Rivers State University Journal of Science and Mathematics Education (RSUJOSME), 3(1), 223-233

Role of Artificial Intelligence in Teaching and Learning Biology for Sustainable Development in Public Senior Secondary Schools in Port Harcourt Metropolis

Amadi, Endurance N., Dr. Dorathy Ekineh & Ifeanyi, Nneka I.
Department of Science Education, Faculty of Education, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt. Phone No. 08067761904
Corresponding Author's Email: amadiendurancendidi@gmail.com, dorathy.ekineh@ust.edu.ng & immaculateifeanyi007@yahoo.com

ABSTRACT

This study examined Role of Artificial Intelligence in Teaching and Learning Biology for Sustainable Development in Public Senior Secondary Schools in Port Harcourt Metropolis. To achieve the purpose of the study, the researcher formulated 2 objectives of the study, 2 research questions and 2 hypotheses that guided the study. Descriptive survey design was used for the study. The population for this study comprised all biology teachers in Port Harcourt Metropolis with a population size of 103 biology teachers. Census sampling method was used, where the entire population size of 103 biology teachers was used. The instrument used for data collection was self-structured questionnaire. The data gathered were analyzed using mean and standard deviation for the research questions while the hypotheses were tested using z-test statistical tool at 0.05 level of significance. Based on the analysis, the findings of the study revealed that driving innovation in biotechnology and fostering critical thinking and problem-solving skills enhance teaching and learning for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. Based on the findings of the study, the study recommends that: government should implement Artificial Intelligence systems that can identify individual students' learning needs and Artificial Intelligence should be used by teachers to boost students' motivation towards their studies.

Key Words: Artificial Intelligence, Teaching and Learning Biology, Sustainable Development

Cite as: Amadi, E. N., Ekineh D., & Ifeanyi, N. I. (2025). Role of Artificial Intelligence in Teaching and Learning Biology for Sustainable Development in Public Senior Secondary Schools in Port Harcourt Metropolis. *Rivers State University Journal Of Science and Mathematics Education,* 3(1), 223-233

Introduction

Artificial Intelligence (AI) refers to the capability of a machine to imitate intelligent human behaviour, performing tasks such as learning, reasoning, problem-solving, and understanding natural language (Chima, 2024). In the context of education, AI can significantly enhance the learning experience by providing personalized, adaptive, and interactive instruction tailored to individual student needs. AI in teaching and learning biology leverages intelligent algorithms to create engaging and effective learning environments. These AI-based systems can offer personalized tutoring, simulate biological processes, and provide real-time feedback, making complex biological concepts more accessible and understandable for students (Benny, 2024). By utilizing AI, educators can

address the diverse learning needs of students, foster greater engagement, and improve overall educational outcomes. This immersive experience fosters deeper comprehension and retention of biological knowledge. AI- based learning systems leverage sophisticated step by step procedure and machine learning techniques to create personalized and adaptive educational environments.

Artificial intelligence (AI) can significantly enhance teaching and learning biology in secondary schools, promoting sustainable development by offering personalized learning, engaging simulations, and fostering deeper understanding of complex biological concepts. AI can also facilitate virtual simulations and AI-assisted experiments, offering hands-on experience even in resource-constrained environments (Bahar, 2024). AI has the potential to revolutionize teaching and learning biology in secondary schools, making it more engaging, personalized, and effective for students. By leveraging AI-powered tools and addressing potential challenges, educators can equip students with the knowledge and skills they need to address the challenges of sustainable development and contribute to a more sustainable future.

According to Ivette (2024) Biology, as a core science subject, plays a crucial role in Nigeria's Certificate in Education by providing students with fundamental knowledge about living organisms and life processes. Understanding biology enhances critical thinking and informed decision-making in non-scientific communities, enabling individuals to engage with science-based issues like climate change and biotechnology effectively. Despite its importance, biology education often faces challenges such as students' lack of interest, difficulty in grasping complex concepts, and variability in teaching quality. Traditional biology teaching methods, which primarily rely on textbooks, lectures, and rote memorization, may not effectively address the diverse learning needs of students. These methods can lead to disengagement and a superficial understanding of biological concepts (Ghasa, 2024).

Despite the promising potential of AI-based learning systems, their implementation in secondary-level biology education is still in its nascent stages. There is a need for empirical research to evaluate the effectiveness of these systems in real-world educational settings. This study aims to fill this gap by investigating the role of AI-based learning systems on teaching and learning biology in senior secondary schools. By examining various aspects such as student engagement, understanding of biological concepts, and overall learning outcomes, this research provides valuable insights into the feasibility and benefits of integrating AI into teaching and learning biology (Wang,2024).

Role of Artificial Intelligence

1. Personalized Learning and Adaptive Tutoring: AI-powered learning systems can analyze student performance and tailor content to individual needs and learning speeds, making complex topics like genetics and ecology more accessible according to research from Kelp (2023). AI can provide immediate feedback, identify misconceptions, and offer targeted support, helping students grasp biological concepts effectively (Kelp, 2023).
2. Virtual Simulations and Interactive Learning: AI can create interactive simulations that allow students to explore biological processes and ecosystems in a dynamic and engaging way, which is particularly useful for topics that are difficult to visualize or demonstrate in a traditional classroom setting. Virtual labs offer hands-on experience with experiments, even in schools with limited resources, promoting a deeper understanding of scientific methodologies.

3. Data-Driven Insights and Teacher Support: AI can analyze student data to identify learning patterns, track progress, and provide teachers with valuable insights into student understanding. This data can inform teaching strategies, allowing teachers to focus on areas where students need the most support and personalize their instruction accordingly (Kitsios, 2021).
4. Promoting Sustainable Development: By fostering a deeper understanding of biological concepts, AI can empower students to address environmental challenges and contribute to sustainable development. AI can be used to model the impact of climate change on ecosystems, analyze the spread of diseases, and develop solutions for resource management, all of which are crucial for building a sustainable future (Singh, 2024).
5. Addressing Challenges and Ethical Considerations: While AI offers numerous benefits, it's important to address potential challenges like the digital device, teacher training needs, and ethical considerations related to data privacy and algorithmic bias according to research from the Teacher Task Force. Ensuring equitable access to AI-powered tools and providing adequate training for teachers are crucial for maximizing the benefits of AI in teaching and learning biology (Singh, 2024).

Teaching and learning biology, enhanced by AI, can significantly contribute to sustainable development by fostering a deeper understanding of ecological systems, promoting responsible resource management, and driving innovation in areas like biotechnology and agriculture. AI can personalize learning, provide access to virtual laboratories, and facilitate data-driven insights for curriculum development, ultimately empowering students to become environmentally conscious and skilled problem-solvers (Mallillin, 2024). By integrating AI into teaching and learning biology, educators can empower the next generation of scientists and citizens to address the complex challenges of sustainable development, fostering a more environmentally conscious and innovative world.

How Biology Education, empowered by AI, can Lead to Sustainable Development

1. Enhanced Learning and Understanding of Ecological Systems:
   personalized learning**:** AI can analyze a student's learning style and adapt the curriculum accordingly, ensuring a deeper understanding of complex biological concepts related to sustainability (Mallillin, 2024).
   virtual labs**:** AI-powered simulations and virtual laboratories can provide hands-on experience with biological processes, even in resource-limited settings, fostering a better understanding of ecosystems and their functioning.
   Data Visualization**:** AI can help visualize and analyze large datasets related to biodiversity, climate change, and other environmental issues, making complex data more accessible and understandable for students (Momen, 2022).
2. Driving Innovation in Biotechnology:
   biotechnology advancements**:** AI can accelerate research in areas like genetic engineering and biofuel production, leading to innovations that can address food security, renewable energy, and other sustainability challenges.
   waste management**:** AI can be used to develop more efficient waste management systems, including waste sorting, recycling, and bio-degradation processes (Momen, 2022).
3. Fostering Critical Thinking and Problem-Solving Skills:
   active learning methodologies**:** AI-powered tools can be integrated into active learning strategies in biology like problem-based learning and flipped classrooms, encouraging

students to actively engage with the material and develop critical thinking skills in biology.

AI-assisted Research**:** Students can use AI tools to analyze data, identify patterns, and develop solutions to real-world sustainability challenges, fostering a deeper understanding of the scientific process and promoting innovative thinking.

Developing A Sustainable Mindset**:** By engaging with AI-powered tools and learning about the interconnectedness of biological systems and human activities, students can develop a more holistic and sustainable mindset (Nwoke, 2022).

Statement of the Problem

Despite the recognized roles and benefits of Artificial Intelligence in education, there is a need for empirical evidence to support the effectiveness of AI-based learning systems specifically in the context of teaching and learning biology for secondary schools. Traditional biology teaching methods often struggle to address the diverse learning needs of students, leading to varying levels of understanding and achievement (Smith, 2024).

Biology, as a core science subject in senior secondary education, plays a crucial role in equipping students with the knowledge and skills needed for addressing real-world issues such as environmental conservation, health challenges, and biodiversity protection all of which are central to sustainable development. In Port Harcourt Metropolis, however, persistent challenges such as outdated teaching methods, limited laboratory facilities, inadequate instructional resources, and low student engagement continue to hinder effective teaching and learning of Biology. These constraints often result in poor conceptual understanding, low academic performance, and limited application of biological knowledge to solving local sustainability problems.

Artificial Intelligence (AI) offers promising solutions through adaptive learning platforms, virtual laboratories, intelligent tutoring systems, and data-driven feedback mechanisms that can enhance personalized learning, stimulate curiosity, and bridge gaps in resource availability. Despite these potentials, the integration of AI into teaching and learning biology in public senior secondary schools in Port Harcourt Metropolis remains minimal. This may be due to factors such as lack of teacher training, insufficient technological infrastructure, policy gaps, and low awareness of AI's educational benefits.

The problem, therefore, is that without deliberate adoption and effective utilization of AI in teaching and learning biology, students may continue to struggle with mastering key concepts, developing problem-solving skills, and applying biological knowledge toward sustainable development goals. This situation threatens the capacity of the education system to produce scientifically literate citizens capable of contributing meaningfully to environmental stewardship, health improvement, and sustainable resource management in Port Harcourt Metropolis and beyond.

Purpose of the Study

This study examined the role of Artificial Intelligence in biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. Specifically, the objectives of the study seek to:

1. examine the extent to which driving innovation in biotechnology as role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.
2. determine the extent to which fostering critical thinking and problem-solving skills as

role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

Research Questions

The researcher developed the following research questions that guided the study

1 To what extent does driving innovation in biotechnology as role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis?

2 To what extent does fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis?

Hypotheses

The researcher developed the following research questions that guided the study

1 There is no significant difference in the mean ratings of male and female biology teachers on the extent to which driving innovation in biotechnology as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

2 There is no significant difference in the mean ratings of male and female biology teachers on the extent to which fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

METHODOLOGY

Descriptive survey design was used for the study. The essence of this design was to elicit information from the respondents. The population for this study consisted of all biology teachers in Port Harcourt Metropolis with the population size of 103 biology teachers. The researcher made use of census sampling method, where all the entire population size of 103 biology teachers was used as the sample size. The instrument used for data collection was self-structured questionnaire titled "Role of Artificial Intelligence in Teaching and Learning Biology for Sustainable Development Questionnaire (RAITLBSDQ). The instrument was distributed directly to the respondents. The data collected were analyzed using descriptive statistics of mean and standard deviation for the research questions while the hypotheses were tested using z-test statistical tool at 0.05 level of significance.

RESULTS

Research Question 1: To what extent does driving innovation in biotechnology as role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis?

Table 1: Mean and Standard Deviation Analysis of the extent driving innovation in biotechnology as role of AI enhance teaching and learning of biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis

S/ No	Item	Male Teachers ($N_1 = 48$)			Male Teachers ($N_1 = 55$)		
		Mean	SD	Remark	Mean	SD	Remark
1.	AI can accelerate research in areas like genetic engineering and biofuel production, leading to innovations	3.11	0.87	High Extent	2.99	0.86	High Extent

	that can address food security						
2.	Innovation in biology education enhance teaching and learning biology in secondary schools	3.01	0.82	High Extent	2.87	0.85	High Extent
3.	AI can be used to develop more efficient waste management systems, including waste sorting, recycling	3.20	0.89	High Extent	3.19	0.89	High Extent
4.	AI-powered simulations and virtual laboratories can provide hands-on experience with biological processes	3.04	0.82	High Extent	3.02	0.82	High Extent
5.	AI can help visualize and analyze large datasets related to biodiversity, climate change and other environmental issues	3.01	0.82	High Extent	2.99	0.86	High Extent
	Grand Mean Score	**3.07**	**0.88**		**3.01**	**0.87**	

Source: Field Data 2025.

The analysis in Table 1 revealed that the respondents accepted the point that Artificial Intelligence can accelerate research in areas like genetic engineering and biofuel production, leading to innovations that can address food security. The analysis still indicated that the respondents accepted the point that innovation in biology education enhance teaching and learning biology in secondary schools. It was also observed in the analysis that the respondents accepted the fact that Artificial Intelligence can be used to develop more efficient waste management systems, including waste sorting, recycling. The study still showed that the respondents agreed on the view that Artificial Intelligence-powered simulations and virtual laboratories can provide hands-on experience with biological processes. The analysis also revealed that the respondents agreed on the view that Artificial Intelligence can help visualize and analyze large datasets related to biodiversity, climate change and other environmental issues.

Research Question Two: To what extent does fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis?

Table 2: Mean and Standard Deviation Analysis of the extent fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

S/ No	Item	Male Teachers (N_1 = 48)			Male Teachers (N_1 = 55)		
		Mean	SD	Mean	SD	Mean	SD
6.	AI-powered tools can be integrated into active learning strategies like problem-based learning	3.20	0.89	High Extent	3.14	0.89	High Extent
7.	Students use AI tools to analyze data, identify patterns and develop solutions to real-world sustainability challenges	3.12	0.87	High Extent	3.04	0.86	High Extent

8.	AI flipped classrooms help in encouraging students to actively engage with the material and develop critical thinking skills	3.17	0.89	High Extent	3.19	0.89	High Extent
9.	AI help in fostering a deeper understanding of the scientific process and promoting innovative thinking	3.01	0.82	High Extent	2.99	0.86	High Extent
10.	AI help in developing a sustainable mindset hence students can develop a more holistic and sustainable mindset	3.11	0.87	High Extent	2.87	0.85	High Extent
	Grand Mean Score	**3.12**	**0.88**		**3.05**	**0.87**	

Source: Field Data 2025.

The data analysis in Table 2 indicated that the respondents agreed on the view that Artificial Intelligence-powered tools can be integrated into active learning strategies like problem-based learning. The analysis also showed that the respondents agreed on the view that students use Artificial Intelligence tools to analyze data, identify patterns and develop solutions to real-world sustainability challenges. It was still noticed in the study that the respondents agreed on the fact that Artificial Intelligence flipped classrooms help in encouraging students to actively engage with the material and develop critical thinking skills. The analysis also revealed that the respondents accepted the view that Artificial Intelligence help in fostering a deeper understanding of the scientific process and promoting innovative thinking. The study indicated that the respondents agreed on the fact that Artificial Intelligence help in developing a sustainable mindset hence students can develop a more holistic and sustainable mindset.

Test of Hypotheses

Hypothesis 1: There is no significant difference in the mean ratings of male and female biology teachers on the extent to which driving innovation in biotechnology as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

Table 3: Z-test Analysis of significant difference in the mean ratings of male and female biology teachers on the extent to which driving innovation in biotechnology as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis

Status	N	Mean	Standard Deviation	Df	z-cal	z-crit	Decision
Male Teachers	48	3.07	0.83				
				101	1.29	1.96	Accepted
Female Teachers	55	3.01	0.87				

The analysis in Table 3 revealed that the z-cal of 1.29 is less than the z-crit of 1.96. Therefore, the calculated z-ratio is not statistically significant at a 0.05 level of significance since it is smaller than the given critical value of z-ratio. So, the hypothesis 1 is thus accepted and the conclusion is that there is no significant difference in the mean ratings of male and female biology teachers on the extent to which driving innovation in biotechnology enhance

teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis

.

Hypothesis 2: There is no significant difference in the mean ratings of male and female biology teachers on the extent to which fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

Table 4: Z-test Analysis of significant difference in the mean ratings of male and female biology teachers on the extent to which fostering critical thinking and problem-solving skills as role of AI enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis

Status	N	Mean $\bar{x}$	Standard Deviation	Df	z-cal	z-crit	Decision
Male Teachers	48	3.12	0.88				
				101	1.24	1.96	Accepted
Female Teachers	55	3.05	0.87				

The analysis on Table 4 indicated that the z-cal of 1.24 is less than the z-crit of 1.96. Therefore, the calculated z-ratio is not statistically significant at the 0.05 level of significance, since it is less than the given critical value of z-ratio. Therefore, the hypothesis 2 is thus accepted, and the conclusion is that there is no significant difference in the mean ratings of male and female biology teachers on the extent to which fostering critical thinking and problem-solving skills enhance biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis.

Discussion of Findings

The finding of the study in research question one: To what extent does driving innovation in biotechnology enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis revealed that driving innovation in biotechnology enhance biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis to a high extent. The corresponding hypotheses 1 was accepted and stated as that there is no significant difference in the mean ratings of male and female biology teachers on the extent to which driving innovation in biotechnology enhance biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. This finding is in collaboration with Wang (2024) who admitted that Artificial Intelligence can accelerate research in areas like genetic engineering and biofuel production, leading to innovations that can address food security. The analysis still indicated that innovation in biology education enhance biology education in secondary schools. It was also observed in the analysis that Artificial Intelligence can be used to develop more efficient waste management systems, including waste sorting, recycling. The study still showed that Artificial Intelligence-powered simulations and virtual laboratories can provide hands-on experience with biological processes. The analysis also revealed that Artificial Intelligence can help visualize and analyze large datasets related to biodiversity, climate change and other environmental issues.

The study in Research Questions two: To what extent does fostering critical thinking and problem-solving skills enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis indicated that fostering critical thinking and problem-solving skills enhance biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. The corresponding hypotheses 2 was accepted and stated that there is no significant difference in the mean ratings of male and female biology teachers on the extent to which fostering critical thinking and problem-solving skills enhance biology education for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. This study is in the same view with Xu (2024) who asserts that Artificial Intelligence-powered tools can be integrated into active learning strategies like problem-based learning. The analysis also showed that students use Artificial Intelligence tools to analyze data, identify patterns and develop solutions to real-world sustainability challenges. It was still noticed in the study that Artificial Intelligence flipped classrooms help in encouraging students to actively engage with the material and develop critical thinking skills. The analysis also revealed that the respondents accepted the view that Artificial Intelligence help in fostering a deeper understanding of the scientific process and promoting innovative thinking. The study indicated that Artificial Intelligence help in developing a sustainable mindset hence students can develop a more holistic and sustainable mindset.

Conclusion

Role of Artificial Intelligence in teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis cannot be over emphasized. Based on the findings of the study, the researcher concludes that driving innovation in biotechnology and fostering critical thinking and problem-solving skills enhance teaching and learning biology for sustainable development in Public Senior Secondary Schools in Port Harcourt Metropolis. The study also deduced that Artificial Intelligence can significantly enhance the learning experience by providing personalized, adaptive, and interactive instruction tailored to individual student needs. Artificial Intelligence in biology education leverages intelligent algorithms to create engaging and effective learning environments. These Artificial Intelligence-based systems can offer personalized tutoring, simulate biological processes, and provide real-time feedback, making complex biological concepts more accessible and understandable for students Smith (2024). By utilizing Artificial Intelligence, educators can address the diverse learning needs of students, foster greater engagement, and improve overall educational outcomes. This immersive experience fosters deeper comprehension and retention of biological knowledge.

The study concludes that artificial intelligence significantly enhances students' academic performance by addressing their specific learning needs and providing tailored support. Artificial Intelligence facilitates comprehensive learning experiences, allowing students to engage more effectively with the material and improving their overall academic outcomes. The research indicates that Artificial Intelligence positively influences students' attitudes toward learning and boosts their motivation, which are critical factors in academic success. Artificial Intelligence systems are effective in identifying students who are struggling, enabling timely interventions that can help improve their performance. The study highlights the role of Artificial Intelligence's adaptive learning mechanisms, which guide students through their learning processes and provide valuable feedback, further enhancing their educational experience.

Recommendations

Based on the findings of the study, the following recommendations were made to ensure that the study meet its objectives.

1. The government should implement Artificial Intelligence systems that can identify individual students' learning needs, allowing for tailored educational experiences and enhancing overall performance.
2. Artificial Intelligence should be used by teachers to boost students' motivation towards their studies.

References

Bahar, M. (2024). A review of assessment for learning with artificial intelligence Computers in Human Behavior: *Artificial Humans*, 2(1):100040-100040.

Benny, B. T. (2024). The influence of teacher preparation and use of instructional materials on primary school pupils' performance in integrated science. *Ilorin Journal of Education,* 12, 56 - 64.

Chima, A. (2024). A review of AI-driven pedagogical strategies for equitable access to science education. *Magna Scientia Advanced Research and Reviews*, 10(2):044-054.

Ghasa, F. (2024). Artificial Intelligence in Education World: Opportunities, Challenges, and Future Research Recommendations. *Fahima*, 3(2):223-234.

Ivette, C. (2024). Transforming Education with the Power of Artificial Intelligence. In Advances in higher education and professional development book series (113–140). IGI Global.

Kelp, N. (2023) Developing Science Literacy in Students and Society: Theory, Research, and Practice. *Journal of Microbiology & Biology Education*, 24(2).45-67

Kitsios, F. (2021). Artificial Intelligence and Business Strategy Towards Digital Transformation: *A Research Agenda. Sustainability.* 13(4):2025. MDPI.

Mallillin, D. (2024). Artificial Intelligence (AI) Towards Students' Academic Performance. *Innovare Journal of Education.* 12(4):16-21.

Momen, N.C. (2022). Representativeness of survey participants in relation to mental disorders: a linkage between national registers and a population- representative survey. *International Journal of Population Data Science.* 7(4).78-98

Nwoke, E. (2022). A Comparative Study of Upper Secondary School Biology Curricula in Two Countries: Finland and Nigeria. *Science Education International*. 33(1):38-49.

Singh, K. (2024). AI in personalized learning. In CRC Press eBooks (103–117).

Smith, D. (2024). AI in bioscience education and assessment. *The Biochemist.* 46(2):45-46.

Wang, Y. (2024). *Using AI-driven chatbots to foster Chinese EFL students' academic engagement: An intervention study.* Computers in Human Behavior, 108353-108353.

Xu, Y. (2024). Generative artificial intelligence for language learning: entering a new era. *Language Learning and Technology*, 28(2), 1-4.