EFFECT OF AI-PERSONALISED LEARNING STRATEGY ON CRITICAL THINKING OF INTEGRATED SCIENCE UNDERGRADUATES IN MAKURDI: THE ROLE OF GENDER

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Abstract
Although critical thinking is important, many undergraduates demonstrate its low acquisition. The study investigated effect of AI-personalised learning strategy (AI-PLS) on critical thinking of Integrated Science undergraduates in Makurdi: The role of gender. Two research questions guided the study. The study adopted a pre-test post-test non-randomized control group quasi experimental research design. Out of the 307 Integrated Science undergraduates in the two regular public universities in Makurdi, a purposive sample of 100 was drawn for the study. A validated and trial-tested Critical Thinking Test with a 0.83 reliability index was used for data collection. Findings showed a significant difference in the critical thinking mean scores of undergraduates taught using AI-PLS and those taught using Lecture Method [$F_{(1, 97)} = 62.798$; $p = 0.000 < 0.05$]. Also, no significant difference existed in the critical thinking mean scores of male and female undergraduates taught Integrated Science using AI-PLS, [$F(1, 31) = 0.551$; $\rho = 0.464 > 0.05$]. Thus, AI-PLS significantly enhance critical thinking skills of Integrated Science undergraduates without gender difference. This infers applying AI-PLS in science teaching/learning would foster critical thinking skills among undergraduate teacher trainees.

Keywords: *AI-Personalised Learning Strategy, Critical Thinking, Gender, Integrated Science and Lecture Method*

Introduction

The rapid advancement of technology, particularly in Artificial Intelligence (AI) has brought about a transformative force across various sectors of human endeavours including education. According to Nursalim et al. (2022) AI has emerged as a powerful tool capable of processing vast amounts of data, identifying patterns, and making predictions with remarkable accuracy in recent years. The integration of Artificial Intelligence in education has transformed academic learning by offering advanced means and methods through which knowledge, skills and attitudes can be effectively transmitted to learners. Fwangnum et al. (2021) posited that advancements in science and technology have changed the educational system in the world at large for growth, development and stability of a nation. The 21st century classroom is a learner-centred environment where students actively search for needed information and learning. Thus, fostering learners' capacity to come up with original answers to pressing problems is needed (Ayua et al., 2022; Ayua et al., 2023; Ayua et al., 2024). The process of knowledge transfer from instructors to learners is continually being improved upon by

stakeholders in education as the world advances (Iweka & Abbort, 2016).

The traditional education system has typically followed a one-size-fits-all approach where students receive the same content and instruction regardless of their individual needs making learning complex and difficult for learners. Currently, the conventional method (lecture method) being used in teaching and learning in Integrated Science has not yielded considerable improvement in students' critical thinking. Though, schools are undergoing major transformations as classrooms are progressively moving from traditional structures to digital learning environments. Taking advantage of these opportunities requires a profound change in the organisation of the educational system. Since the dawn of the 21st century, the world has witnessed remarkable progress in scientific and knowledge domains, driven by factors like knowledge revolution and rapid technological advancements (Ayua et al., 2023). A 21st century classroom is characterised by interactive learning, higher-order thinking skills and students' engagement. Ayua et al. (2023) further stressed that the negligence by science teachers to employ better suited teaching methods has led to abstraction; which makes the students less active and more prone to rote learning. Factors responsible for low critical thinking skills of learners in Integrated Science, such as learners' inability to interact directly with learning materials, wrong perception of science by learner's and fundamentally, the strategy employed by teachers could be addressed by the use of AI-Personalised Learning strategy.

AI-Personalised Learning Strategy is an educational technique in Integrated Science that uses AI platform or tools to concentrates on individual students' learning processes and caters to their wants, talents and concerns through machines and computers. Hennekeuser et al. (2024) posited that AI enables personalised learning by adapting educational content to meet the unique needs of individual students. The strengths, and weaknesses of individual learner need to be considered in teaching and learning but little or no attention is given to the area of students' strengths and weaknesses to properly enhance learning. However, AI platforms can analyse students' strengths and weaknesses through sophisticated algorithms and machine learning techniques, enabling educators to deliver targeted interventions and customised curriculum content (Abdallah et al., 2020; Rampersad, 2020).

Studies have shown that students in personalised learning environments exhibit improved self-efficacy and a more positive attitude towards their education (Johnson & Smith, 2019). These experiences are achievable through AI-driven tools that analyse vast amounts of data to identify learning gaps, and tailor interventions accordingly. For instance, AI-powered platforms, such as adaptive learning systems, have been shown to enhance student engagement and performance by providing effective feedback and customised learning pathways. Facione (2020) stressed that educators often rely on questioning techniques, collaborative activities, and assignments to enhance students' ability to evaluate information and develop independent perspectives. However, the rapid information processing and insightful responses provided by AI challenge traditional learning methods, raising questions about the distinctions between human learning and machine-based learning in education. The educational revolution propelled by AI in the digital era signifies a paradigm shift in how knowledge is imparted and acquired. By harnessing the power of Al technologies, educators can create dynamic learning environments that empower students, foster innovation, and pave way for more inclusive and equitable education system which calls for a shift

from the traditional method known as lecture method.

Lecture Method is the oldest approach of teaching. It is an approach which involves the introduction of the topic or concept by explanation or brainstorming about the topic and then giving work examples (Tukur et al, 2016). Learners are not able to construct their individual knowledge and skills because learning is passive. Obro (2022) stressed that lecture method has not benefitted students much due to its passive nature as it does not create opportunity for students' active participation in learning. In Integrated Science lecture method entails the teacher explaining Integrated Science concepts, demonstrating examples, while students listen, take notes and occasionally ask questions which in turn block the cultivation of critical thinking of students.

The ability to make valid judgement based on evidence is one of the basic skills in science. Ayua et al. (2022) noted that critical thinking is one that considers, relates and evaluates all aspects of a situation or problem. Science itself is premised on evidence and making conclusions based on the presented substantial evidence. Critical thinking is the process of evaluating thoughts, evaluating arguments, dealing with problems or making judgements based on gathering and evaluating various information and opinions about specific standards to give the best solution. Critical thinking allows people to deduce with more logic to process big time information and to look at all sides of issues to produce more solid conclusions. Generally, critical thinking is considered to be very important for enabling one to analyse, evaluate, explain and restructure thinking, thereby ensuring the act of thinking without false belief (Abakpa et al., 2022).

It can be illustrated that critical thinking is among the crucial skills of thinking, requiring learners to be proactive in thinking about situations based on thoughts, experience and beliefs. However, Foong (2016) viewed critical thinking as an aspect of several learning and innovative skills that are necessary to prepare students for post-secondary education and the professional building. Critical thinking ability is essential not only to help learners in learning but to generate a basis for inception into the society and meeting the needs of the society at large. Critical thinking is therefore a liberating force in education and powerful resource in one's personal and civil life (Benidiktus et al., 2017). The ideal critical thinker is habitually inquisitive, well informed, trustful of reason and open-minded. To harvest critical thinking, the learning process for students might be completely transformed by the application of artificial intelligence in education which could be gender friendly.

The term 'gender' is used in referring to a person's self-representation as male or female. It is the character of being male or female, man or woman, boy or girl Ayua et al. (2022). Gender is seen as a socially ascribed attribute that differentiate female from males (Danjuma & Bileya, 2022). In this study gender implies male or female undergraduates offering Integrated Science. Naturally, gender could encompass the characteristics associated with being male or female, man or woman, boy or girl (Ayua & Agbedye, 2020). In Africa science is viewed as a field of study mainly for male gender which creates an imbalance against females in science. Filgona (2016) noted imbalance against girls in science, technology and mathematics. Females view science as a field of study for males. Abakpa (2016) found that there is no significant difference in science achievement between male and female students in cognitive structures when critical thinking is considered. Ayua (2022) globally militates against equitable participation of boys and girls in science education especially in Africa. This implies that gender peculiarities affect

teaching, learning as well as critical thinking of students in Integrated Science.

Integrated Science was introduced in an attempt to teach science as a unified whole aimed at presenting a holistic picture of science and technology content to the students. This is because the content houses all the various components of sciences being presented to the learner in a unified and holistic manner. It is established in the National Policy of Education (Federal Republic of Nigeria - FRN, 2013) that Integrated Science is of great importance to both students and the nation at large. Integrated Science is one of the science subjects designed to expose learners to scientific and technological knowledge and skills that will assists them to make informed decisions, develop survival strategies and learn to contribute meaningfully in the contemporary society. Ayodele (2016) further explained that Integrated Science also known as Basic Science is the bedrock to further understanding of advanced studies in science, technology and engineering. According to Ayua et al. (2021) Integrated Science also known as Basic science constitutes a core subject within the curriculum of a nation at the basic education stage

Theoretically, the study is anchored on Jerome Bruner's Theory of Discovery Learning (1966), which emphasises the active role of the learner in the construction of knowledge. Bruner argued that learning is most effective when students are encouraged to discover principles, relationships, and concepts by themselves, rather than passively receiving information from teachers. According to Bruner, education should be structured in ways that stimulate curiosity, inquiry, and problem-solving, as these processes lead to deeper understanding, long-term retention, and the development of higher-order cognitive skills such as critical thinking. Central to Bruner's theory is the idea that learning is an active, exploratory process. Bruner rejected instructional approaches that rely heavily on rote memorisation and direct transmission of knowledge. Instead, he proposed that learners should be presented with carefully designed problems, examples, and situations that prompt them to search for patterns, formulate hypotheses, and draw conclusions. Through this process of discovery, learners engage in meaningful cognitive activity, which strengthens their ability to think critically. This emphasis on active engagement aligns strongly with contemporary AI-Personalised Learning environments, which are designed to place learners at the centre of the instructional process.

Empirically, research on Artificial intelligence and critical thinking presents mixed findings. Shaminja et al. (2025) carried out a study Assessing the effect of artificial intelligence usage on critical thinking skills among undergraduates of Rev. Fr. Moses Orshio Adasu University, Makurdi and found out that AI in spite its benefits encouraged the culture of laziness and impedes critical thinking culture among undergraduates in Makurdi. On the other hand, Jasmadi et al. (2024) investigated on critical thinking: An analytical study on the impact of Artificial Intelligence (AI) usage on students at Al Washliyah Darussalam University, Banda Aceh and reported that AI can enhance students' critical thinking skills, particularly in data analysis, problem-solving, and decision-making. Similarly, Amilhasad (2025) carried out a study on the Use of Artificial Intelligence in Promoting Critical Thinking Skills among Students of Bachelor of Arts in English Language Studies at Mindanao State University–Sulu. The results indicated a general agreement among students on the positive role of AI in promoting critical thinking, particularly in the areas of AI tools and ethical considerations. Tahir and Latif (2025) further carried out a study on exploring the role of Artificial Intelligence

on Students' Critical Thinking and Problem-Solving Skills at higher Education Institution in Pakistan and reported that students generally perceive AI as enhancing synthesis, evaluation, and analysis skills, with education faculty students reporting higher positive perceptions compared to those from natural sciences and no significant gender differences were observed. This reveals a key debate that Artificial intelligence may enhance critical thinking skills in some context while discouraging Independent though in others.

Statement of the Problem

The development of critical thinking is central to science education because it equips learners with the ability to analyse evidence, generate new ideas, and solve problems effectively. However, research has shown that many science students exhibit low levels of critical thinking (Abakpa, 2016). The continued use of the traditional lecture method, which limits learner participation and interaction, may contribute to this problem. Although AI-personalised learning strategy have been shown in other contexts to foster learner engagement and cognitive development, little is known about their impact on undergraduates' critical thinking within the Nigerian context, particularly in universities in Makurdi. There is also limited understanding of how gender influence the effectiveness of such strategy. It is against this background that this study investigates the impact of AI-personalised learning strategy on critical thinking of Integrated Science undergraduates in universities in Makurdi With the following objectives:

1. To find out the effect of AI-Personalised Learning Strategy on critical thinking of Integrated Science undergraduates in universities in Makurdi.
2. To ascertain the effect of AI-Personalised Learning Strategy on critical thinking of Integrated Science undergraduates based on gender.

Research Questions

1. What is the difference between the mean critical thinking of undergraduates taught Integrated Science using AI-Personalised Learning Strategy and those taught using lecture method?
2. What is the difference between the mean critical thinking of undergraduates taught Integrated Science using AI-Personalised Learning Strategy based on gender?

Hypotheses

1. There is no significant difference between the mean critical thinking of undergraduates taught Integrated Science using AI-Personalised Learning Strategy and those taught using lecture method.
2. There is no significant difference between the mean critical thinking of undergraduates taught Integrated Science using AI-Personalised Learning Strategy based on gender.

Method

The study used a pre-test post-test non-equivalent control group quasi experimental research design. The quasi-experimental design is a research methodology that lies between the rigor of a true experimental method (true experimental design includes random assignment to at least one control and one experimental/interventional group) and the flexibility of observational studies (Maciejewski, 2020). The study was guided by two research questions and two null hypotheses. Out of the population of 307 (143 males & 164 females) Integrated Science undergraduates in two regular public universities in Makurdi, Benue State, Nigeria [Joseph Saawuan Tarka University (formerly Federal university of Agriculture) and Benue State University (now Rev. Fr Moses Orshio Adasu University)], a two-stage sample of 100

undergraduates in 300 level was used for the study. Firstly, purposive sampling: Two co-educational regular public universities with similar facilities and academic characteristics were selected. Secondly, the intact classes were randomly assigned to the experimental and the control groups to avoid disruption of the universities' timetables. Critical Thinking Test (CTT) was used for data collection. The CTT had two sections. Section A; elicited personal information from the respondents; while section B; contained 20 multiple-choice items which tested the critical thinking ability of research participants involving: Inference, recognition of assumptions, deduction, interpretation, and evaluation of argument. The CTT was validated by three experts and trial-tested on 15 undergraduates who were not part of the actual sample for the study so as to guide against priming. The data gathered from the trial-test were subjected to the Person Product Moment Correlation statistic, which yielded a reliability value of 0.83.

The research assistant on the experimental group was trained on how to use the AI-Personalised Learning Strategy, and the research assistant for the control group were trained on how to use the lecture method. A pretest was administered to both the experimental and control groups before commencement of the treatment. Both groups were taught the earth and the Universe. After five weeks of treatment, a post-test was administered in both groups. The data collected were analysed using mean and standard deviation to answer the research questions; while the Analysis of covariance (ANCOVA) was used to test the null hypotheses at 0.05 alpha level of significance.

Results

The results of the study are presented in Tables 1 to 4 as follows:

Table 1: Mean and Standard Deviation of Undergraduates' Critical Thinking based on Teaching Method

Method	**Sample (n)**	**Pre-CTT**		**Post- CTT**		**Gain**
		Mean	**St. D**	**Mean**	**SD**	
AI-Personalised Learning Strategy (AI-PLS)	34	7.06	3.56	21.82	9.03	**14.76**
Lecture Method (LM)	66	6.70	3.34	10.76	4.87	**4.06**
Difference		**0.36**		**11.06**		**10.70**

The results in Table 1 revealed that undergraduates taught Integrated science AI-Personalised Learning Strategy had critical thinking mean scores of 7.06 with standard deviation of 3.56 in the pre-CTT and critical thinking mean scores of 21.82 with standard deviation of 9.03 in the post-CTT. Undergraduates taught Integrated science AI-PLS using Lecture Method had critical thinking mean scores of 6.70 with standard deviation of 3.34 in the pre-CTT and critical thinking mean scores of 10.76 with standard deviation of 4.87 in the post-CTT. Table 1 further showed that undergraduates taught using AI-PLS had mean gain scores of 14.76 while those taught using LM had a mean gain score of 4.06. Thus, there was a mean gain difference AI-PLS of 10.07 in favour of undergraduates taught Integrated science using AI-Personalised Learning Strategy. This showed that undergraduates taught

using AI-PLS developed critical thinking more as compared to those taught using LM. However, SD for LM at Post-CTT was lower showing that their scores were clustered closer to their mean scores than for AI-PLS.

Table 2: Mean and Standard Deviation of Critical Thinking of Male and Female Undergraduates Taught Integrated Science using AI-Personalised Learning Strategy

Gender	**Sample (n)**	**Pre-CTT**		**Post- CTT**		**Gain**
		Mean	**St. D**	**Mean**	**SD**	
Male	12	7.33	3.45	22.33	10.12	**15.00**
Female	22	6.91	3.69	19.73	8.71	**12.82**
Difference		**0.42**		**2.60**		**2.18**

The results in Table 2 showed that male undergraduates taught Integrated science using AI-Personalised Learning Strategy had critical thinking mean scores of 7.33 with standard deviation of 3.45 in the pre-CTT and critical thinking mean scores of 22.33 with standard deviation of 10.12 in the post-CTT. Female Undergraduates who were taught Integrated science using the same AI-Personalised Learning Strategy had critical thinking mean scores of 6.91 with standard deviation of 3.69 in the pre-CTT and critical thinking mean scores of 19.73 with standard deviation of 8.7 in the post-CTT. Table 2 also revealed that male undergraduates taught Integrated science using AI-PLS had mean gain scores of 15.00 while female undergraduates taught using the same AI-PLS had a mean gain score of 12.82 with a mean gain difference of 2.18 in favour of the male undergraduates taught Integrated science using AI-Personalised Learning Strategy. This explained that male undergraduates taught using AI-PLS developed critical thinking more as compared to their female counterpart undergraduates taught Integrated science using AI-PLS. There was a lower SD of 8.7 for females at the post-CTT showing that females scored clustered closer to their mean score than male undergraduates.

Table 3: ANCOVA Summary of Undergraduates' Critical Thinking Based on Teaching Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2768.000[a]	2	1384.000	31.987	.000	.397
Intercept	4498.353	1	4498.353	103.966	.000	.517
Pre-CTT	20.103	1	20.103	.465	.497	.005
Teaching Methods	**2717.112**	**1**	**2717.112**	**62.798**	**.000**	**.393**
Error	4196.960	97	43.268			
Total	28048.000	100				
Corrected Total	6964.960	99				

Table 3 shows ANCOVA statistic summary that $F_{(1, 97)} = 62.798$; $\boldsymbol{\rho} = 0.000 < 0.05$. This suggests that the probability level is less than the specified alpha of 0.05. The null hypothesis was rejected. This means that there was a significant

difference in the critical thinking mean scores of undergraduates taught using AI-PLS and those taught using the LM in Integrated Science. This implies that AI-PLS significantly develops undergraduates' critical thinking abilities more than LM in Integrated Science. The partial eta squared value of 0.393 was considered to be a large effect size, indicating that the AI-PLS has a substantial impact on undergraduates' critical thinking abilities. This means that approximately 39.3% of the variance in undergraduates' critical thinking can be attributed to the difference between the two teaching methods and also, there is a strong association between the AI-PLS and undergraduates' critical thinking.

Table 4: ANCOVA Summary of Undergraduates' Critical Thinking Based on Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	87.379[a]	2	43.690	.504	.609	.032
Intercept	2338.979	1	2338.979	26.991	.000	.465
Pre-CTT	34.645	1	34.645	.400	.532	.013
Gender	**47.739**	**1**	**47.739**	**.551**	**.464**	**.017**
Error	2686.385	31	86.658			
Total	17268.000	34				
Corrected Total	2773.765	33				

The ANCOVA statistic summary in Table 4 states that $F_{(1, 31)} = 0.551$; $\rho = 0.464 > 0.05$. This specifies that the probability level is greater than the stated alpha of 0.05. Thus, the null hypothesis was not rejected. This indicates that there is no significant difference in the development of critical thinking mean scores of male and female undergraduates taught Integrated Science using AI-PLS. It means that AI-PLS is effective and has no significant gender-based discrepancies in learning outcomes for both males and females. The partial eta squared value of 0.017 is considered as a small effect size, indicating that male and female undergraduates perform similarly in critical thinking scores when taught using AI-PLS. This means that approximately 1.7% of the variance of undergraduates' critical thinking can be attributed to no statistically significant difference between male and female undergraduates.

Discussion

Regarding the effect of AI-Personalised Learning Strategy on Critical Thinking, a significant difference in the mean critical thinking of Integrated Science undergraduates taught using AI-Personalised Learning Strategy and those taught using the Lecture Method was established [F (1, 97) = 62.798; p = 0.000 < 0.05]. The AI-PLS group had a mean gain of 14.76 as against 4.06 for the Lecture Method group, with a large effect size. This shows that AI-PLS is significantly more effective in developing critical thinking skills than the Lecture Method. This outcome is consistent with Bruner's Theory of Discovery Learning (1966), which stresses that learners construct knowledge best through active exploration, problem-solving, and inquiry rather than passive reception of information. AI-PLS probably eased this by providing personalised content, instant

feedback, and adaptive learning paths that addressed individual strengths and weaknesses, thereby promoting analysis, evaluation, and inference skills. This finding lines up with Jasmadi et al. (2024), Amilhasad (2025), and Tahir and Latif (2025) who found that AI can enhance students' critical thinking in areas of data analysis, problem-solving, and decision-making. In disparity, the Lecture Method is basically teacher-centred and inert, as reported by Obro (2022), which may clarify the partial improvement in critical thinking. This implies that fitting AI-PLS into Integrated Science teaching in at the university education level in Nigeria can offer a scalable method to fostering critical thinking skills among Integrated Science undergraduate teacher trainees.

About the effect of AI-Personalised Learning Strategy on Critical Thinking Based on Gender, the study revealed no significant difference in the critical thinking mean scores of male and female undergraduates taught Integrated Science using AI-PLS, $F(1, 31) = 0.551$; $p = 0.464 > 0.05$. Although males had a little higher mean gain of 15.00 related to 12.82 for females, the difference was not statistically significant, and the effect size of 0.017 was negligible. This suggests that AI-PLS boosts critical thinking irrespective of gender. This finding opposes the perception that science is a male-dominated discipline, as reported by Filgona (2016), and supports unbiassed participation in science education. It is steady with Tahir and Latif (2025) and Abakpa (2016) who established no significant gender variances in mental results when creative instructional stratagems were used. Hypothetically, this indicates that AI-driven personalised learning diminishes gender discrepancies by tailoring teaching to individual learning needs rather than to group characteristics. In practice, it means lecturers can implement AI-PLS in Integrated Science classrooms without reservation that it will profit both male and female undergraduates equally, thereby indorsing inclusivity and fairness in the progress of critical thinking skills.

Conclusion

The study was concluded based on the findings that AI-PLS has significantly enhance critical thinking skills of Integrated Science undergraduates and there is no significant difference in the development of critical thinking skills of male and female undergraduates taught Integrated Science using AI-PLS.

Recommendations

Based on the findings, the following recommendations were made:

1. Lecturers should use AI-Personalize Learning Strategy in teaching Integrated Science in the university.
2. Students should be trained, enlightened and equipped with knowledge and devices such as android phones, desktops, laptops and so on for easy integration of AI-PLS in the process of teaching and learning to enhance critical thinking among Integrated Science undergraduates in Nigerian universities.

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