

Effect of Ai-Generated Contents on Secondary School Students' Mastery of Physics Concepts

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ABSTRACT: The study investigated on the effect of AI-generated contents on secondary school students' mastery of physics concepts. Quasi-experimental research design with a pre-test and post-test control group approach was used. The population consisted of 1740 senior secondary school one (SSS1) students studying physics in 16 co-educational secondary schools in Mkpato Enin Local Government Area. A sample of 94 SSS1 students drawn from two intact classes from two randomly selected schools was used for the study. The instrument for data collection was Physics Concept Mastery Test (PCMT). The reliability of the instrument was determined using Kuder Richardson formula (K-20) and the coefficient of 0.75 was obtained. Data was analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (t-tests) to test the hypotheses at a 0.05 significance level. The results of findings revealed that there was a significant difference in physics concept mastery between students taught using AI-generated contents and traditional learning method in favour of AI-generated contents. There was no significant difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning method. The study recommended that schools and educational institutions should explore the integration of AI-generated contents to improve students' physics concept mastery, as this method has shown to be more effective than traditional learning methods. It was concluded that the teaching method, particularly AI-based ITS, has a significant impact on physics concept mastery, with AI-generated contents showing superior effectiveness over traditional learning methods.

KEYWORDS: AI-generated, Content Mastery, Physics, Learning Method.

INTRODUCTION

Today's modern learner is a complex, energetic and technology driven individual that is challenged and inspired in his learning. He needs to collaborate and incorporate technology into classroom experiences. There is need for the acquisition of appropriate skills, social abilities and complex competencies to equip the learner to contribute to the society (Akpan, et al., 2023). Artificial Intelligence (AI) is a computer programme software useful in personalized learning, adaptive learning, special needs education, virtual tutors, as well as immersive learning (Akpan et al., 2024). Artificial Intelligence (AI) has significantly transformed the educational landscape, providing innovative ways to enhance teaching and learning. One of the most promising applications of AI in education is the development of intelligent tutoring systems (ITS), which are designed to provide personalized learning experiences tailored to the needs of individual students. AI-generated contents leverage machine learning algorithms, natural language processing, and data analytics to offer real-time feedback, adjust instructional content, and promote active learning. These systems are increasingly being integrated into various disciplines, including physics, to address learning gaps and improve concept mastery (Woolf, 2021). Physics, as a fundamental science, requires a deep conceptual understanding and strong problem-solving skills. Traditional teaching approaches, which rely heavily on lectures and rote memorization, often fail to engage students effectively. Many students struggle with abstract concepts such as Newtonian mechanics, electromagnetism, and quantum physics, leading to misconceptions and poor academic performance. AI-generated contents provide a solution by offering adaptive instruction that aligns with students' cognitive levels, reinforcing conceptual understanding through interactive simulations, guided problem-solving, and personalized assessments (Luckin et al., 2022; Itighise & Akpan 2021). Recent studies have demonstrated the effectiveness of AI-generated contents in improving students' conceptual understanding and problem-solving abilities. For example, a study by Xie et al. (2023) found that students who used an AI-driven tutoring system for physics showed a 25% improvement in problem-solving efficiency compared to those who relied solely on traditional teaching methods. The study emphasized the role of adaptive learning pathways in addressing individual misconceptions and enhancing critical thinking skills. Sunday, Umanah and Udofia (2025) found that students taught using computer-based molecular modelling performed significantly better than those taught with the expository teaching strategy.

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Similarly, research by Chen *et al* (2022) examined the impact of AI tutors on students' engagement levels in secondary school physics classes. The findings indicated that AI-generated contents increased students' motivation and participation by providing real-time hints, interactive simulations, and scaffolding support. The study also highlighted that students who used AI tutors demonstrated a deeper understanding of concepts and retained knowledge longer than their peers in conventional learning environments. Furthermore, a meta-analysis conducted by Patel and Singh (2023) reviewed 50 studies on AI-driven tutoring systems in STEM education. The analysis revealed that AI tutors significantly improved students' learning outcomes, particularly in complex problem-solving scenarios. The authors noted that AI-generated contents were especially effective in bridging learning gaps for students with different cognitive abilities, making physics more accessible and comprehensible. Study by Akpan and Itighise (2019) revealed that the effect of utilization of ICT tools in instructional delivery improve students learning outcome.

The effectiveness of AI-generated contents can be understood through Vygotsky's Zone of Proximal Development (ZPD). According to Vygotsky (1978), learning occurs most effectively when students operate within their Zone of Proximal Development, which is the gap between what they can achieve independently and what they can accomplish with guidance. AI-generated contents act as scaffolding tools that provide personalized assistance, guiding students through their ZPD by offering real-time feedback, hints, and adaptive content tailored to their learning pace. This theory supports the integration of AI tutors as they create dynamic and individualized learning experiences that foster deeper conceptual understanding and cognitive development in physics.

Despite the promising potential of AI-generated contents, there remains a gap in research concerning their impact on students' mastery of physics concepts in different educational contexts, particularly in developing countries. Most existing studies have been conducted in technologically advanced regions, where access to AI-driven educational tools is widespread. However, there is limited empirical evidence on how these systems perform in resource-constrained environments and their effectiveness in addressing the unique challenges faced by students in such settings (Sunday, Atabang & Ekon, 2025; Adeyemi & Uche, 2023). Additionally, while AI-generated contents have been widely studied in mathematics and computer science education, their specific application to physics remains underexplored. Physics requires not only theoretical understanding but also the ability to apply concepts in practical problem-solving scenarios. This study aims to fill this gap by evaluating the effectiveness of AI-generated contents in improving students' conceptual mastery of physics, focusing on personalized instruction, real-time feedback, and engagement strategies.

Gender is another variable considered in this study. Gender is a psychological term describing behaviour and attributes expected of individuals on the basis of being either male or female (Akpan, 2022; Umanah & Sunday, 2022; Umanah & Atabang, 2025). The role of gender in AI-generated contents adoption and effectiveness remain an important consideration in educational research. Empirical studies have shown that gender differences can influence students' interaction with AI-driven learning tools. Akpan *et al.* (2024) observed that male students have more awareness and utilization of AI technology in learning than female counterparts while Umanah and Sunday (2025), Umoetuk and Akpan (2023) and Sunday, Edet and Akpan (2025) found that both male and female students benefited from computer-based learning as well as engage more with the interactive features and adaptive feedback mechanisms, leading to higher retention rates. Furthermore, Sunday *et al.* (2025) found no difference in male and female students taught using computer-based molecular modelling, hackathon and expository teaching strategies. Likewise, Akpan (2022) reported no significant difference in gender due to resources used in teaching and learning process. Conversely, research by Okeke and Adeyemi (2022) highlighted that male students demonstrated greater confidence in navigating AI-driven learning environments, potentially due to prior exposure to technology. These findings suggest that gender-responsive strategies should be integrated into AI-generated contents design to ensure equitable learning opportunities for all students, thereby maximizing the impact of these technologies in physics education.

The integration of AI-generated contents into education aligns with global educational goals, particularly Sustainable Development Goal 4 (SDG 4), which emphasizes inclusive and equitable quality education. By leveraging AI and computer technologies, educators can create adaptive learning environments that cater to diverse student needs, ultimately enhancing learning outcomes and promoting lifelong learning opportunities (Akpan *et al.*, 2024; Umoetuk *et al.*, 2025). Furthermore, educational policies and curriculum reforms increasingly advocate for the adoption of digital tools to enhance science learning. However, empirical data on the scalability, accessibility, and long-term impact of AI tutors in physics education is still emerging. This study seeks to provide empirical insights into the role of AI-generated contents in bridging learning gaps, improving problem-solving abilities, and fostering a deeper understanding of physics concepts. Given these considerations, this study investigates the influence of AI-generated contents on students' concept mastery in physics, providing empirical insights that will inform policy decisions, curriculum design, and the adoption of AI technologies in secondary school education.

STATEMENT OF THE PROBLEM

Despite the growing interest in AI-generated contents (IGC) in education, their application in secondary school physics remains underexplored. Traditional instructional methods often fail to accommodate the diverse learning needs of students, leading to persistent misconceptions and poor academic performance in physics. While AI-generated contents have shown potential in

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providing personalized and adaptive learning experiences, there is limited empirical evidence regarding their effectiveness in improving students' mastery of physics concepts. Furthermore, challenges such as accessibility, teacher preparedness, and student engagement in technology-enhanced learning environments need to be addressed. This study, therefore, seeks to investigate the influence of AI-generated contents on students' concept mastery in physics, providing insights that will inform educational policies and pedagogical strategies.

RESEARCH QUESTIONS

1. Is there a significant difference in physics concept mastery between students taught using AI-generated contents and traditional learning method?
2. Is there a significant difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning method?

HYPOTHESES

1. There is no significant difference in physics concept mastery between students taught using AI-generated contents and traditional learning method.
2. There is no significant difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning method.

METHODS

This study adopts a quasi-experimental research design with a pre-test and post-test control group approach. The experimental group was exposed to AI-based ITS, while the control group followed Traditional Learning Method (TLM). The population consisted of 1740 senior secondary school one (SSS1) students studying physics in 16 co-educational secondary schools in Mkpato Enin Local Government Area. A sample of 94 SS1 students drawn from two intact classes from two randomly selected schools was used for the study. Two schools were randomly selected from the 16 schools in the study area using simple random sampling technique. The instrument for data collection was Physics Concept Mastery Test (PCMT), a standardized test developed to assess students' understanding of fundamental physics concepts. The test consists of 30 multiple-choice questions covering key topics such as Newtonian mechanics, electricity, and thermodynamics. Socratic AI was used as the AI-generated contents (AI-GC) for teaching of the control group. The PCMT was content and face validated by experts in physics education and educational technology to ensure its relevance and clarity. A pilot study was conducted using 30 students outside the sample population. The test-retest method was applied, and reliability was determined using Kuder Richardson formula (K-20), and a reliability coefficient of 0.75 was obtained. Pre-test administration to both experimental and control groups was carried out. Also, implementation of AI-generated contents in the experimental group for three weeks, while the control group followed traditional learning method. In the selected school for AI-generated contents, the teaching was carried out using an AI-generated content in an intact SS1 class, with a focus on students' understanding of fundamental Physics concepts. Students engaged with the system individually, responding to questions and tasks that were automatically adjusted to their level of understanding. The AI-generated content provided instant feedback and remedial support where misconceptions were detected, ensuring that students could correct errors immediately and reinforce their knowledge. The researcher facilitated the learning process by first introducing the topic and objectives of the lesson, guiding students in navigating the system, and supplementing the AI-based instruction with clarifications where necessary. This allowed the system to personalize instruction while maintaining a classroom structure where students actively explored and mastered the fundamental Physics concepts at their own pace. Lastly post-test administration was carried out to evaluate students' concept mastery after the intervention. Data was analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (t-tests) to test the hypotheses at a 0.05 significance level.

RESULTS

Research Question One: Is there a significant difference in physics concept mastery between students taught using AI-generated contents and traditional learning method?

Table 1: Mean and standard deviation on the difference in physics concept mastery based on teaching methods

Teaching Methods	N	Pretest		Posttest		Mean Gain
		Mean	SD	Mean	SD	
AI-generated content TLM	45	5.22	2.03	22.24	4.45	17.02
	49	5.29	1.57	17.69	4.11	12.40

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The results in Table 1 show that prior to the intervention, students in both the AI-generated content group and the traditional learning method (TLM) group had similar pretest mean scores: 5.22 (SD = 2.03) for the AI-GC group and 5.29 (SD = 1.57) for the TLM group. This suggests that both groups started with comparable levels of knowledge. After the intervention, the AI-GC group achieved a higher posttest mean score of 22.24 (SD = 4.45), while the TLM group had a posttest mean score of 17.69 (SD = 4.11). The mean gain for the AI-GC group was 17.02, compared to 12.40 for the TLM group. This indicates that students taught using AI-GC experienced a greater improvement in their physics concept mastery than those taught using the traditional method. The higher mean gain in the AI-GC group suggests that AI-generated content had a more significant impact on student learning outcomes.

Research Question Two: Is there a significant difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning method?

Table 2: Mean and standard deviation on the difference in physics concept mastery based on teaching method and gender

Teaching Method	Gender	n	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
AI-GC	Male	19	5.26	2.26	22.74	4.45	17.48
	Female	26	5.19	1.90	21.88	4.51	16.68
TLM	Male	22	5.09	1.82	18.13	4.52	13.04
	Female	27	5.44	1.34	17.33	3.80	11.89

The result in Table 2 shows the physics concept mastery scores of male and female students taught using AI-generated contents and the Traditional Learning Method (TLM), beginning with the pretest performance. In the pretest, male students in the AI-generated contents group had a mean score of 5.26 (SD = 2.26), while female students had a mean of 5.19 (SD = 1.90). In the TLM group, male students scored 5.09 (SD = 1.82), and females had a mean score of 5.44 (SD = 1.34). These values show that pre-instruction physics mastery levels were relatively similar across all groups. For the posttest, male students in the AI-generated contents group had a mean score of 22.74 (SD = 4.45), and females scored 21.88 (SD = 4.51), resulting in mean gains of 17.48 and 16.68, respectively. In the TLM group, males scored 18.13 (SD = 4.52) and females 17.33 (SD = 3.80), with mean gains of 13.04 and 11.89, respectively. Overall, students taught using the AI-generated contents demonstrated greater improvement in physics concept mastery than those in the traditional learning method. Male students showed slightly higher gains than female students in both instructional methods. This indicates a difference in physics concept mastery between male and female students across both teaching methods, with the gap more pronounced under AI-generated contents.

TESTING THE HYPOTHESES

Hypothesis One: There is no significant difference in physics concept mastery between students taught using AI-generated contents and traditional learning method.

Table 3: Result of Analysis of Covariance (ANCOVA) on the difference in physics concept mastery based on teaching methods

Source	Type III Squares	Sum of Df	Mean Square	F	Sig.
Corrected Model	486.973 ^a	2	243.487	13.161	.000
Intercept	4012.961	1	4012.961	216.917	.000
Pretest	1.224	1	1.224	.066	.798
Teaching_Methods	484.730	1	484.730	26.202*	.000
Error	1683.495	91	18.500		
Total	39292.000	94			
Corrected Total	2170.468	93			

a. R Squared = .224 (Adjusted R Squared = .207)

ANCOVA test result in Table 3 reveals that there is a significant difference in the mean physics concept mastery scores of students taught using AI-generated contents and those taught using the traditional learning method $\{(F_1, 91) = 26.202, p = 0.000\}$ for teaching methods. Since the p-value is less than the 0.05 level of significance, the null hypothesis one of this study is therefore rejected,

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meaning that the teaching methods (AI-generated contents vs. traditional learning) had a significant effect on students' physics concept mastery. Thus, there is a significant difference in physics concept mastery between students taught using AI-generated contents and those taught using the traditional method, with students in the AI-generated contents group achieving higher mastery.

Hypothesis Two: There is no significant difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning method.

Table 4: Result of Analysis of Covariance (ANCOVA) on the difference in physics concept mastery based on gender

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	502.439 ^a	4	125.610	6.702	.000
Intercept	3997.638	1	3997.638	213.299	.000
Pretest	.900	1	.900	.048	.827
Teaching_Methods	481.979	1	481.979	25.717	.000
Gender	15.465	1	15.465	.825	.366
Teaching_Methods * Gender	.030	1	.030	.002	.968
Error	1668.029	89	18.742		
Total	39292.000	94			
Corrected Total	2170.468	93			

a. R Squared = .231 (Adjusted R Squared = .197)

ANCOVA test result in Table 4 reveals that there is no significant difference in physics concept mastery between male and female students taught using AI-generated contents and the traditional learning method, as indicated by the gender effect: ($F(1, 89) = 0.825$, $p = .366$). Since the p-value is greater than the 0.05 level of significance, the null hypothesis is not rejected. This result suggests that gender does not significantly influence students' mastery of physics concepts, regardless of the teaching method used.

DISCUSSION OF FINDINGS

The result on the difference in physics concept mastery between students taught using AI-generated contents and those taught using the traditional learning method revealed a significant difference in the mean achievement scores between the two teaching methods. This suggests that the instructional method has a substantial impact on students' ability to master physics concepts. AI-generated contents proved to be more effective in enhancing students' learning compared to the traditional method. This finding emphasizes the potential of AI-driven learning environments in improving students' concept mastery, offering a modern and interactive approach to teaching that may better cater to individual learning needs. The result of findings is in line with Xie *et al* (2023) who found that students who used an AI-driven tutoring system for physics showed a 25% improvement in problem-solving efficiency compared to those who relied solely on traditional teaching methods. The result is also in line with Chen *et al* (2022) who found that AI-generated contents increased students' motivation and participation by providing real-time hints, interactive simulations, and scaffolding support. Also, the result further agrees with Itighise and Akpaetor (2014) who found that digital media utilization in teaching and learning environment significantly influence students' performance in tertiary institutions in Akwa Ibom State.

The result of analysis on the difference in physics concept mastery between male and female students taught using AI-generated contents and traditional learning methods revealed that there was no significant difference in the mastery of physics concepts based on gender. This finding suggests that both male and female students performed similarly, regardless of the teaching method employed. The lack of gender-based differences supports the notion that the teaching method, rather than gender, is a more influential factor in students' ability to grasp physics concepts. This result aligns with that of Zhang *et al.* (2023) who found that both male and female students benefited from AI-based tutoring leading to higher retention rates. Also, the result is in line with Umanah and Atabang (2025) who found that there is no significant difference in mean achievement scores of male and female students taught using animated and static infographic instructional materials in isomerism in Chemistry. Conversely, the result disagrees with that of Itighise *et al* (2022) who found that male students demonstrated greater confidence in utilization of web 2.0 technology in teaching and learning process in Akwa Ibom State. Similarly, Itighise and Babayemi (2023) found that there is no significant difference in utilization of virtual reality teaching by male and female students in Science Education.

CONCLUSION

In conclusion, the study confirmed that the teaching method, particularly AI-based ITS, has a significant effect on physics concept mastery, with AI-generated contents showing superior effectiveness over traditional learning methods. However, gender did not

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influence the students' ability to master physics concepts, nor did it interact with the teaching methods to affect the learning outcomes. This suggests that while instructional methods are crucial for enhancing learning, gender does not play a significant role in students' academic achievements in physics. Hence, AI-driven tutoring provides personalised learning, immediate feedback, aiding students' diverse learning needs.

RECOMMENDATIONS

1. Schools and educational institutions should explore the integration of AI-generated contents to improve students' physics concept mastery, as this method has shown to be more effective than traditional learning methods.
2. Educators should focus on refining and enhancing teaching strategies rather than considering gender when developing instructional materials or methods, since gender did not significantly affect learning outcomes.
3. Since gender did not influence concept mastery, educational approaches should be gender-neutral, fostering an inclusive and equal learning environment where both male and female students have equal opportunities to succeed.
4. Future research should explore how different teaching methods interact with other student characteristics such as learning styles, prior knowledge, and motivation to identify the most effective ways to support all learners in mastering complex subjects like physics.

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