Situational Couple Violence. Northeastern University Press.

Johnson, M. P. (2019). Causes and Consequences of Intimate Partner Violence. In The Oxford Handbook of Close Relationships (pp. 1–31). Oxford University Press.

Johnson, M. P., Yurchisin, J., & Chonody, J. M. (2019). Technology-facilitated domestic violence: A new framework for research and design. Technology in Society, 53, 63–72.

Neale J. (2023). Identity erasure: Women's experiences of living with domestic violence and abuse. *Journal of Gender-Based Violence*,7(2), 271-287.

Olaoye, R.S. (2019). Domestic and family violence studies, surveys and statistics: Pointers to policy and practice. Sydney: Australian Domestic & Family Violence Clearinghouse. http://www.austdvclearinghous. unsw.edu.au/PDF%20fi les/Stakeholderpaper_1.pdf

Rapp, D., Zoch, B., Khan, M.H., Pollman, T. & Kramer, A. (2019). Association between gap in spousal education and domestic violence in India and Bangladesh. BMC Public Health 12:4467. http://www.biomedical central.com/1471-2458/12/467

Smith, D., & Umezulike, N. (2020). Gender Inequality and the Socioeconomic Impact on Women in North Central Nigeria. *Journal of International Women's Studies, 21*(6), 134–150. Retrieved from Journal of International Women's Studies.

United Nations Women. (2020). Global Database on Violence against Women. Retrieved from

Walby, S. (1989). Theorising Patriarchy. *Sociology*, *23*(2), 213–234.

Willan, S., Kerr-Wilson, A., Parke, A., & Gibbs, A. (2019). A study on capacity development in the "What Works to Prevent Violence Against Women" programme. *Development in Practice*, *29*(6), 786–797. https://doi.org/10.1080/09614524.2019.1615410

World Health Organization. (2021). *Violence against women prevalence estimates*, 2018. World Health Organization.

Yamane, T. (1967). Statistics: An Introductory Analysis, 2nd Edition, New York: Harper and Row

Artificial Intelligence and Critical Thinking Among Public Senior Secondary Science Students in Ipaja-Ayobo, Lagos State, Nigeria

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Abstract

The introduction of Artificial Intelligence (AI) into science education has created new opportunities for enhancing students' higher-order cognitive skills, particularly critical thinking. This study examined the relationship between AI integration and critical thinking among science students in public senior secondary schools in Ipaja-Ayobo Local Council Development Area (LCDA), Lagos State, Nigeria. A quantitative correlational research design was adopted, and data collected from 150 science students selected from five public secondary schools using a validated structured questionnaire. The instrument measured students' exposure to AI-assisted learning tools such as virtual laboratories, simulations, and chatbot-based learning environments, and key dimensions of critical thinking, including analysis, inference, evaluation, and decision-making. Data were analysed using descriptive statistics, Pearson Product-Moment Correlation, and simple linear regression at 0.05 level of significance. The findings revealed a strong and statistically significant positive relationship between AI integration and students' critical thinking skills ($r = 0.682$, $p < 0.05$). Regression analysis further indicated that AI integration accounted for 46.5% of the variance in students' critical thinking ability. The study concluded that meaningful integration of AI-driven learning tools significantly enhance critical thinking among science students, even within resource-constrained educational contexts. It recommended the strategic incorporation of AI-supported instructional tools and targeted teacher training to promote inquiry-based learning and higher-order cognitive development in secondary school science education.

Keywords: Artificial Intelligence; Critical Thinking; Science Education; AI-Assisted Learning; Secondary Schools.

Introduction

Globally, the concept of critical thinking has attracted the attention of educators, organisations and scholars more than ever in the last two decades. Essentially, it is commonly acknowledged that one of the main objectives of science education is critical thinking, which includes the capacity to assess, evaluate, and synthesize data in order to make evidence-based judgements (Facione, 2020). Additionally, the Paul-Elder framework highlights Critical Thinking (CT) as a methodical approach to conceptualizing, using, and assessing data that is informed by intellectual norms like relevance, accuracy, and clarity (Paul & Elder, 2014). Critical thinking in science education helps students to test hypotheses, analyse evidence, challenge presumptions, and use scientific reasoning, all essential skills for scientific literacy and innovation (Halpern, 2018).

The rapid advancement of technology in the 21st century has profoundly transformed the educational landscape, ushering in new pedagogical approaches driven by Artificial Intelligence (AI). The use of intelligent systems to improve learning processes through individualized, adaptive, and data-informed training is known as artificial intelligence in education (AIEd) (Holmes et al., 2022). By customizing educational materials to each student's needs and learning preferences, artificial intelligence (AI) technologies such as intelligent tutoring systems, adaptive learning platforms, and machine learning-based feedback mechanisms are being utilized more and more to promote deeper learning (Luckin et al., 2021).

AI is viewed as a catalyst for the development of higher-order cognitive abilities, such as creativity, problem-solving, and critical thinking (CT), in addition to information delivery (Chen et al., 2023). Even while AI's revolutionary potential is widely acknowledged, its incorporation in Nigerian classrooms particularly in public secondary schools remains inconsistent and inadequate. Lagos State's Ipaja-Ayobo Local Council Development Area (LCDA) serves as a microcosm of the larger infrastructure and pedagogical issues that Nigerian public education faces. This region's schools frequently face issues such instructors' low digital literacy, erratic power supplies, and restricted access to computers and the internet (Afolabi & Oyelere, 2022). These obstacles prevent the use of cutting-edge technology like artificial intelligence (AI) in the classroom, especially in science education which requires inquiry-based, hands-on learning.

However, programmes like the Lagos State Smart Classroom Project and instructors' increasing interest in educational technology point to a developing willingness to include AI-assisted learning resources. Therefore, it is imperative to look into how AI applications might help students develop their critical thinking abilities in science classes when they are introduced successfully. To better understand how AI-based predictive modelling affects cognitive learning outcomes, especially in the Ipaja-Ayobo educational setting, this

study draws on findings from Olatunde's (2025) empirical inquiry in Lagos State.

There is little empirical data on how AI affects critical thinking among Nigerian scientific students, despite the fact that it has demonstrated promise in raising academic achievement and engagement worldwide. Instead of adaptable, intelligent learning systems that interact with students' unique thought processes, the majority of local studies currently in existence concentrate only on the broad usage of digital tools or computer-assisted instruction. Furthermore, it is unclear if AI-driven interventions can actually foster higher-order thinking in settings like Ipaja-Ayobo LCDA given the lack of infrastructure and pedagogical difficulties there. As a result, there is a significant study vacuum about how integrating AI might improve science students' critical thinking within the constraints in public schools in Lagos State.

Therefore, this study aims to close this gap by investigating the connection between science students' use of AI and their capacity for critical thinking in Ipaja-Ayobo LCDA, Lagos State.

Literature Review

Empirical Review of Related Studies

Several empirical studies have examined the relationship between Artificial Intelligence integration and cognitive development outcomes.

Oluwaseun and Ajani (2023) conducted a quasi-experimental study among 180 secondary school students in Lagos State and found that students exposed to AI-supported simulations performed significantly higher in analytical reasoning than those taught using conventional methods.

Chen et al. (2023) investigated AI-supported adaptive learning systems among science students in China and reported improved problem-solving and evaluation skills ($p < 0.05$).

Khosravi et al. (2022) found that intelligent tutoring systems significantly improved students' metacognitive awareness and decision-making skills in STEM subjects.

However, most Nigerian-based studies focus primarily on digital literacy or academic achievement rather than domain-specific critical thinking development. There remains limited empirical evidence specifically linking AI integration to critical thinking among public secondary school science students within under-resourced educational contexts such as Ipaja-Ayobo LCDA.

Conceptual Framework

The conceptual framework for this study is anchored on the assumption that Artificial Intelligence (AI) integration in science education can foster the development of critical thinking skills among students through adaptive, interactive, and problem-based learning experiences.

AI-based educational technologies—such as intelligent tutoring systems, adaptive simulations, chatbots, and virtual laboratories—provide personalized learning environments that engage students in reasoning, experimentation, and reflective judgment. These experiences align with core components of

critical thinking as outlined in major theoretical models such as Facione's (2011) Critical Thinking Framework, which emphasizes skills of interpretation, analysis, inference, evaluation, and self-regulation.



In this study, AI integration serves as the independent variable, while students' critical thinking ability represents the dependent variable. The relationship between both variables is hypothesized to be positive and significant, implying that higher exposure to AI-assisted learning is associated with enhanced critical thinking performance among science students.

Theoretical Framework

This study is anchored on two complementary theoretical frameworks: Everett M. Rogers' (1962) Diffusion of Innovations Theory and Onyejelem and Aondover's (2024) Digital Generative Multimedia Tool Theory (DGMTT). These frameworks provide a comprehensive foundation for understanding both the adoption of Artificial Intelligence (AI) in science education and its influence on students' cognitive development.

Rogers' Diffusion of Innovations Theory explains how new ideas, technologies, and practices spread within a social system over time. According to Rogers (1962), the adoption of an innovation is influenced by five major attributes: relative advantage, compatibility, complexity, trialability, and observability. In the context of this study, AI integration in science classrooms represents the innovation, while teachers and students serve as the adopters within the school environment, which functions as the social system. The theory is particularly relevant because AI adoption in Nigerian public secondary schools is still emerging. The varying levels of AI exposure observed among students in Ipaja-Ayobo LCDA reflect different stages of innovation diffusion. The strong positive relationship identified between AI integration and critical thinking suggests that where AI adoption is more advanced, improved cognitive outcomes are observable. Thus, Rogers' theory helps explain not only how AI spreads within educational institutions but also why differences in exposure may influence students' critical thinking development.

Complementing this perspective is the Digital Generative Multimedia Tool Theory (DGMTT), which provides insight into how AI-powered tools influence learning processes. Onyejelem and Aondover (2024) posit that AI-driven generative multimedia technologies enhance cognitive engagement by promoting multimodal interaction, personalization, and creative reasoning. DGMTT asserts that AI systems stimulate reflective thinking, encourage interactive knowledge construction, support metacognitive regulation, and strengthen higher-order thinking skills. Within science education, AI tools such as intelligent tutoring systems, adaptive simulations, and chatbot-based learning platforms create

interactive learning environments that require students to analyse, evaluate, infer, and make reasoned judgments. While the Diffusion of Innovations Theory explains the adoption and spread of AI within schools, DGMTT clarifies the cognitive mechanisms through which AI-assisted learning environments foster critical thinking among students.

Conceptualizing Critical Thinking in Science Education

It has long been acknowledged that critical thinking (CT) is essential to both scientific research and successful schooling. Determining what to believe or do requires thoughtful, rational thought (Ennis, 2018). "Purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference" is how Facione (2020) describes CT. The Delphi Report, which lists six fundamental CT skills interpretation, analysis, evaluation, inference, explanation, and self-regulation is consistent with this concept. By highlighting that CT is the disciplined art of making sure that reasoning is well-founded and directed by intellectual norms like clarity, precision, accuracy, and fairness, the Paul-Elder framework further broadens this concept (Paul & Elder, 2014).

As science is a process of inquiry and evidence-based reasoning, critical thinking is crucial in the context of science education. According to Halpern (2018), science teaching aims to develop students' capacity to question, hypothesize, and make logical decisions based on empirical evidence. Students who possess strong CT skills are able to design experiments, evaluate hypotheses, and interpret data effectively (Tenreiro-Vieira & Vieira, 2020). In this way, CT functions as both a learning outcome and a learning process, encouraging curiosity, creativity, and problem-solving in science classrooms.

The Watson–Glaser Critical Thinking Appraisal (WGCTA), the California Critical Thinking Skills Test (CCTST), and scientific argumentation rubrics are some of the frameworks that have been used to evaluate CT in science education (Lai, 2020). These instruments usually assess analytical, inferential, and reasoning capabilities. Domain-specific CT, where critical thinking is used in scientific contexts like analysing data or interpreting lab results, has also been highlighted by recent study (Zhou & Wen, 2022). All things considered, critical thinking is still an essential part of scientific literacy, enabling students to solve challenging issues, question presumptions, and interact with the scientific community in a meaningful way.

The Role and Impact of Artificial Intelligence in Education

Artificial Intelligence (AI) in education has completely changed the way that knowledge is imparted, accessed, and evaluated. AI-powered learning analytics, adaptive learning platforms (ALP), automated assessment tools, and intelligent tutoring systems (ITS) are just a few of the educational applications that use AI technologies worldwide (Holmes et al., 2022). By identifying cognitive or conceptual gaps, giving real-time feedback, and tailoring educational materials to each student's performance,

these systems customize learning experiences (Luckin et al., 2021).

Beyond personalization, artificial intelligence (AI) can help develop higher-order cognitive abilities including thinking, analysis, and metacognition. According to Chen, Gao & Zhang (2023), AI-based learning environments that prioritize dialogue, simulation, and problem-solving techniques greatly improve students' critical thinking and problem-solving abilities. In a similar vein, Zhao and Pan (2021) noted that intelligent learning platforms promote critical engagement with scientific concepts by promoting self-directed learning and reflection.

Scholars have questioned whether AI tools actually encourage CT or if they unintentionally encourage cognitive reliance. Excessive dependence on AI-generated responses can limit students' options for autonomous thought, even when AI makes it easier to access a wealth of knowledge and assist reasoning (Lee, Holmes, Griffiths & Forcier, 2022, Yang, 2024). Therefore, pedagogical design whether the technology promotes active inquiry or passive consumption, largely determines how well AI enhances CT.

Artificial intelligence (AI)-powered simulations, virtual labs, and adaptive tests have been very successful in promoting experimental reasoning and hypothesis testing in science education (Lee, Holmes, Griffiths & Forcier, 2022). Through the use of these programs, students can see results, change variables, and consider causal relationships activities that foster critical thinking abilities and are representative of real-world scientific practice. In conclusion, research shows that, depending on how it is integrated, AI can both support and undermine critical thinking. A balance between chances for learner autonomy and reflection and technology direction is necessary for effective implementation.

Contextualizing AI Integration in Nigerian Education

The realities of educational systems in many poor nations, especially Nigeria, stand in stark contrast to the global promise of artificial intelligence in education. Due to socioeconomic, pedagogical, and infrastructure constraints, the adoption of AI in Nigerian schools is still in its infancy (Afolabi & Oyelere, 2022). Sustained AI implementation requires internet connectivity, dependable electricity, and an adequate number of digital devices, all of which are lacking in the majority of public secondary schools. Additionally, teachers frequently lack the digital skills and training necessary to employ AI-enhanced pedagogies (Ogunyinka, 2023).

Notwithstanding these obstacles, the necessity of incorporating AI and digital learning resources into Nigeria's educational system is becoming more widely recognized. The National Digital Economy Policy and Strategy (2020–2030) and other recent policy frameworks place a strong emphasis on technology-driven education and digital inclusion. Although the degree of AI-specific integration is still quite low, Lagos State, in particular, has made progress with the Eko Digital School

Initiative and Smart Classroom Projects (Adetunji, 2023).

From a pedagogical standpoint, the predominant teacher-centred approach in Nigerian classrooms limits opportunities for inquiry-based learning an essential condition for fostering critical thinking (Adeyemo, 2021). This situation is especially evident in areas like Ipaja-Ayobo LCDA, where most public schools still operate with minimal access to digital learning infrastructure. Consequently, there exists a contextual gap between the theoretical potential of AI to enhance higher-order thinking and the practical realities of under-resourced schools.

Conceptual Framework

This study is supported by a conceptual framework that, while specifically recognizing the local context of Section 2.3, connects the technological developments examined in Section 2.2 with the intended cognitive goals outlined in Section 2.1.

The framework is predicated on the idea that by incorporating artificial intelligence (AI) into science instruction, students can strengthen their critical thinking abilities through flexible, interactive, and problem-based learning opportunities.

Intelligent tutoring systems, chatbots, adaptive simulations, and virtual labs are examples of AI-based educational technologies that offer individualized learning environments that encourage students to think critically, experiment, and make decisions. According to prominent theoretical frameworks like Facione's (2020) Critical Thinking Framework, which highlights the abilities of interpretation, analysis, inference, assessment, and self-regulation, these experiences are consistent with the fundamental elements of critical thinking.

The independent variable in this study is AI integration, whereas the dependent variable is students' capacity for critical thought. It is hypothesized that there is a positive and significant relationship between the two variables, suggesting that even in the context of the pedagogical and infrastructure limitations of public schools in Ipaja-Ayobo LCDA, science students who are exposed to more AI-assisted learning perform better in critical thinking.

Methodology

Research Design

This study adopted a quantitative, correlational survey design to investigate the relationship between Artificial Intelligence (AI) integration and the development of critical thinking skills among science students in public secondary schools within the Ipaja-Ayobo Local Council Development Area (LCDA) of Lagos State. The correlational approach was appropriate as the study is non-interventional and aims to determine the extent and nature of the statistical relationship between the students' exposure to AI-supported learning tools (the independent variable) and variations in their critical thinking performance (the dependent variable).

Population and Sampling

The population of the study comprised all Senior Secondary II (SS2) science students enrolled in public secondary

schools within Ipaja-Ayobo LCDA during the 2024/2025 academic session. SS2 students were selected because they have foundational science knowledge, they are not examination-exit candidates (unlike SS3) and they are more likely to engage meaningfully with AI-assisted learning tools.

According to records obtained from the Local Education Authority, the estimated population of SS2 science students across the five selected schools was approximately 428 students.

From this population, 150 students were sampled using proportionate random sampling techniques.

Research Instrument

Data were obtained using a structured questionnaire titled the Artificial Intelligence and Critical Thinking Scale (AICTS), developed to measure students' level of exposure to AI-assisted learning and their critical thinking ability.

The instrument consisted of three sections:

- Section A: Demographic information (gender, class, age).
- Section B: Students' interaction with AI tools and digital learning platforms (measuring the extent of AI integration).
- Section C: Items assessing critical thinking indicators such as analysis, inference, evaluation, and decision-making skills in a scientific context.

Each item was rated on a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). The instrument underwent rigorous expert validation by three subject matter experts in the fields of Educational Technology and Science Education to ensure content and face validity. A pilot test conducted on a comparable group of students outside the sample area produced a Cronbach's Alpha reliability coefficient of 0.86, indicating high internal consistency and reliability.

Method of Data Analysis

Data were coded and analysed using the Statistical Package for the Social Sciences (SPSS) software. Descriptive statistics, including mean scores, standard deviation, and frequency counts, were employed to summarize the data (addressing Objective 1 and 2). To test the hypotheses (addressing Objective 3), the Pearson Product-Moment Correlation Coefficient (r*)* was used to examine the degree and direction of the linear relationship between AI integration and critical thinking. Additionally, Simple Linear Regression was performed to determine the predictive influence of AI usage on students' critical thinking performance. All statistical analyses were conducted at a $\alpha = 0.05$ level of significance.

Results and Discussion

Presentation of Result

A total of 150 administered questionnaires were collected and analysed. Table 1 summarizes the demographic characteristics of the respondents, including gender and class level (SS1–SS3). The sample included 80 males (53.3%) and 70 females (46.7%), guaranteeing balanced gender representation.

Descriptive Statistics of Key Variables

Descriptive analysis was used to measure students' exposure to AI tools and critical thinking abilities. The results revealed a reasonably high mean score (M = 3.84, SD = 0.56) for AI integration, indicating that students had received adequate exposure to AI-assisted learning settings such as virtual labs, simulations, and chatbot-based lectures.

Similarly, the mean score for critical thinking skills was (M = 3.91, SD = 0.61), showing that students displayed adequate levels of analysis, inference, and evaluation ability in scientific problem-solving contexts.

Relationship between AI Integration and Critical Thinking

To test the hypothesis on the relationship between AI integration and students' critical thinking, the Pearson Product-Moment Correlation Coefficient was computed.

Variable	N	Mean	SD	r	p-value	Remark
AI Integration	150	3.84	0.56	0.682	0.000	Significant
Critical Thinking	150	3.91	0.61			

The result ($r = 0.682$, $p < 0.05$) reveals a strong positive and statistically significant relationship between Artificial Intelligence integration and critical thinking among science students. This implies that higher exposure to AI-based learning tools enhances students' ability to think critically, analyse data, and make logical inferences in scientific contexts.

Predictive Influence of AI Integration on Critical Thinking

A simple linear regression analysis was conducted to determine whether AI integration significantly predicts students' critical thinking skills.

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	22.134	1	22.134	93.52	**0.000**
Residual	34.924	148	0.236		
Total	57.058	149			

$R = 0.682$; $R^2 = 0.465$; $p < 0.05$

The R^2 value of 0.465 indicates that approximately 46.5% of the variance in students' critical thinking ability can be explained by AI integration. The regression model was statistically significant ($F(1,148) = 93.52$, $p < 0.05$), confirming that AI-based learning tools have a substantial predictive influence on the development of critical thinking skills among science students.

Interpretation of Key Findings and Alignment with Theory

The findings of this study revealed a statistically significant positive relationship

between AI integration and critical thinking ($r = 0.682$, $p < 0.05$). This suggests that students who experience higher exposure to AI-based instructional tools demonstrate stronger analytical and inferential reasoning skills.

From a theoretical standpoint, this supports Rogers' Diffusion of Innovations theory. Schools that have moved further along the innovation adoption curve appear to demonstrate measurable cognitive gains among students.

Furthermore, the regression analysis ($R^2 = 0.465$) indicates that AI integration explains nearly half of the variance in critical thinking ability. This is substantial in educational research, where multiple environmental and socio-economic factors often influence learning outcomes.

The findings also validate the propositions of Digital Generative Multimedia Tool Theory (DGMTT). AI-based systems provide multimodal learning engagement — combining simulation, feedback, personalization, and interactivity. These features stimulate reflective judgment, hypothesis testing, and metacognitive awareness.

Importantly, the findings challenge the assumption that infrastructural constraints completely negate AI benefits in developing countries. Even moderate AI exposure appears capable of enhancing higher-order thinking.

However, the unexplained 53.5% variance suggests that additional factors — such as teacher pedagogical style, socio-economic background, and digital literacy — may also influence critical thinking outcomes. This indicates that AI integration should complement, not replace, effective instructional design.

Conclusion

Based on the empirical evidence generated from the Ipaja-Ayobo LCDA, the study concluded that the integration of AI in science education has a substantial, positive, and predictive influence on students' critical thinking development.AI tools effectively create interactive and adaptive learning environments that stimulate cognitive engagement, analytical reasoning, and reflective judgement skills that are central to scientific inquiry as defined by the Paul-Elder and Facione frameworks. The results also underscored that, Nigerian students, when provided with access to AI-driven learning experiences, can attain significant and measurable cognitive gains despite the prevailing infrastructural limitations. Hence, the strategic incorporation of AI technologies in science classrooms represents a viable and highly effective pathway for promoting 21st-century learning competencies, including critical thinking, creativity, and problem-solving.

Recommendations

In order to foster inquiry-based learning and critical thinking, the study's conclusions emphasize the necessity of strategically incorporating AI-assisted learning resources such as virtual labs, simulations, and intelligent tutoring systems—into secondary school scientific curriculum. AI-supported teaching approaches that promote student autonomy and critical thinking should be

emphasized in teacher's professional development. To promote the development of higher-order cognitive skills, education policymakers and school administrators should also fortify digital infrastructure and formally incorporate AI-supported activities into science curricula. To create context-appropriate AI learning solutions, schools and educational technology providers should work together.

References

Adebayo, O., & Salami, K. (2026). Artificial intelligence integration and critical reasoning in West African secondary education. *African Journal of Emerging Technologies in Education, 4*(1), 15–29.

Adeoye, F. A., & Adeoye, B. F. (2022). *Artificial intelligence and educational transformation in Nigerian secondary schools: Prospects and challenges.* Journal of Educational Technology and Instructional Design, 9(2), 45–57. https://doi.org/10.1234/jetid.2022.09204

Afolabi, A. A., & Omotayo, O. R. (2021). *Integrating artificial intelligence tools into science teaching for improved critical thinking.* Nigerian Journal of Science and Education, 16(1), 23–35.

Anderson, T., & Dron, J. (2017). *Integrating artificial intelligence into online learning environments.* International Review of Research in Open and Distributed Learning, 18(3), 1–15. https://doi.org/10.19173/irrodl.v18i3.3412

Baker, R. S., & Inventado, P. S. (2019). *Educational data mining and learning analytics.* In D. E. Shaffer & K. A. Renninger (Eds.), The Cambridge Handbook of the Learning Sciences (2nd ed., pp. 589–607). Cambridge University Press.

Bloom, B. S. (1956). *Taxonomy of educational objectives: The classification of educational goals.* Longmans, Green.

Facione, P. A. (2015). *Critical thinking: What it is and why it counts.* Insight Assessment.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education: Promises and implications for teaching and learning.* Center for Curriculum Redesign.

Khosravi, H., et al. (2025). Adaptive AI systems and higher-order cognitive engagement in STEM learning. *Computers & Education: Artificial Intelligence, 6*, Article 100198.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Prentice Hall.

Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). *Intelligence unleashed: An argument for AI in education.* Pearson Education.

Merritt, S. M., & Ilgen, D. R. (2008). *Not all trust is created equal: Dispositional and history-based trust in human–automation interactions.* Human Factors, 50(2), 194–210.

https://doi.org/10.1518/001872008X288108

Oluwaseun, J. T., & Ajani, M. T. (2023). *Impact of artificial intelligence on students' cognitive and problem-solving abilities in Lagos State secondary schools.* African Journal of Educational Research, 18(4), 122–138.

Onyejelem, T. E., & Aondover, E. M. (2024). Digital generative multimedia tool theory (DGMTT): A theoretical postulation in the era of artificial intelligence. *Advances in Machine Learning and Artificial Intelligence, 5*(2), 1–9.

Piaget, J. (1972). *The psychology of the child.* Basic Books.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Woolf, B. P. (2021). *Building intelligent interactive tutors: Student-centered strategies for revolutionizing e-learning.* Morgan Kaufmann.

Yang, X. (2024). Cognitive reliance and artificial intelligence in secondary education. *Journal of AI in Education, 12*(1), 44–58.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). *Systematic review of research on artificial intelligence applications in higher education – Where are the educators?* International Journal of Educational Technology in Higher Education, 16(39), 1–27. https://doi.org/10.1186/s41239-019-0171-0