conventional lecture method?

Table 2: Mean and Standard Deviation of academic achievement of male and female students exposed to artificial intelligence technologies.

Treatment	N	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
Male	17	13.71	5.059	18.00	6.255	4.29
Female	23	12.04	3.522	15.48	5.542	3.44

Table 2 above shows that the students were intellectually homogeneous prior to therapy (pre-test), with mean scores of 13.71 and 12.04 for male and female students, respectively. The male students gained an average of 4.29 between pre-test and post-test, as seen in the table. The average gain was higher than the female's (3.44). This results in a mean difference of 0.85 in favor of the male. Male students scored slightly higher than females.

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H_{01}: AI therapy has no substantial influence on students' academic achievement in Chemistry (before and post-test scores).

Table 3: Synopsis of the Important Primary Effects of Treatment's Analysis of Covariance (ANCOVA)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1068.084[a]	2	534.042	66.797	.000	.783
Intercept	285.330	1	285.330	35.688	.000	.491
PreAchiev.test	47.984	1	47.984	6.002	.019	.140
AI groups	305.631	1	305.631	38.228	.000	.508
Error	295.816	37	7.995			
Total	12320.000	40				
Corrected Total	1363.900	39				

a. R Squared = .783 (Adjusted R Squared = .771)

Once the covariate, Chemistry accomplishment scores, is taken into account, Table 3 above shows that there is a statistically significant main impact of treatment (AI) on students' Chemistry achievement [F (1, 37) = 38.228, P <.05, FSI 2 =.508]. As a result, the null hypothesis—that there is no significant main effect of treatment (AI) on students' achievement in Chemistry—was rejected because the associated precise probability value (.000) was below the.05 alpha level. The estimate of partial eta squared was.508. The results showed that the treatment explained 50.8% of the difference in students' chemistry achievement. That is to say that there is a significant difference in mean academic performance of students taught Chemistry using artificial intelligence technologies and those taught using conventional lecture method, in favour of experimental group (artificial intelligence technologies).

H_{02}: Gender does not significantly affect students' academic performance in chemistry as measured by their scores on pre- and post-tests. Below, Table 4 summarizes the analysis of covariance (ANCOVA) of the significant main effect of gender on students' academic performance in chemistry (as measured by their scores on the pre and post evaluations).

Table 4: Summary of the analysis of covariance (ANCOVA) of the significant main effect of gender on students' academic performance in chemistry (as measured by their scores on the pre and post evaluations)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	768.931[a]	2	384.465	23.909	.000	.564
Intercept	49.286	1	49.286	3.065	.088	.077
Pretest	706.770	1	706.770	43.953	.000	.543
Gender	6.478	1	6.478	.403	.530	.011
Error	594.969	37	16.080			
Total	12320.000	40				
Corrected Total	1363.900	39				

a. R Squared = .564 (Adjusted R Squared = .540)

According to Table 4's findings, there is no large difference existed in the mean achievement scores of male and female students who are exposed to chemistry. [$F_{(1,37)}$ = .403, P>.05, $\square^2$ = .011]. With a matching exact probability value of.530, an F-ratio of.403 was produced, which was higher than the.05 alpha threshold. As a result of this discovery, hypothesis 2 was not rejected. The computed Eta square value showed that gender explained 1.1% of the variation in students' chemistry achievement. That is to say, there is no significant difference in mean academic achievement of male and female

Chemistry students taught Chemistry using artificial intelligence technologies.

H_{03}: The academic achievement of students (as measured by their pre and post-test scores) in Chemistry is not significantly impacted by the interaction of treatment (AI and CLM) and gender.

Table 5: Summary of Analysis of Covariance (ANCOVA) of the Significant Interaction effect of treatment (AI and CLM) and gender on students' academic achievement (pre and post-tests scores) in Chemistry.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1073.060[a]	4	268.265	32.283	000	.787
Intercept	276.364	1	276.364	33.258	.000	.487
pretest	39.666	1	39.666	4.773	.036	.120
Gender	4.927	1	4.927	.593	.446	.017
groups	278.726	1	278.726	33.542	.000	.489
gender * groups	.037	1	.037	.004	947	.000
Error	290.840	5	8.310			
Total	12320.000	40				
Corrected Total	1363.900	9				

a. R Squared = .787 (Adjusted R Squared = .762)

Table 5 shows how treatment (AI and CLM) and gender interact to affect senior secondary school students' chemistry learning outcomes [F (1, 35) =.004, P >.05, 2 =.000]. It may be deduced that the interaction impact of therapy and gender on students' learning outcomes in chemistry is not significant because P (.947) is higher than alpha (α) values. This suggests that the gender of students and the use of artificial intelligence technology models and traditional lecture methods have no effect on the learning outcomes of chemistry.

VI. DISCUSSION

The findings reveals that students in the experimental group outperformed those in the control group. Students who were taught using artificial intelligence technology outperformed their peers who were taught using traditional discussion methods in Chemistry learning outcome examinations. The reason for the better performance may be linked to the fact that method is a significant factor in student performance in basic science. This finding confirms what Afiya (2023) said that AI can play a crucial role in improving the quality of learning generally. One of the significant challenges in teacher education is ensuring that teachers have a strong foundation in the subject matter they teach. AI can automate administrative tasks such as test evaluation, allowing teachers more time to focus on teaching rather than grading tests.

Based on gender, the study showed that 'male students had a mean performance test score slightly higher than the female students, but the mean difference was statistically insignificant. This indicates that gender has no significant effect on the performance of Chemistry students when exposed to artificial intelligence technologies. This agrees with Abdulrahman (2022) observed that 'gender inequalities are interwoven with social class, ethnicity, sexuality, disability, and other factors identified as influencing attainment' 'Also, Adebanjo (2024) noted that there are signs of boys being vulnerable to becoming disaffected. He stated further that boys tend to be less careful about rules and are more indifferent to being reprimanded. Therefore, the impact of the treatment on participants' performance is the same for both genders.

Examined against the backdrop of the gender main effect's insignificance, the result indicates that gender cannot be biased on chemistry education. The lack of gender interaction effects may be due to the behaviorist nature of the researcher's techniques, which ensured strong facilitative learning that results in high levels of accomplishment for both sexes (male and female). One possible explanation for the findings could be the orientation or counseling that

the students received prior to beginning treatment. They learned that women can succeed in chemistry and that it's not simply a subject for guys. Additionally, students saw illustrations of the kinds of occupations that people with Chemistry can undertake.

VII. CONCLUSION

Based on the findings it can be concluded that the use of artificial intelligence technologies enhances student learning outcomes in Chemistry more than the use of the conventional lecture method of teaching. The result of a non-significant difference in the mean academic performance between male and female students that were exposed to artificial intelligence technologies indicated the efficacy of the artificial intelligence technologies as a medium of instruction for the teaching of Chemistry without being gender bias. With the use of artificial intelligence technologies, the study revealed no gender disparity in performance. This, therefore, implies that if the right instructional design is used by Chemistry teachers, it is believed that both male and female students will perform equally well in Chemistry.

VIII. RECOMMENDATIONS

The following suggestions are offered in light of the research's findings.

1. AI technologies should be taught in scientific methodology courses at teacher training institutes, and pre-service and in-service teachers should be trained in their application.
2. Teachers of chemistry should incorporate activities that will promote both teachers' and students' use of artificial intelligence technologies.
3. Because the employment of artificial intelligence technology by curriculum implementers (teachers) has improved students' learning outcomes and performance in Chemistry, curriculum developers should support and promote this approach.

Limitations and Suggestions for Further Studies

In this study, some difficulties were encountered during the experimental procedures because of faulty equipment and chemicals, which resulted in some errors in the expected results. In addition, the students could not understand the procedures and rubrics given due to limited time, so an alternative method is to prepare adequately well in advance to check that all the equipment and chemicals are in good condition. Furthermore, as a recommendation, the experimental procedure should be well explained to enable students' get proper understanding of experimental procedure. The study recruited only two secondary schools in Ila local government Area. This was due to financial constraints and time; as a result, a study can be done recruiting more students from different local government Area of the Osun State or other parts of Nigeria.

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