

CHATBOT-BASED TUTORING AND ACADEMIC PERFORMANCE OF BIOLOGY STUDENTS IN PUBLIC SECONDARY SCHOOLS IN AKWA IBOM STATE, NIGERIA

Ekwutosi, Olivia Onyeka.^{*}, Nwachukwu, Norah Nnema.^{**}, Enefiok, Joseph Edem.^{*}, Ekpu, Felicia Saturday^{*} and Albert, Joy Chinenye^{***},

^{*}Department of Human Kinetics and Health Education,
Faculty of Education, University of Uyo

^{**}Department of Nursing Sciences, Rhema University, Aba. Abia State

^{***}Department of Teacher Education, National Institute of Languages Aba, Abia state

Abstract

The utilization of the Chatbot AI has been observed to have a positive impact on academic performance of students by enhancing learning motivation. The study assessed the difference in academic performance of senior secondary school biology students exposed to Chatbot AI and those exposed to the expository method, using gender as a moderating variable. The study adopted the pretest-posttest control group quasi-experimental design and was conducted in Akwa Ibom State, Nigeria. The population consisted of 40,840 Senior Secondary School two students offering Biology in 235 schools. A total of 384 students (166 males and 218 females) were divided into control and treatment groups. A Biology Achievement Test (BAT) was developed and validated for content and face validity. Reliability was established using the Kuder-Richardson formula 21. Findings revealed that Chatbot AI significantly improved students' performance (72.85) compared to traditional methods (54.77), with equal high outcomes for both genders. The study concluded that Chatbot AI enhances engagement, provides immediate feedback, and fosters critical thinking, advocating for its integration into Akwa Ibom's educational curriculum to improve students' learning and retention.

Keywords: Academic performance, Senior secondary school, Biology students, Chatbot AI, Expository method and gender

Introduction

In today's rapidly advancing technological era, the integration of Artificial Intelligence (AI) into educational settings has gained significant attention. One area that has witnessed notable advancements is the use of Chatbot AI in enhancing the learning experience and academic outcome of students (Kooli, 2023). According to Kooli (2023), the integration of Artificial Intelligence (AI) and Chatbots into education and research completely revolutionized the educational sector specifically as from the end of 2022. John McCarthy in 1956 first coined the term "Artificial Intelligence" (AI) for an intelligent machine system at the Dartmouth Conference (Xu *et al.*, 2023) and today it is a worldwide name. ELIZA, (not an acronym) developed by Joseph Weizenbaum at Massachusetts Institute of Technology (MIT) in 1966, was the world's first Chatbot. Today, Chatbots are used across a wide range of platforms and applications, such as websites, mobile apps and social media platforms.

The one-way communication from teacher to students in expository teaching method is not doing students any good, it leads to passive learning, limited engagement and encourages memorization in the place of retention. The advantages of using Chatbot AI include low cost, less time in obtaining feedback, better interaction, personalized and creative learning, engagement and motivation, and improved efficiency when used in instruction (Llic and Markovic, 2016). Chatbot AI have significant educational potential and positive impact on student learning and satisfaction through its personalized learning support (Winkler and Söllner, 2018). It can offer immediate, interactive and continuous support service to students, serving as a virtual tutor or study partner. Chatbot's potential impact on Biology and other fields is immense as it can answer life biological science questions, become a useful learning tool but its effectiveness may depend on how it is integrated into the curriculum and the support students receive from teachers (Hassoun *et al.*, 2022).

Chatbot AI for Biology will be the cross-cutting technology that will enhance our ability to do biological research at every scale. Biologist expect Chatbot AI to revolutionize Biology in the 21st century much like statistics transformed Biology in the 20th century. Chatbot AI can reinforce biological concepts by providing concise explanations and examples which can enable students to review and revise key topics by posing questions to the Chatbot. It can break biological terminologies into bits, create a more interactive and immersive learning environment, which can help students better understand the concept. It can also offer additional information or prompt students to think critically about the subject matter, consolidating their understanding (Cunningham-Nelson *et al.*, 2019). However, it is important to consider gender factors when developing and implementing Chatbot AI systems in education, to ensure equal utilization and an optimal learning experience for students of all gender. Researches have suggested gender differences in confidence levels may impact the utilization of Chatbot AI.

According to aresearch by Franken, and Mauritz, (2021) on self-awareness test, women had lower understanding of AI than men. Females, in general, may be less likely to engage with technology or express confidence in their abilities to solve problems. This may lead to varying levels of utilization based on gender. Also, there is a clear gender gap in academic performance between male and female students, with boys lagging behind girls in terms of subject grades, secondary school graduation, and tertiary level enrolment and completion. The utilization of Chatbot AI systems however, may inadvertently reflect gender biases due to the data used to train them. If the training data contains gender stereotypes or biases, the Chatbot's responses may perpetuate those biases, leading to potential disparities in the learning experience unless the Chatbot was trained with contents that are unbiased and inclusive to provide supports for users of all gender.

Apparently, In April 2016, Bill Gates told a large audience of educational technology entrepreneurs and investors that "we really haven't changed (student) outcomes" with Educational Technology, but he held out the promise that "we can surprise people by really making education better both here in the United States and around the world" (Molnar, 2019). Chatbot AI emerges as a promising solution to effectively address some educational issues. Some educational institutions are increasingly turning to

Chatbot AI, recognizing their relevance, while others are more cautious and do not rush to adopt them in modern educational settings. Chatbots are now used across various sectors, including education.

Chatbot AI have been applied for both instruction and learning within the education sector. Chatbots strategized for educational purposes are described as educational Chatbots. Chatbots in the education industry is an AI-powered (Chatbot AI) virtual assistant designed to interact with students, teachers, and other stakeholders in the educational ecosystem. Using advanced conversational AI and generative AI technologies, Chatbots can engage in natural language conversations, providing personalised support and delivering relevant information on various educational topics. Chatbot AI specialize in personalized tutoring, homework help, concept learning, standardized test preparation, discussion and collaboration, and mental health support. Evidence has shown that tools designed with pedagogical guardrails that provide step-by-step reasoning support durable learning far better than open-ended general-purpose LLMs (Fesler et al., 2024).

Furthermore, Udeh, (2024) identified two types of factors capable of influencing students' academic achievement as Internal (individual) and external (environmental) factors. According to him, the internal factors are mainly factors that reside within the student's personal, psychological, and behavioural control. Factors such as learning engagement and motivation, psychological resilience and self-efficacy, and academic emotions. External or environmental factors which include the home, the school, and parental influence, the interactive effects of the students and materials as well as socioeconomic status of parents. In recent times, educators in Nigeria have been increasingly concerned about the need to improve on the academic achievement of students. In the same vein, Akubuiro, (2018) asserted that parents, teachers and society in general are worried and apprehensive about the best way to improve academic standards, achievement and performances, and that is where the utilization of recent technologies like Chatbot AI come in.

The results of the study conducted by Wu, and Yu (2023) indicates that AI Chatbots had a large effect on students' learning outcomes. Moreso, AI Chatbots had a greater effect on students in higher education, compared to those in primary education and secondary education. In addition, short term interventions were found to have a stronger effect on students' learning outcomes than long term interventions. It could be explained by the argument that the novelty effects of AI Chatbots could improve learning outcomes in short interventions, but it has worn off in the long interventions (Nowak and Fox, 2018). Beyond academic performance, AI Chatbots have also been instrumental in building relationships with student retention, reducing summer melt and increasing graduation rates when implemented effectively.

According to researchers, in the fall of 2018, California State University System (CSUN) opted to test CSUNny by allowing half of all first-time freshmen access to the Chatbot and measuring their success against a control group that did not use CSUNny. Three years later, in the fall of 2021, students who were given access to CSUNny were "significantly more likely" to still be enrolled at the university and were more likely to have

already graduated (5.6 %) than their control group counterparts (3.6 %). Similar success was found by Georgia State University, one of the first institutions to use a Chatbot with the stated goal of reducing summer melt by staying in contact with students when they were away from campus. Pounce, Georgia State's Chatbot, reduced summer melt by 22 percent and has continued to evolve since then. In 2021, Pounce was offered to a group of political science students to remind them of upcoming exams, assignment deadlines and more. Students who used the Chatbot received better grades and were more likely to pass than those who did not. There is significant and diverse literature on what drives student success in the classroom. Scholars have looked at such factors as the impact of different types of instructors (Miskolczi and Rakovics, 2018).

The utilization of the Chatbot AI has been observed to have a positive impact on academic performance by enhancing learning motivation. Effective and ethical employment of Chatbot AI plays a significant role in promoting educational progress and enhancing academic achievement among students. Researches have shown that active engagement in Chatbot AI can improve students' critical thinking skills and promote their problem-solving abilities thereby contributing to a better academic performance.

However, a study by Kuhail et al., (2022) assessed whether gender plays a role in students' perception of the personality-imbued Chatbots. Their findings showed a positive impact of Chatbot personality on perceived Chatbot authenticity and intended engagement, while student gender did not play a significant role in the students' perception of Chatbots. According to an article published by Pew Research Centre in 2022, women in the U.S. are less likely than men to say that technology has had a mostly positive effect on society (42% vs. 54%) and more likely to say technology has had equally positive and negative impacts (45% vs. 37%). In addition, women are less likely than men to say they feel more excited than concerned about the increased use of AI computer programs in daily life (13% vs. 22%). Gender remains a factor in views about AI and technology's impact when accounting for other variables, such as respondents' political partisanship, education and race and ethnicity.

According to Baxter *et al.* (2018), there have been many studies that show how gender affects human perceptions of a conversational agent. However, there is limited research on the effect of gender when applied to a Chatbot system. Nass, Moon and Green's seminal study (2017) tested whether computers would trigger the same social scripts, expectations, and attributions associated with male and female gender stereotypes. They concluded that "the tendency to gender-stereotype is not only deeply ingrained but can be triggered by minimal gender cues, even when those cues are disembodied". One character was developed to have more stereotypically feminine features whereas the other character had less stereotypically feminine traits. Besides from visual cues, all aspects of both characters were identical as to their professions as medical doctors, their voice outputs and their lecturing content. The visual cues to the level of femininity complied with gender stereotypes and influenced the user's evaluation of the characters and the content of their lectures (Nass *et al.*, 2017).

Recent studies highlight that gender stereotyping is commonplace in HCI and brings with it both positive and negative results. (Rhim *et al.*, 2014). Subtle cues of visual

stereotypes in pedagogical agents can have an impact on a user's learning experience and the way they absorb content in a digital environment. According to the report, the proliferation of female-gendered conversational agents was primarily driven by customer preference and a non-critical examination of the product development decisions by product teams, which could entrench and perpetuate biases about women today. According to Nowak and Fox (2018), when avatars are gendered, they elicit gender stereotypes and people may then expect the avatars to have gendered knowledge. This might be due to the general stereotyping of women and men. Such attribution of (gendered) knowledge and stereotypes to Chatbots may be partly explained by the Computers Are Social Actors framework (CASA) stating that people respond to media agents mindlessly and therefore interact with them using the same script as one would use for human-to human interactions (Nass and Moon, 2020). People tend to expect the qualities of women to be linked with commonality; they should be warm, helpful to others and nurturing, while men's stereotypical domain refers to their agency, their competence and authority (Ellemers, 2018). These stereotypical responses and expectations could in theory be applied to Chatbots as social agents.

Gambino *et al.*, (2020) suggested that although the social scripts we apply when talking human to human might not necessarily always apply directly to media agents (such as Chatbots), given that these media agents are now so common, we as humans might have developed scripts that we use in interaction with them. These human-machine scripts may be, similarly to human-human scripts, applied mindlessly (Gambino *et al.*, 2020). When it comes to gender, different streams of research on conversational agents suggest that a female voice is deemed as more helpful regardless of the gender of the individual who interacts with an agent. This might be linked to females in general being perceived as more friendly (warm) and more helpful (De Angeli and Brahnam, 2006). However, we do not know enough about the extent to which the usage of gender cues within text only Chatbots especially its language style or assigned identity may elicit social gender stereotypes and how those stereotypes affect how Chatbots are perceived in terms of their knowledge and helpfulness.

Basically, some Biology instructors face difficulties in explaining and teaching complex Biology concepts, while most of them want their students to go beyond memorization to think critically, reason scientifically, and solve problems. Though, their delivery methods do not stimulate the students enough to sustain retention especially in some educational settings (in rural areas) where access to comprehensive Biology resources, subject matter experts, or laboratory materials may be limited. Moreover, studies have shown high entries and poor results of students in internal and external Biology examination. The problem of this study is to find out if there is any difference in retention and academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those taught with expository methods?

Methodology

The study adopted a quasi-experimental, non-equivalent pretest, post-test control group design. This design was appropriate because the researcher utilized intact classes to

avoid disrupting the school administration and regular classroom schedule, while the assignment of the treatment to the participating class arms was randomised. This research was conducted in Akwalbom State. The population of the study consisted of all the 48,840 (29,583 females and 22,260 males) Senior Secondary School two students offering Biology as a core subject in the 235 public Secondary schools in Akwalbom State, Nigeria. To avoid treatment diffusion, the researcher assigned entire schools to either the experimental or control group. A sample size of 384 senior secondary school two students male and female in sciences offering biology as a core subject was obtained using multi-stage sampling procedure. At the first stage, all three senatorial districts in Akwa Ibom state were used for the study. At the second stage, two local government Areas were randomly selected from each senatorial district giving a total number of six LGAs. At the third stage, two schools per LGA were randomly selected from the list of public schools in the six LGAs using a computer random number generator or paper balloting, giving a total of twelve public schools. Using a flip coin method, six schools each were assigned the experimental and control groups. At the fourth stage, from each of the twelve selected schools, one intact class arm (approximately 32 students per arm) was randomly picked by drawing papers from a hat giving us a sample size of 384 (218 females and 166 males) students being a perfect representative of the state's student population which places the gender distribution of senior secondary Biology students in Akwa Ibom state at roughly 57 percent female and 43 percent male. The researcher developed instrument called Biology Achievement Test (BAT) with a brief demographic section at the top asking the students tick their gender(either M or F) was used for data collection. The validation was done through content, and face validity by 3 experts all from the University of Uyo. The researcher then incorporated all corrections into the work. Kuder-Richardson formula 21 Test-retest method was used to access the reliability at 0.05 level of reliability. Descriptive Statistics of Mean and Standard Deviation as well as Analysis of Covariance (ANCOVA) were used to test the hypotheses at .05 level of significance.

Results

Hypothesis One: There is no significant difference in academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those exposed to expository method.

Table 1.Descriptive Statistics of the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those taught with expository method

Group	Pre-Test Mean (X)	SD	Post-Test Mean (X)	SD	N	Mean gain
ChatBot AI	51.25	3.166	72.85	7.42	359	21.60
Expository	51.22	3.155	54.77	6.23	241	3.55

Data presented in Table 1 indicated that students in experimental group had pre-test mean score of 51.25 with 3.17 standard deviation and those in the control group had pre-test mean score of 51.22 with 5.156 standard deviation, indicating that both groups had almost similar scores in performance. In posttest, students exposed to Chatbot AI had a mean performance score of 72.85 and a standard deviation of 7.42. While those taught Biology with expository method had a mean performance score of 54.77 and a standard deviation of 6.23. The mean gained for the experimental group was 21.60 while the mean gained for the control group was 3.55. This indicated that students exposed to Chatbot AI performed higher than students taught Biology with expository method.

Table 2: ANCOVA analysis of the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those exposed to expository method

Source	Type III Sum of Squares	df	Mean Square	F	Sig. @p<.05	Decision
Corrected Model	47153.093 ^a	2	23576.546	485.65	.00	**
Intercept	38609.055	1	38609.055	795.31	.00	**
Pre-test	13.576	1	13.576	.28	.60	S
Group	47143.616	1	47143.616	971.11	.01	S
Error	28982.047	597	48.546			
Total	2657364.000	600				
Corrected Total	76135.140	599				

R Squared = .619 (Adjusted R Squared = .618)

Source: Researcher's Field data (2025).

Table 2 shows that the Analysis of Covariance (ANCOVA) of mean performance scores of students exposed to Chatbot AI and those taught Biology using expository method. The result showed that F-Cal value of 971.11 was found to be significant in .01 which is less than 0.05 ($P < 0.05$) at 0.05 level of significant set for the study. The null hypothesis one is therefore rejected indicating that there is significant difference in academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those exposed to expository method.

Hypothesis Two: There is no significant difference in the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI based on gender.

Table 3: Descriptive Statistics of the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those taught with expository method based on their gender

Gender	Pre-Test Mean (X)	SD	Post-Test Mean (X)	SD	N	Mean gain
Male	51.31	3.180	72.93	7.41	172	21.62
Female	51.18	3.160	72.78	7.44	187	21.60

Data presented in Table 3 shows that male students had pre-test mean score of 51.31 with standard deviation of 3.18 and their female counterpart had pre-test mean score of 51.18 with standard deviation of 3.16, indicating that male and female performed at the same rate before treatment. In Posttest, male students who were exposed to Chatbot AI had a mean performance score of 72.93 and a standard deviation of 7.41. On the other hand, female students exposed to Chatbot AI had a mean performance score of 72.78 and a standard deviation of 7.44. The mean gained for the male group was 21.62 while the mean gained for the female group was 21.60. This is an indication that male and female students performed equally high when exposed to Chatbot AI.

Table 4: ANCOVA analysis of the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those exposed to expository method based on gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig. @p<.05	Decision
Corrected Model	2.002 ^a	2	1.001	.018	.98	NS
Intercept	31305.147	1	31305.147	565.913	.00	**
Pre-test	7.987	1	7.987	.000	.99	NS
Gender	2.002	1	2.002	.036	.85	NS
Error	19693.173	356	55.318			
Total	1925076.000	359				
Corrected Total	19695.175	358				

R Squared = .000 (Adjusted R Squared = -.006)

Source: Researcher's Field data (2025).

Table 4 shows that the Analysis of Covariance (ANCOVA) of mean performance scores of students exposed to Chatbot AI based on gender. The result showed that F-Cal value of .036 was found to be not significant in .85 which is greater than 0.05 ($P < 0.05$) at 0.05 level of significant set for the study. The null hypothesis two was therefore retained indicating that there is no significant difference in the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI based on gender.

Discussion of Findings

Table 3 revealed through the Analysis of Covariance (ANCOVA) of mean performance scores of students exposed to Chatbot AI and those taught Biology using expository method. The result showed that F-Cal value of 971.11 was found to be significant in .01 which is less than 0.05 ($P < 0.05$) at 0.05 level of significant set for the study. This outcome leads to the decisive rejection of the null hypothesis one confirming the presence of a highly significant difference in the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI and those exposed to expository method in Akwa

Ibom public secondary Schools. The magnitude of the obtained F-cal value (971.11) is extremely large, suggesting not only a statistical difference (that the difference is unlikely due to chance) but also a very large practical significance (effect size). This Robust statistical evidence strongly indicates that the instructional method employed (Chatbot AI) had a profound impact on students' performance in Biology.

This finding, agrees with the findings of Chuah and Kabilan (2021), who found out that the use of ChatBot AI provided students with a dynamic learning experience where content is delivered interactively, fostering deeper understanding through engagement rather than passive reception of information as in expository method, thereby enhancing students' academic performance. Similarly, Baroud et al., (2025) in their study titled "Improving Biology learning in high school with ChatGPT: A case study in Morroco" discovered that AI technologies facilitate deeper learning and promote critical thinking and complex concepts mastery more effectively than traditional approaches such as the expository method, which is characterized by one-way communication from teacher to student.

Conclusively, the current findings from Akwa Ibom public secondary schools support the idea that AI integration can serve as a powerful solution to educational infrastructure challenges. The success of the Chatbot AI method suggests that it effectively compensates for limitations often found in traditional public schools settings such as limited access to comprehensive laboratory materials, subject-matter experts, or up-to-date resources. The study confirms that, even in this specific regional context, AI is a powerful and pedagogically aligned enhancement that significantly improves academic achievement in Biology.

Hypothesis 2, table 4 revealed that the F-Cal value of .036 was found to be not significant in .85 which is greater than 0.05 ($P < 0.05$) at 0.05 level of significant set for the study. The null hypothesis two was therefore retained indicating that there is no significant difference in the academic performance in Biology of Senior Secondary School students exposed to Chatbot AI based on gender. This result aligns with previous research on gender differences in technology-mediated learning environments by Siddiq and Scherer (2019) who suggested that in digital learning contexts, gender disparities in academic performance tend to diminish or become negligible. Suggesting that well-designed educational technologies, particularly those leveraging AI, can effectively promote gender equity in learning outcomes by addressing individual needs regardless of demographic differences.

Furthermore, the finding is also in line with Ekuinam et al., (2024) in their study titled "The difference in academic performance of senior secondary school biology students exposed to Chatbot AI or expository method based on their gender which revealed that gender does not significantly influence the performance of students exposed to Chatbot AI because the decision to learn has nothing to do with gender. They further argued that Chatbot AI provides personalized learning tailored to individual students irrespective of their gender. This is a positive outcome, as one of the key promises of AI in education is to provide a neutral, individualized learning environment that bypasses

traditional classroom dynamics and potential instructor biases, and as such promote equitable access to personalized support irrespective of gender.

Additionally, the findings of this study is consistent with Kuhail et al., (2022) in their study on “Interacting with a Chatbot-Based Advising System: Understanding the Effect of Chatbot Personality and User Gender on Behaviour”. They observed that there’s no significant effect on matching the gender of users and chatbots. In other words, students’ gender has no significance on user behaviour when interacting with a virtual agent. The field of STEM education has historically struggled with gender achievement gaps. This study provides valuable evidence that integrating generative AI tools into high school Biology(a foundational STEM subject) can be achieved without disadvantaging either male or female students. This suggests that the Chatbot AI method is a robust and gender-neutral pedagogical alternative to the conventional expository method, which often fails to engage or meet the diverse learning needs of all students equally.

Conclusion

The study concluded that Utilization of Chatbot AI in teaching and learning Biology concepts is more effective than the use of traditional expository method because chatbot AI engages students in interactive conversations, provide immediate feedback and reinforce Biology knowledge which can encourage critical thinking in the students thereby improving their academic performance in Biology. The individualized nature of Chatbot interaction allows students to engage with complex biological concepts, such as meiosis or genetics, at their own pace without the pressure of public performance often associated with gender dynamics in traditional classrooms. Gender does not significantly affect the performance of students exposed to Chatbot AI because the decision to learn does not depend on gender. Also, Chatbot AI is designed to overcome the challenge of gender disparity. Moreover, Chatbot AI provides personalized learning tailored to individual students irrespective of gender. The findings showed that students taught Biology using ChatBot AI outperformed those taught with traditional expository method. The study also revealed that male and female students performed equally high when exposed to Chatbot AI. The chatbot AI’s success likely stems from its ability to offer adaptive and private feedback, a feature noted for benefiting all learners equally. It was therefore recommended that:

- i. Curriculum planners and designers should integrate Chatbot AI into the educational system in Akwalbom State to support student learning and retention.
- ii. Akwalbom State government should sponsor the partnership with technology providers to develop and implement Chatbot AI platforms tailored to specific needs of senior secondary school students and potentially improve academic performance and retention.
- iii. AI chatbots should be positioned as supplementary tools and not replacement for teachers and the teachers should be trained to mentor students during AI interactions, guiding their inquiries as well as ensuring that concepts are correctly internalized and mitigate the risk of over-reliance or cheating. The students must be taught how to ask AI effective questions to get meaningful relevant answers.

- iv. Chatbots should be deployed to focus on known challenging Biology subject identified by local educators, such as Genetics, Cell structure, or complex physiological processes in order to address areas where traditional instruction struggles.
- v. Government and Educational Stakeholders should prioritize increased funding for reliable power solutions (E.g., solar inverters for charging hubs and connectivity equipment) as well as investment in resilient internet connectivity for targeted schools.
- vi. Government should also implement mandatory comprehensive professional development programmes focused specifically on AI-supported pedagogy. The training should address teacher's fears and demonstrate how AI can alleviate workload (e.g., automated assessment) and enhance their teaching.

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