

The Predictive Power of AI-Generated Formative Assessments on Students' Academic Achievement in Chemistry

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Abstract

The cynosure of the study was to determine the potency of chemistry formative assessment generated by Natural Language Processing Artificial Intelligence tools in predicting students' academic achievement in Chemistry. The study adopted the correlational research design. The direction of the study was provided by two research questions and two hypotheses. The study sampled 336 final-year chemistry-education undergraduate students in Enugu State, Nigeria. The sample was drawn by simple random sampling across public tertiary institutions in the State. The instruments for data collection were "AI-Generated Chemistry Test Questionnaire" (AIGCTQ) and a proforma of students' achievement in Chemistry. The instruments were validated by three experts in the Department of Science Education, University of Nigeria, Nsukka. The reliability of AIGCTQ was 0.84, determined by Cronbach Alpha method. The data for the study was collected using google form and analyzed using Regression Analysis. Coefficient of determination was used for answering the research questions while the hypotheses were tested at 5% level of significance using regression t-test statistic. The findings of the study showed that AI-Generated Formative Assessment predicted 63.2% of students' achievement in Chemistry. Also, gender significantly moderated the predictive power of AI-Generated Formative Assessment on students' achievement in Chemistry. Based on the result, it was concluded that AI-generated formative assessments can be used to predict students' achievement in chemistry. Hence, it was recommended among others that parents and teachers should encourage students to use AI-Generated formative assessment questions for predicting students' academic achievement in Chemistry.

Keywords: AI-Generated, Artificial Intelligence, Formative Assessments, Natural Language Processing, Chemistry Achievement

Introduction

The current educational landscape has witness endless possibilities with the fusion of natural language processing artificial intelligence (NLP-AI) model in pedagogy. Artificial intelligence (AI) now influences pedagogical interventions and garner increasing commendation from educational stakeholders due to its transformative potentials that reshape students' learning and assessment experiences. According to Ugwoke et al. (2025), assessments are very crucial for evaluating aspects of educational development, especially in the formative

sense. Formative assessments have received ample literature support (Aparicio et al., 2021; Uduak et al., 2023; Nnaji et al., 2024). As crucial components of instruction, formative assessments are useful tools for tracking trends in ongoing learning supports (Stiggins & Chappuis, 2020). In this study, formative assessments include measures employed during the learning process to poke the effectiveness of instructional intervention, diagnose learning difficulties, call students' attention to important

points, or demand feedbacks that will be used to improve learning.

Formative assessments can also be done using AI technology, even with greater benefits and precision supposed. Onyido and Nwaogu (2022) highlighted that the possibilities of AI technology cannot be underestimated in the 21st century classroom, especially in assessments. According to Tamoliūnė et al. (2024), integrating AI technology enhances the efficacy of assessment, as such, AI should gain wide entry into classroom assessments. Artificial intelligence (AI) covers all machines and allied components that are capable of performing tasks which typically require human intelligence to execute (Xu & Ouyang, 2022). In this study, AI connote computerized systems capable of performing pedagogical-related tasks which require reasoning, perception and learning, as well as take decisions as if it was a thinking human teacher.

The enrichment of AI's capabilities hinges on three core principles which make the machine capable of behaving like a superhuman. Artificial intelligence (AI) leverages Machine Learning (ML) - data training algorithms to enable systems predict and make decisions without being explicitly programmed (Lo Piano, 2020); Deep Learning (DL) - uses neural networks with many layers ("deep") to analyze various factors of data (Andras et al., 2020); and Natural Language Processing (NLP) - combines computational linguistics, machine learning, and deep learning to process and analyze text and speech (Geetha & Gomathy, 2023; Chen et al., 2024). These principles enable AI to develop workable solutions for addressing human challenges; especially, NLP enables machines and data systems to understand, interpret, and generate human language in such applications like chatbots, translation services, and voice-activated assistants, towards addressing specific human need (Soori et al., 2023). Specifically, this principle can provide educational value for most classroom assessments (González-Calatayud et al., 2021; Dhara et al., 2022), especially in science subjects like Chemistry.

Chemistry stands out as a branch of science concerned with the properties, composition, behaviour and structure of matter. According Ezeudu et al. (2019a) highlighted that chemistry facilitates human understanding of common materials and processes, and equips most of the work force in the nation. Nwafor et al. (2023) defined chemistry as the study of matter, its applications, and reactions, highlighting its importance in daily life and efficiency. Chemistry connotes the scientific study of substances, their forms, and changes that characterizes them. It is the basics for most scientific

pursuits involving particles and matter. The importance of chemistry is felt in almost all areas of human life, including food and drinks preservation (Gude, 2017), chemical and technical emissions (Vooradi et al., 2019), water purification (Ihekweeme, 2023), management of environmental pollution and waste management (El Darai, et al., 2024), manufacturing (Santos et al., 2024), medicine and health (Rafique et al., 2024), among others. However, the achievement of students in chemistry has not been impressive; students generally underachieve in chemistry (Bedada & Fita, 2023), irrespective of gender. Following the serious concern this situation poses to educators and educational stakeholders, the present study sought to determine the predictive power of AI-Generated formative assessments on students' academic achievement in chemistry. This way, educators and stakeholders can trust the findings of this study in predicting students' academic achievement in chemistry, towards ensuring that students achieve satisfactorily in the subject, irrespective of their gender.

Gender has been a reoccurring issue of debate in chemistry, and other science related subjects. According to Saibu et al. (2023), gender contributes to the unsatisfactory achievement of students in chemistry. Ezeudu et al. (2019b) defined gender as a set of socially and culturally defined roles, behaviours, characteristics and qualities imposed on defined on individuals based on their biological and physiological appearances in different societies. To Ezeagwu and Nebo (2024), gender refers to social expectations on individuals based on their physiological and biological characteristics. This implies that cultural and environmental responses follow expectations from male and female chemistry-student gender groups, as viewed in this study.

Some scholars argue that gender gaps exist in chemistry (Jegade and Olu-Ajayi, 2017; Okeke, 2018; Irakoze et al., 2021; Rahama et al., 2024; Ezeagwu & Nebo, 2024). However, Ezeudu et al. (2019b); Saibu et al. (2023) revealed no significant difference between the achievement of male and female students in Chemistry. Some studies highlight that the adoption of AI technology in chemistry formative assessments may exacerbate the existing gender gaps (Hilale, 2021). Overall, Isaak et al., (2022); Carvaja et al., (2025) found that AI widened existing gender gaps in the disadvantage of females, perhaps due to the significant underrepresentation of females in the world of AI. These evidences have not depicted a consensus on the role of gender on students' academic achievement in chemistry, especially with AI-Generated formative assessments

(AI-GFAs) and underscores the need to investigate gender as a factor in this study.

Artificial intelligence (AI) adoption in formative assessments have continued to garner empirical support. Hwang et al. (2020); Richardson and Clesham (2021); Xu and Ouyang (2022) opined that adopting AI in assessments have the potential to rebrand education with objectivity, adaptability, consistency, convenience, enhanced efficiency, prompt-personalized feedback flexible access, rich multimedia resources, automatic grading and performance assessment, prompt identification at risk students, among others, with continuous learning improvements which meet standards and maintains educational quality. A plethora of scholars hoarded support for the integration of AI in assessments, in view of the ample benefits it amasses over traditional assessment (Martínez-Comesa et al., 2023; Slimi, 2023; Vieriu & Petrea, 2025; Ugwoke et al., 2025). Therefore, there is a need to investigate the role of AI-GFAs in chemistry education, both empirically and theoretically.

Theoretically, the study is grounded in Constructivist Learning Theory (CLT) by Vygotsky (1978). The CLT posit that knowledge is actively constructed by learners through experiences and interactions with their environment. When students engage AI-GFAs, they collaborate and subconsciously build social learning experiences with the AI systems, which aid in construction of knowledge to reach the Zone of Proximal Development (ZPD). The study aligns with the CLT since AI-GFAs foster personalized learning experiences and provides immediate feedback which enables students to take ownership of their learning processes, and, construct their own knowledge from exposure to AI-GFAs, as evident in previous studies.

Following mammoth evidences of enviable potentials associated with integrating AI in assessments, one could only wonder if the same outcomes can be replicated in chemistry-education formative assessments. More so, the concern if AI-GFAs is potent in predicting students' academic achievement in chemistry has to be assessed. The contribution of this study to the body of knowledge presents invaluable insights into the educational role of AI in formative assessments, thus promoting effective teaching and learning in chemistry. Therefore, the present study was compelled with the overarching need to investigate the predictive power of AI-GFAs on students' academic achievement in chemistry. To address the cynosure of this study, the following research questions were addressed in the study:

1. What is the predictive power of AI-Generated Formative Assessments on students' achievement in Chemistry?
2. What is the moderating influence of gender on the predictive power of AI-Generated Formative Assessments on students' achievement in Chemistry?

Hypotheses

HO₁: The predictive power of AI-Generated Formative Assessments on students' academic achievement in Chemistry is not significant.

HO₁: Gender does not moderate the predictive power of AI-Generated Formative Assessments on students' academic achievement in Chemistry.

Materials and Methods

The correlational research design was used in the study to determine the predictive power of AI-GFAs on students' academic achievement in chemistry. The correlation research design, according to (Devi et al., 2022) is non-experimental, applied in determining the strength and direction of the relationship(s) between two (or more) predictor variable(s) and criterion variable(s). The present study sought the predictive power of Artificial Intelligence Generated Formative Assessments (AI-GFAs, as predictor variable), on students' academic achievement in chemistry (as criterion variable) without manipulating any variable in the study.

The study was conducted in Enugu State, Nigeria. The study sampled 336 final-year chemistry-education undergraduate students in the two public universities (Enugu State University of Science and Technology [ESUT] and University of Nigeria, Nsukka [UNN]) in Enugu State, Nigeria. The sample size was determined using the Taro Yamene's formula. The sample comprised of 151 male students and 185 female students, who participated in the study (Figure 1). The sample was drawn from a population of 2,114 final-year chemistry-education undergraduate students in public universities in Enugu State. The sample for the study was drawn using a simple random sampling technique. Simple random sampling technique was considered appropriate for the study because the data for the study were collected online.

The researchers developed and used two instruments for data collection in the study following extensive literature review. The instruments, titled "AI-Generated Chemistry Test Questionnaire" (AIGCTQ) and a proforma of students' achievement in Chemistry. The instrument, AIGCTQ was designed on the four-point Likert scale response option type. AIGCTQ is made up of two sections;

Section A elicited students' demographic data, such as gender, school name and level of academic study, while Section B held 13 item statements on AI-Generated Formative Assessments. The proforma collected data on students' current academic records, Cumulative Grade Point Average (CGPA), a consent and an attestation of accurate data. The instrument was introduced in a short message which preceded the AIGCTQ.

The instruments were face validated by three experts in Measurement and Evaluation Unit and Chemistry Education Unit, Department of Science Education, University of Nigeria, Nsukka, in line with the purpose of the study. The suggestions and recommendations of the validators were considered and incorporated to produce the final version of the instruments. The internal consistency of the AIGCTQ was computed using the Cronbach Alpha method, and 0.84 was obtained. Cronbach Alpha method was considered more suitable for the polytomously rated scale. The data for the study was collected online, via the google form platform. In order to retrieve tallied data on both instruments, both were assessed through a single link (https://docs.google.com/forms/d/1obPEH0smTL_L

kFFHfNQwzqGp8CDnDXeB n-4HFHHpTFE/edit?chromeless=1) and participants submitted their responses at once, when completed online. The data for the study was collected between September 15th, 2024 and March 15th, 2025.

The data retrieved from the instruments were coded by the researchers, and prepared for analysis. The data collected from the study were converted to percentages to ensure comparability. Correlation "coefficients of determination" obtained from Linear Regression Analysis in Statistical Packages for Social Science (SPSS) and Haye's Process Macro were used to answer the research questions while the hypotheses were tested using the associated t-statistics, at 5% significance level, in the SPSS version 25.0 platform. Regression Analysis was considered more appropriate as the most suitable statistical tool for predicting the associations between the predictor and the criterion variables. Correlation coefficients (r) < 0.20 (very low), $0.20 \leq r < 0.40$ (low), $0.40 \leq r < 0.60$ (moderate), $0.60 \leq r < 0.80$ (high), and $0.80 \leq r \leq 1.00$ (very high) were used as mark-offs for variables association decision. The null hypothesis was only rejected when the associated p-value was less than 0.05.

Results

The results of the study are presented in order of the research questions and associate hypotheses.

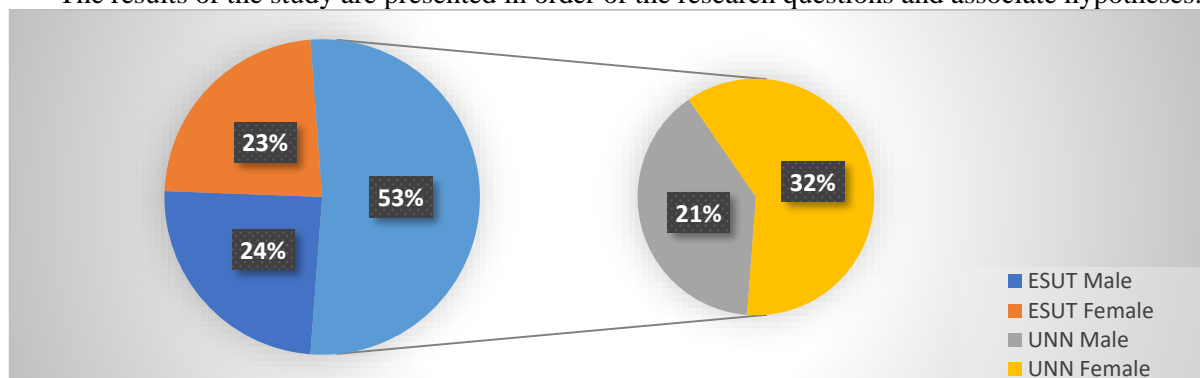


Figure 1: Percentage of sample distribution by gender for the Study

Figure 1 shows the demographic characteristics of the participants in the study. The analysis of the sample distribution for the study shows that 55% (185) participants are female while 45% (151) participants are male. The figure also

shows that female undergraduate chemistry students who participated in the study out-numbered their male counterpart by 10% (+34 female chemistry students).

Table 1

The predictive power of AI-GFAs on students' achievement in Chemistry

Model	n	R	R ²	Adjusted R ²	Std. Error of the Estimate
AIGFAs * CHEM_ACH	336	0.795 ^a	0.632	0.631	2.476

a. Predictors: (Constant), AI-Generated Formative Assessments

The result in Table 1 shows that the correlation coefficient between the predictor and criterion variables is 0.795. This indicates that there is a high positive association between Artificial Intelligence Generated Formative Assessments (AI-

GFAs) and students' academic achievement in chemistry. The coefficient of determination, R^2 of 0.632 indicates that AI-GFAs predict 63.2% of students' academic achievement in chemistry.

Table 2

Significance of the predictive power of AI-GFAs on students' achievement in Chemistry

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	25.264	1.200		21.060	0.000
AI-GFAs	0.656	0.027	0.795	23.939	0.000

a. Dependent Variable: Chemistry Achievement

The result in Table 2 shows that the t-value of 23.939 and an associated p-value of 0.000, $t(1, 335) = 23.939$, $p = 0.000$ was obtained for the predictive power of Artificial Intelligence Generated Formative Assessments (AI-GFAs) on students' academic achievement in chemistry. Since the probability value of $0.000 < 0.05$ at 5% level of

significance, the researchers reject the null hypothesis one which states that the predictive power of AI-GFAs on students' academic achievement in Chemistry is not significant. Therefore, the predictive power of AI-GFAs on students' academic achievement in Chemistry is significant.

Table 3

Moderating influence of gender on the predictive power of AI-GFAs on students' achievement in Chemistry

Model	n	R	R^2	MSE	F
AIGFAs * CHEM_ACH * Gender	336	0.7998 ^a	0.6397	6.0336	196.5168

a. Predictors: (Constant), AI-Generated Formative Assessments

The result in Table 3 shows that the correlation coefficient between the predictor and criterion variables when moderated by gender is 0.7998. This indicates that there is a high positive association between AI-GFAs and students'

academic achievement in chemistry when moderated by gender. The coefficient of determination, R^2 of 0.6397 indicates that AI-GFAs predict 63.97% of students' academic achievement in chemistry when moderated by gender.

Table 4

Significance of the moderating influence of gender on the predictive power of AI-GFAs on students' achievement in Chemistry

	coeff	se	t	p	LLCI	ULCI
constant	27.9132	1.5744	17.7296	0.0000	24.8161	31.0102
AI_GFAs	0.5929	0.0361	16.4101	0.0000	0.5218	0.6640
Gender	-6.0830	2.4077	-2.5265	0.0120	-10.8193	-1.3468
Int_1	0.1439	0.0549	2.6199	0.0092	0.0359	0.2520

Product terms key:

Int_1 : AI_GFAs x gender

The result in Table 4 shows that the t-value of 2.6199 and an associated p-value of 0.0092, $t(1, 335) = 2.6199$, $p = 0.0092$ was obtained for the predictive power of Artificial Intelligence Generated Formative Assessments (AI-GFAs) on students'

academic achievement in chemistry under the moderating influence of gender. Since the probability value of $0.0092 < 0.05$ at 5% level of significance, the researchers reject the null hypothesis two which states that gender does not moderate the predictive power of

AI-Generated Formative Assessments on students' academic achievement in Chemistry. Therefore, gender significantly moderates the predictive power of AI-GFAs on students' academic achievement in Chemistry.

Discussion of Findings

The findings of the study revealed that Artificial Intelligence Generated Formative Assessments (AI-GFAs) predicts students' academic achievement in chemistry. Also, the predictive power of AI-GFAs on students' academic achievement in Chemistry is statistically significant. The findings of this study may have turned out so due to the wide acceptance of AI in educational engagements. Most students are familiar with AI and use the same in their academic tasks. Also, the findings of this study may have turned out so due to many educational possibilities that have been identified with the use of AI. Students now rely on AI for addressing their academic challenges. Furthermore, AI has been associated with objectivity, accuracy and efficiency in generating personalized feedback for students, which enable teachers and students focus on what is essentially important (Owan et al., 2023).

The findings of this study align to certain extents with the findings of previous studies in literature. The findings of this study agree with that of Vieriu and Petrea (2025) to the extent that AI formative assessments can improve students' academic achievement. Also, it agrees with those of Martínez-Comesa et al. (2023); Ugwoke et al. (2025) to the extent that AI can be effectively used for formative assessments to enhance students' academic achievement. The findings of this study call to mind the need for AI to be widely adopted in schools for chemistry formative assessments as it has demonstrated a high potential to improve students' academic achievement in chemistry.

The findings of the study revealed that gender has a moderating influence on the predictive power of Artificial Intelligence Generated Formative Assessments (AI-GFAs) on students' academic achievement in chemistry. Also, the moderating influence of gender on the predictive power of AI-GFAs on students' academic achievement in chemistry is statistically significant. The findings of this study may have turned out so due to the inherent gender differences in terms of manipulating technological tools and devices. Males are often favoured when technology is involved, especially in the nascent stages. The general cultural perspectives see females as gullible and incapable of navigating technological bottlenecks, presuming that males have a "superior-ability" to address such situations. Also,

the result may have turned out so due to the existing difference in male and female students' achievements in chemistry accounted in the literature prior to the study which may have affected the engagements of bot gender in the study (Rahama et al. 2024; Ezeagwu & Nebo, 2024).

The findings of this study align to certain extents with the findings of previous studies in literature. The findings of this study agree with that of Armutat et al. (2024); Carvaja et al. (2025) to the extent that gender influences the relationship between AI formative assessments and students' academic achievement. Also, it agrees with those of Rahama et al. (2024); Ezeagwu and Nebo (2024) to the extent that AI-GFAs can influence students' academic achievement in chemistry. However, the findings of this study disagree with the findings of Ezeudu et al. (2019b); Saibu et al. (2023) who found no difference in students' chemistry achievement, to the extent that the AI-GFAs can influence students' academic achievement in chemistry. The findings of this study call to mind the moderating influence of gender on the relationship between AI adoption in schools for chemistry formative assessments on students' academic achievement in chemistry.

Conclusion

The curiosity in the study was the predictive power of AI-GFAs on students' academic achievement in chemistry. This was fueled by the evolving role of gender in growing fields of human endeavours in the current century; perhaps, it could serve essentially to improve students' academic achievement in chemistry. The researchers concluded that Artificial Intelligence Generated Formative Assessments (AI-GFAs) predicts students' academic achievement in chemistry. Also, students' gender moderates the predictive power of AI-GFAs on their academic achievement in chemistry.

Recommendations

Relying on the outcome of this study, the researchers recommended that:

1. Students should leverage AI-Generated formative assessment questions for predicting their academic achievement in chemistry.
2. Teachers should encourage students to use AI-Generated formative assessment questions for predicting students' academic achievement in chemistry.
3. Parents should encourage students to use AI-Generated formative assessment questions for predicting students' academic achievement in chemistry.

4. Government should collaborate with experts in providing support, training, facilities and adapting AI infrastructure to local chemistry content syllabus for effective implementation AI-Generated formative assessments in predicting students' academic achievement in Chemistry.

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