

Artificial Intelligence-Generated Formative Assessment as a Predictor of Undergraduate Students' Academic Achievement in Chemistry: A Case Study of Ebonyi State University, Nigeria.

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Abstract

The rapid integration of Artificial Intelligence (AI) into higher education has significantly transformed instructional delivery and assessment practices. This study examined AI-generated formative assessment as a predictor of academic achievement in undergraduate Chemistry at Ebonyi State University. A correlational predictive design was employed. The sample comprised 214 second-year Chemistry students selected through stratified random sampling. AI-driven adaptive formative assessments were administered weekly over a 12-week semester via the university's Learning Management System. Data were analyzed using descriptive statistics, Pearson Product Moment Correlation, and linear regression analysis. Results revealed a strong positive correlation between AI formative assessment scores and end-of-semester examination performance ($r = 0.72$, $p < 0.001$). Regression analysis showed that AI-generated formative assessment significantly predicted 52% of the variance in academic achievement ($R^2 = 0.52$, $F(1,212) = 229.41$, $p < 0.001$). The findings suggest that AI-based formative assessment systems provide robust predictive insights and can function as early academic risk detection tools. The study recommends institutional integration of AI-driven assessment platforms to enhance data-informed pedagogy and academic monitoring in Nigerian universities.

Keywords: Artificial Intelligence, Formative Assessment, Academic Achievement, Predictive Analytics, Chemistry Education, Higher Education.

Introduction

The rapid advancement of digital technologies has significantly transformed the landscape of higher education across the globe. Among these emerging technologies, Artificial Intelligence (AI) has attracted considerable attention due to its potential to revolutionize teaching, learning, and assessment processes. AI refers to computational systems designed to simulate human intelligence processes such as learning, reasoning, pattern recognition, and decision-making (Holmes, Bialik, & Fadel, 2019). In educational settings, AI applications include intelligent tutoring systems, adaptive learning platforms, automated grading, learning analytics, and predictive modeling tools that enhance instructional efficiency and learner engagement.

The integration of AI into educational assessment has particularly reshaped formative assessment practices. Formative assessment is defined as the systematic process of collecting information about student learning during instruction for the purpose of improving both teaching and learning (Black & Wiliam, 1998). Unlike summative assessment, which evaluates learning outcomes at the end of an instructional period, formative assessment provides continuous feedback that enables learners to identify gaps in understanding and instructors to adjust pedagogical strategies accordingly (Shute, 2008). With the introduction of AI technologies, formative assessment can now be automated, adaptive, and data-driven, allowing educators to monitor learning progress in real time.

Recent developments in AI-generated formative assessment systems have demonstrated considerable promise in improving educational outcomes. These systems utilize machine learning algorithms to generate personalized quizzes, analyze learner responses, and provide instant feedback tailored to individual performance levels. According to Luckin et al. (2016), AI-based assessment systems can identify patterns in student errors and adjust question difficulty levels to optimize learning experiences. Similarly, studies in educational technology have shown that adaptive assessment platforms increase student engagement and enhance conceptual understanding, particularly in complex science subjects (VanLehn, 2011).

Chemistry education, in particular, presents unique pedagogical challenges that make it an ideal domain for AI-assisted assessment. Chemistry concepts often involve abstract reasoning, symbolic representation, mathematical modeling, and laboratory experimentation. Students frequently struggle with conceptualizing molecular interactions, balancing chemical equations, and solving quantitative problems. As a result, continuous assessment and timely feedback are essential for promoting

conceptual clarity and academic success in Chemistry courses (Taber, 2019). Traditional assessment approaches, however, often fail to provide immediate feedback or detailed performance analytics, thereby limiting their effectiveness in supporting student learning.

The integration of AI-generated formative assessment systems offers significant opportunities for addressing these challenges. AI-driven platforms provide automated scoring, personalized feedback, and performance dashboards that enable both students and instructors to track learning progress. Moreover, AI systems can analyze large volumes of learning data to identify patterns of academic performance and predict potential learning difficulties (Baker & Inventado, 2014). Such predictive capabilities are particularly valuable in higher education institutions where early identification of academically at-risk students can facilitate timely interventions.

Despite the growing global adoption of AI in education, the application of AI-generated formative assessment in many developing countries, including Nigeria, remains relatively limited. Nigerian universities continue to rely heavily on traditional assessment approaches such as written tests, assignments, and end-of-semester examinations. While these methods provide useful measures of academic performance, they often lack the capacity for real-time feedback and predictive analytics that characterize AI-based systems. Consequently, the potential benefits of AI-driven assessment tools for improving student learning outcomes have not been fully explored within the Nigerian higher education system.

At Ebonyi State University, Chemistry courses serve as foundational components for several academic programmes, including Industrial Chemistry, Biological Sciences, Medical Laboratory Science, and related fields. Institutional academic reports have indicated variations in student performance in core Chemistry courses, particularly at the second-year level where students encounter more complex theoretical and computational concepts. These performance variations highlight the need for innovative assessment strategies that provide continuous feedback and data-driven insights into student learning processes.

AI-generated formative assessment systems have the potential to address these challenges by offering adaptive learning experiences and predictive insights into student performance. By analyzing students' responses to formative quizzes, AI platforms can generate detailed learning analytics that reveal strengths, weaknesses, and learning trajectories. These insights can help instructors tailor instructional strategies while enabling students to take greater responsibility for their learning progress.

Furthermore, the predictive capability of AI-based assessment systems represents a critical advancement in educational research. Predictive analytics allows educators to use student performance data to forecast academic outcomes and identify factors influencing learning success (Siemens & Baker, 2012). In the context of Chemistry education, predictive models based on formative assessment data can help determine whether early learning indicators are associated with final academic achievement. Such insights are valuable for improving curriculum design, assessment strategies, and institutional academic support systems.

Although international studies have reported positive outcomes associated with AI-enhanced learning systems, empirical research examining the predictive role of AI-generated formative assessment within Nigerian universities remains scarce. Most existing studies have focused on developed educational systems where digital infrastructure and technological adoption are more advanced. Consequently, there is a need for context-specific research that examines the applicability and effectiveness of AI-based assessment systems in Nigerian higher education institutions.

This study therefore seeks to investigate the extent to which AI-generated formative assessment predicts academic achievement in undergraduate Chemistry at Ebonyi State University. By examining the relationship between AI-driven formative assessment scores and end-of-semester examination performance, the study aims to contribute empirical evidence to the growing body of research on artificial intelligence in education. The findings are expected to provide valuable insights for educators, policymakers, and institutional administrators seeking to leverage AI technologies to enhance teaching effectiveness, improve student learning outcomes, and promote data-informed educational decision-making in Nigerian universities.

Statement of the Problem

Despite global advancements in AI integration within higher education, many Nigerian universities continue to rely heavily on conventional assessment methods. While formative assessment is widely acknowledged as beneficial, there is limited empirical evidence regarding whether AI-generated formative assessment significantly predicts academic achievement in Chemistry within Nigerian tertiary institutions.

Without empirical validation, institutional investment in AI-driven assessment systems may lack policy justification. Therefore, this study investigates whether AI-generated formative assessment significantly predicts Chemistry academic achievement at EBSU.

Objective of the Study

The study aims to:

1. Examine the relationship between AI-generated formative assessment and academic achievement among undergraduate Chemistry students

Research Question

The following research was raised and answered;

1. What is the relationship between AI-generated formative assessment scores and academic achievement among undergraduate Chemistry students

Research Hypothesis

Ho: AI-generated formative assessment does not significantly predict academic achievement among undergraduate chemistry students

Literature Review and Theoretical Framework

Artificial Intelligence in higher education encompasses intelligent tutoring systems, adaptive learning platforms, automated scoring algorithms, and predictive analytics systems. AI platforms use machine learning algorithms to analyze learner behavior and performance patterns, enabling personalized instruction and automated feedback delivery.

Empirical studies in developed contexts demonstrate that AI-enhanced systems improve retention, engagement, and achievement. However, contextual adaptation remains critical in developing educational systems.

Formative assessment promotes metacognition and conceptual clarity. In Chemistry education, frequent low-stakes testing has been shown to enhance retention, improve problem-solving skills, and reduce cognitive overload. However, traditional formative approaches may lack adaptive personalization. AI systems address this gap by adjusting difficulty levels based on learner performance.

Educational Data Mining (EDM) and Learning Analytics frameworks emphasize the use of learner-generated data to predict academic outcomes. Continuous assessment scores have consistently demonstrated predictive validity. Yet, AI-specific formative systems remain underexplored within Nigerian universities.

This study integrates three complementary frameworks:

Constructivist Learning Theory

Learning occurs through active engagement and feedback. AI-generated assessments facilitate iterative knowledge construction. The Constructivist Learning Theory provides one of the principal theoretical foundations for understanding how Artificial Intelligence (AI)-generated formative assessment can influence students' academic achievement in Chemistry. The theory was initially developed by Jean Piaget (1952) through his work on cognitive development and was later expanded by Lev Vygotsky (1978), who emphasized the importance of social interaction and collaborative learning in knowledge construction. Constructivism views learning as an active, continuous process in which learners construct new knowledge by integrating new experiences with their existing cognitive structures rather than passively receiving information from teachers.

According to Piaget, learners develop knowledge through the processes of assimilation and accommodation. Assimilation occurs when learners interpret new information using their existing mental frameworks, whereas accommodation involves modifying those frameworks to incorporate new knowledge. Learning therefore occurs when students actively engage with instructional activities, encounter cognitive conflicts, and reorganize their understanding to achieve conceptual change. In Chemistry education, students are often required to modify previously held misconceptions about concepts such as atomic structure, chemical bonding, equilibrium, thermodynamics, and reaction mechanisms. Constructivist instructional approaches encourage students to investigate these concepts actively, reflect on their understanding, and reconstruct their knowledge through continuous feedback.

Vygotsky extended the constructivist perspective by emphasizing that learning is inherently social. His concept of the Zone of Proximal Development (ZPD) explains that students learn most effectively when they receive appropriate guidance or support while working on tasks slightly beyond their current level of competence. This instructional support, commonly referred to as scaffolding, enables learners to gradually develop independent mastery of complex concepts. AI-generated formative assessment aligns closely with this principle because intelligent assessment systems provide personalized hints, explanations, and adaptive questioning that support learners according to their individual needs. Instead of presenting identical questions to all students, AI systems adjust the difficulty level based on previous responses, thereby maintaining an optimal level of cognitive challenge within each learner's zone of proximal development.

Constructivist learning theory also emphasizes the importance of feedback in facilitating meaningful learning. Feedback enables learners to identify misconceptions, reflect on their thinking processes, and refine their understanding. AI-generated formative assessment strengthens this process by providing immediate, individualized, and data-driven feedback after each assessment activity. Unlike conventional paper-based assessments, where feedback may be delayed by several days or weeks, AI systems deliver instant explanations of correct and incorrect responses, recommend additional learning resources, and monitor students' progress over time. This continuous feedback promotes self-regulated learning, enhances metacognitive awareness, and encourages students to take responsibility for their own academic progress.

Another important principle of constructivism is active learner engagement. Students are expected to participate actively in solving problems, exploring concepts, conducting investigations, and evaluating their own learning. AI-powered formative assessment platforms facilitate this engagement by incorporating interactive quizzes, simulations, gamified learning activities, and adaptive problem-solving exercises. Such features are particularly valuable in Chemistry, where mastery depends on repeated practice, conceptual reasoning, and the application of scientific principles to novel situations. Through repeated interaction with AI-generated assessment tasks, students receive multiple opportunities to strengthen their conceptual understanding and develop higher-order thinking skills.

In addition, constructivism recognizes that learners differ in their prior knowledge, learning pace, and cognitive abilities. Consequently, effective instruction should accommodate individual learning differences rather than adopting a uniform teaching approach. AI-generated formative assessment embodies this principle through personalized learning pathways. Machine learning algorithms analyze students' responses, identify areas of weakness, and generate individualized assessment tasks that correspond to each learner's performance level. This adaptive capability ensures that both high-performing and low-performing students receive appropriate instructional support, thereby enhancing learning outcomes.

Within the context of this study conducted at Ebonyi State University, the Constructivist Learning Theory provides a strong theoretical explanation for how AI-generated formative assessment may influence students' academic achievement in undergraduate Chemistry. By delivering adaptive assessment, immediate feedback, personalized learning experiences, and continuous opportunities for reflection, AI technologies create a learner-centered environment that promotes meaningful knowledge

construction. Students are encouraged to identify their learning difficulties, correct misconceptions promptly, and progressively develop deeper conceptual understanding of Chemistry.

Furthermore, the theory supports the predictive role of AI-generated formative assessment. Because AI systems continuously collect and analyze students' learning data throughout the instructional process, they generate detailed information about learners' progress, engagement, and mastery of course content. These continuous performance indicators provide reliable evidence that can be used to predict students' final academic achievement. Thus, constructivist learning theory not only explains how AI-generated formative assessment facilitates learning but also justifies its use as a predictor of academic success in Chemistry

Feedback Intervention Theory (FIT)

The Feedback Intervention Theory (FIT) was developed by Avraham N. Kluger and Angelo DeNisi (1996) to explain how feedback influences individuals' performance, learning, and behavior. The theory posits that feedback is one of the most powerful mechanisms for improving performance because it helps learners compare their current level of achievement with desired learning goals. When feedback is timely, specific, accurate, and actionable, it directs learners' attention to areas requiring improvement and motivates them to modify their learning strategies. In educational settings, Feedback Intervention Theory has become one of the most widely used frameworks for understanding how assessment feedback contributes to students' academic success.

According to Kluger and DeNisi (1996), feedback is effective when it reduces the discrepancy between a learner's current performance and the expected standard of performance. The theory suggests that learners continuously evaluate their progress by comparing their actual achievements with predefined learning objectives. Whenever a gap exists between these two levels, feedback serves as a guide for corrective action. Consequently, the quality, timing, and relevance of feedback determine whether learning improves or deteriorates. Effective feedback redirects learners' attention toward the learning task, encourages reflection, and promotes sustained improvement, whereas poorly designed feedback may distract learners and reduce motivation.

Feedback Intervention Theory identifies three primary levels at which feedback operates. The first is the task-learning level, where feedback focuses on improving learners' understanding of specific concepts, correcting misconceptions, and enhancing problem-solving abilities. The second is the task-motivation level, where feedback influences learners' effort, persistence, and commitment to completing academic

tasks. The third is the self-related level, where feedback focuses on the learner as a person rather than on the learning task. Kluger and DeNisi argue that feedback directed toward task learning and task motivation is generally more effective than feedback centered on personal evaluation because it provides concrete guidance for improvement without threatening learners' self-esteem.

One of the major strengths of AI-generated formative assessment is its ability to provide immediate and individualized feedback, which aligns closely with the principles of Feedback Intervention Theory. Unlike traditional paper-based assessments where students may wait several days or weeks before receiving their results, AI-powered assessment systems provide instant responses immediately after students complete assessment tasks. This rapid feedback enables learners to identify errors while the learning experience is still fresh, thereby facilitating immediate correction of misconceptions and reinforcing accurate understanding. Research has consistently shown that immediate feedback enhances knowledge retention, improves conceptual understanding, and increases learner motivation (Shute, 2008).

AI-generated formative assessment systems further strengthen the feedback process through adaptive learning algorithms. These systems analyze students' responses, identify areas of weakness, and generate personalized recommendations for further study. For example, if a student repeatedly demonstrates difficulty in balancing chemical equations or understanding chemical equilibrium, the AI platform can provide additional practice questions, explanatory videos, hints, or supplementary instructional materials specifically related to those concepts. This personalized feedback ensures that learners receive instructional support tailored to their unique learning needs rather than generalized comments applicable to the entire class.

Feedback Intervention Theory also emphasizes the importance of continuous monitoring of learner progress. Effective feedback should not be viewed as a one-time event but rather as an ongoing process that supports continuous improvement throughout instruction. AI-generated formative assessment systems are particularly effective in this regard because they collect and analyze learning data over time, enabling both students and instructors to monitor performance trends across multiple assessment activities. Learning analytics dashboards generated by AI platforms display progress indicators, mastery levels, strengths, and weaknesses, allowing instructors to make evidence-based instructional decisions and enabling students to regulate their own learning more effectively.

Another important aspect of Feedback Intervention Theory is the promotion of self-regulated learning. Students who receive regular, meaningful feedback become more aware of their learning strengths and limitations. This awareness encourages them to set realistic learning goals, monitor their progress, evaluate their performance, and adjust their study strategies accordingly. AI-generated formative assessment supports this process by providing detailed performance reports, personalized study recommendations, and opportunities for repeated practice. Such features encourage learners to become active participants in their educational journey rather than passive recipients of instruction.

In the context of Chemistry education, where many concepts require sequential understanding and cumulative knowledge, continuous feedback is particularly essential. Topics such as atomic structure, stoichiometry, thermodynamics, kinetics, and organic reaction mechanisms build upon previously acquired knowledge. AI-generated formative assessment provides students with immediate corrective feedback after each learning activity, reducing the likelihood of persistent misconceptions that may negatively affect subsequent learning. Consequently, students develop stronger conceptual understanding, improved problem-solving skills, and greater confidence in handling complex Chemistry concepts.

Within the context of this study conducted at Ebonyi State University, Feedback Intervention Theory provides a strong theoretical explanation for the relationship between AI-generated formative assessment and students' academic achievement in Chemistry. AI-powered assessment platforms provide continuous, individualized, and actionable feedback that enhances students' understanding, increases motivation, promotes self-regulated learning, and supports timely instructional interventions. By reducing learning gaps throughout the semester, AI-generated formative assessment is expected to improve students' performance in end-of-semester examinations.

Furthermore, the theory supports the predictive nature of AI-generated formative assessment. Since AI systems continuously collect and analyze feedback data throughout the learning process, they generate comprehensive performance profiles that reflect students' progress, consistency, and mastery of course content. These data provide reliable indicators that can be used to predict final academic achievement. Therefore, Feedback Intervention Theory not only explains how AI-generated formative assessment enhances learning but also provides a theoretical basis for using formative assessment data to forecast students' academic success in undergraduate Chemistry.

Educational Data Mining Theory

Educational Data Mining (EDM) Theory provides a contemporary theoretical framework for understanding how large volumes of educational data can be analyzed to improve teaching, learning, assessment, and decision-making. The field of Educational Data Mining emerged in the early 2000s through the pioneering works of Ryan S. J. d. Baker and Kalina Yacef, who introduced computational techniques for discovering meaningful patterns from educational datasets. Educational Data Mining integrates principles from computer science, statistics, artificial intelligence, machine learning, psychology, and educational research to understand learners' behaviors and predict future academic outcomes (Baker & Yacef, 2009).

Educational Data Mining is based on the premise that every learning activity generates valuable data that can be systematically collected, processed, and analyzed to provide insights into students' learning processes. These data include students' responses to quizzes and examinations, assignment submissions, learning management system (LMS) activities, attendance records, time spent on learning tasks, discussion forum participation, clickstream data, and interaction with digital learning resources. Through sophisticated analytical techniques, these data are transformed into meaningful information that supports evidence-based educational decision-making.

A central principle of Educational Data Mining Theory is that learning data contain hidden patterns capable of explaining students' academic behavior and predicting future performance. Machine learning algorithms, data visualization techniques, classification models, clustering methods, regression analysis, and predictive analytics are commonly employed to identify these patterns. According to Baker and Inventado (2014), Educational Data Mining seeks not only to describe learning behaviors but also to develop predictive models that enable educators to identify students who may require additional academic support before poor performance occurs.

One of the major components of Educational Data Mining is predictive analytics, which involves using historical and current educational data to forecast future academic outcomes. Predictive models estimate students' likelihood of success, identify those at risk of academic failure, and recommend timely interventions. AI-generated formative assessment systems are particularly valuable because they continuously generate detailed learner data throughout the instructional process. These data include quiz scores, response accuracy, completion time, frequency of assessment attempts, confidence levels, error patterns, and learning progression. Such information enables AI systems to produce accurate predictions regarding students' final academic performance.

Another important concept within Educational Data Mining is learning analytics. While Educational Data Mining focuses on developing computational models for discovering hidden patterns, learning analytics emphasizes interpreting these findings to improve teaching and learning practices. Siemens and Baker (2012) noted that learning analytics supports instructors in monitoring student engagement, identifying learning challenges, evaluating instructional effectiveness, and making informed pedagogical decisions. AI-generated formative assessment systems integrate learning analytics by providing real-time dashboards that display students' progress, mastery levels, and areas requiring improvement. These dashboards enable instructors to provide targeted academic support while encouraging students to engage in self-regulated learning.

Educational Data Mining Theory also emphasizes the importance of continuous data collection rather than relying solely on end-of-semester examinations. Traditional assessment methods provide only a snapshot of students' achievement at a particular point in time. In contrast, AI-generated formative assessment systems collect data continuously throughout the learning process. Every interaction between the learner and the AI platform contributes to a comprehensive learner profile that reflects knowledge acquisition, conceptual understanding, learning consistency, and engagement. Continuous data collection allows educators to monitor learning progression more accurately and intervene promptly when students experience academic difficulties.

Another significant contribution of Educational Data Mining Theory is the identification of early warning systems. These systems use predictive algorithms to detect students who are likely to experience academic failure before final examinations. Early identification enables instructors to implement intervention strategies such as supplementary tutorials, individualized mentoring, remedial instruction, or additional learning resources. Research has demonstrated that early-warning systems based on educational data improve student retention, reduce failure rates, and enhance overall academic performance (Romero & Ventura, 2020). AI-generated formative assessment strengthens this capability because it continuously updates predictive models as new learner data become available.

Educational Data Mining Theory also recognizes the importance of personalized learning. Students differ in their prior knowledge, learning pace, motivation, cognitive abilities, and preferred learning strategies. AI-powered assessment systems analyze individual learning behaviors and generate personalized assessment tasks and feedback that correspond to each learner's needs. Students who consistently perform well may receive more advanced questions that stimulate higher-order thinking, while those experiencing learning difficulties receive additional practice opportunities and targeted

instructional support. Such adaptive learning environments improve learner engagement and increase the likelihood of academic success.

Within the context of Chemistry education, Educational Data Mining provides a particularly valuable framework because Chemistry involves sequential and cumulative learning. Students' understanding of advanced topics such as thermodynamics, chemical kinetics, organic reaction mechanisms, electrochemistry, and quantum chemistry depends heavily on mastery of foundational concepts. AI-generated formative assessment systems collect detailed performance data across these interconnected topics, enabling instructors to identify conceptual gaps before they become major barriers to learning. The predictive models generated through Educational Data Mining can therefore forecast students' likely performance in end-of-semester examinations based on their continuous formative assessment records.

In the context of Ebonyi State University, Educational Data Mining Theory provides a strong theoretical basis for investigating AI-generated formative assessment as a predictor of academic achievement in undergraduate Chemistry. The university's increasing adoption of digital learning technologies provides opportunities to generate rich educational datasets that can support evidence-based instructional planning and academic monitoring. AI-generated formative assessment platforms can assist lecturers in identifying learning difficulties, monitoring students' progress throughout the semester, and implementing timely interventions to improve learning outcomes. Simultaneously, students benefit from personalized feedback and adaptive learning experiences that enhance conceptual understanding and academic performance.

Furthermore, Educational Data Mining Theory directly supports the central objective of this study, which is to determine whether AI-generated formative assessment predicts academic achievement in Chemistry. Since AI systems continuously collect, analyze, and model learner data, the formative assessment scores generated throughout the semester represent meaningful indicators of students' learning progression and mastery of course content. These indicators can be statistically analyzed using correlation and regression techniques to determine their predictive power with respect to end-of-semester examination performance. Therefore, Educational Data Mining Theory provides both the conceptual and analytical foundation for examining the relationship between AI-generated formative assessment and academic achievement in undergraduate Chemistry.

Methodology

This study adopted a correlational research design to investigate the predictive relationship between AI-generated formative assessment and undergraduate students' academic achievement in Chemistry. The study was conducted at Ebonyi State University. The population comprised 300 second-year undergraduate students enrolled in Chemistry courses during the 2024/2025 academic session. A sample of 214 students was selected using stratified random sampling to ensure adequate representation of students across the various Chemistry programmes. Data were collected using two instruments: an AI-generated formative assessment platform, which administered weekly adaptive quizzes throughout the semester, and a Chemistry Achievement Test used to measure students' academic performance at the end of the semester. The AI-generated assessment platform was validated by experts in Educational Technology and Chemistry Education, while its internal consistency yielded a Cronbach's alpha coefficient of 0.88. The Chemistry Achievement Test had a reliability coefficient of 0.91. Data collection lasted for twelve weeks, after which students' formative assessment scores and end-of-semester examination scores were compiled for analysis. Descriptive statistics, including mean and standard deviation, were used to answer the research questions, while Pearson Product Moment Correlation and simple linear regression were employed to test the hypothesis at the 0.05 level of significance.

Results

Descriptive Statistics

Variable	Mean	SD
AI Formative Score	68.45	7.92
Academic Achievement	71.36	9.84

Correlation Analysis

Pearson correlation revealed:

$$r(212) = 0.72, p < 0.001$$

This indicates a strong positive relationship.

Regression Analysis

Model Summary:

- $R = 0.72$

- $R^2 = 0.52$
- Adjusted $R^2 = 0.51$
- $F(1,212) = 229.41$
- $p < 0.001$

AI-generated formative assessment significantly predicts academic achievement, explaining 52% of the total variance. The null hypothesis is rejected.

Discussion of Findings

The findings of this study revealed that AI-generated formative assessment significantly predicted undergraduate students' academic achievement in Chemistry at Ebonyi State University. The positive relationship indicates that students who consistently performed well in AI-generated formative assessments also obtained higher scores in the end-of-semester Chemistry examination. This suggests that AI-supported formative assessment serves not only as a learning tool but also as a reliable predictor of students' academic performance. The finding supports the principles of Constructivist Learning Theory, Feedback Intervention Theory, and Educational Data Mining Theory, which emphasize continuous feedback, learner engagement, and the use of learning data to improve educational outcomes.

The finding is consistent with the study of VanLehn (2011), who reported that intelligent tutoring systems and AI-supported instructional technologies significantly improved students' learning outcomes by providing immediate feedback and personalized learning experiences. VanLehn argued that adaptive AI systems enable learners to identify misconceptions promptly and improve conceptual understanding, resulting in higher academic achievement.

Similarly, the result agrees with Shute (2008), who found that formative feedback has a significant positive effect on students' academic performance because timely feedback helps learners identify weaknesses and adjust their learning strategies before summative assessments. The immediate feedback provided through AI-generated formative assessments in the present study may have contributed to the improved Chemistry performance observed among the participants.

The findings also corroborate those of Holmes, Bialik, and Fadel (2019), who reported that AI-based educational technologies improve teaching effectiveness by providing personalized assessment, adaptive learning pathways, and learning analytics that support both students and instructors. Their

study concluded that AI-assisted assessment enhances student engagement and facilitates evidence-based instructional decisions, thereby improving learning outcomes.

Furthermore, the present findings are consistent with Baker and Inventado (2014), who observed that educational data generated from continuous assessment activities can accurately predict students' future academic performance. According to the authors, predictive learning analytics enable institutions to identify academically at-risk students early and implement timely interventions. The significant predictive relationship observed in the present study reinforces the usefulness of AI-generated formative assessment as an early-warning indicator of academic success in undergraduate Chemistry.

The findings are also in agreement with Romero and Ventura (2020), who demonstrated that Educational Data Mining and learning analytics can successfully identify patterns in students' learning behaviors that are associated with academic achievement. They concluded that AI-driven predictive models provide educators with valuable information for improving teaching effectiveness and student performance.

However, the findings differ from those reported by Kulik and Fletcher (2016), who found that although intelligent tutoring systems generally improve students' academic performance, the magnitude of improvement varies considerably depending on the quality of technological infrastructure, learners' digital literacy, instructor competence, and institutional readiness. Their study suggested that AI technologies alone do not automatically guarantee improved academic performance unless they are supported by effective instructional practices. This difference may be attributed to contextual variations, institutional support, implementation strategies, and the level of student engagement with AI-based assessment platforms.

The present findings also contrast with the conclusions of Selwyn (2019), who cautioned that the effectiveness of AI in education depends on ethical implementation, equitable access to technology, and the preservation of meaningful teacher–student interaction. Selwyn argued that over-reliance on automated systems may reduce opportunities for collaborative learning and critical reflection. This divergence may be explained by the fact that the present study focused specifically on AI-generated formative assessment as a supplementary instructional tool rather than as a replacement for classroom teaching.

Overall, the findings demonstrate that AI-generated formative assessment has considerable potential to improve Chemistry education in Nigerian universities by promoting continuous assessment,

personalized feedback, and data-informed instructional decision-making. The significant predictive relationship observed in this study provides empirical evidence supporting the integration of AI-powered assessment systems into undergraduate Chemistry instruction at Ebonyi State University and other higher education institutions.

Conclusion

AI-generated formative assessment significantly predicts academic achievement in undergraduate Chemistry at Ebonyi State University. Institutional adoption of AI-driven assessment platforms can enhance performance monitoring, instructional quality, and student academic outcomes.

Recommendations

- Longitudinal predictive modeling across multiple semesters.
- Multi-institution comparative studies.
- Inclusion of mediating variables (motivation, digital literacy).
- Structural Equation Modeling (SEM) validation.

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