



Examining the Integration of Artificial Intelligence in Undergraduate Chemistry Education Programmes

Stephen Chinedu Nwafor & Maria Tsakeni

Department of Mathematics, Natural Sciences and Technology Education, Faculty of Education, University of the Free State, Bloemfontein, South Africa

ORCID: <https://orcid.org/0000-0003-2220-9748>

ORCID: <https://orcid.org/0000-0003-3208-1362>

Corresponding Author: Nwafor.SC@ufs.ac.za

Abstract

This study examined the integration of artificial intelligence (AI) in Chemistry Education programmes in universities. A quantitative approach was used; specifically, a descriptive survey research design was adopted. The study was done using 224 respondents comprising 209 undergraduate chemistry education/natural science students and 15 science education lecturers with a speciality in Chemistry or natural science in South Africa and Nigeria. A questionnaire entitled “Integration of Artificial Intelligence in Chemistry Education Programmes (IAICEP)”, developed by the researchers, was used for data collection and shared with the respondents using a Google form link. The internal consistency of QIAICEP was established using Cronbach alpha to be 0.86 after validation by three experts. Mean and standard deviation were used to answer the research questions, while an independent sample t-test was utilised to test the hypothesis at a 0.05 level of significance. The results showed that both students and lecturers perceived that the integration of artificial intelligence into Chemistry Education programmes is to a low extent. However, they acknowledge the positive influence of AI in improving students’ learning outcomes by improving their accessibility to educational materials, and increasing their problem-solving skills, interactivity and interest in learning. Also, the challenges encountered by institutions towards incorporating AI into the chemistry education programmes are the high cost of AI tools, insufficient resources, poor training of teachers and students, difficulty in integrating AI into the existing curriculum and poor knowledge of the ethical considerations of AI. The researchers recommended the establishment of partnerships with technology companies to provide students with internship opportunities and lecturers with professional training focused on AI and its usage in education.

Keywords: Artificial intelligence, Chemistry education programmes, learning outcome, challenges and universities

Introduction

One of the scientific courses available to senior high school students is chemistry. The study of composition, structure, characteristics, and reactions of matter, particularly at the atomic and molecular levels, is known as chemistry. Many facets of our everyday existence, including food, medicine, and the materials used in production, are supported by this fundamental science (Ajayi, 2017). The scientific study of matter, including its characteristics, composition, structure, behaviour, and the changes it goes through during chemical reactions, is known as chemistry. Students are taught Chemistry to develop knowledge and scientific

skills to understand the structure and properties of matter. The teaching of Chemistry in secondary schools is carried out by Chemistry teachers. According to Chikendu (2022), chemistry teachers are professionally trained with pedagogical skills and comprehension to successfully impart the content and relevant instructional materials to the students. Chemistry teachers in the digital era are expected to utilise ICT facilities in teaching and training students to develop ICT skills. As technology becomes more and more integrated into the classroom, educators must be adept at using a diversity of digital tools and have the



motivation to fully train and equip themselves with the abilities, know-how, and mindsets needed to succeed in a variety of dynamic learning contexts.

In most universities in South Africa, there is an evolving advancement of technology in higher education. Hence, Tundrea (2020) called for the reappraisal of current Programmes to ensure a better integration of AI in pre-service teachers. In response, the government of South Africa launched a five-year plan in 2025 to press forward the digitalisation of the country without leaving any sector. This they hope to achieve through technological policy, fast and affordable internet connectivity and access (Department of Communications and Digital Technologies (DCDT), 2025). Similarly, the Core Curriculum and Minimum Academic Standards (CCMAS) were introduced by the Federal Government of Nigeria through the Ministry of Education and have been in effect for the past two academic sessions. The CCMAS for Chemistry education program was created to be used in all Nigerian universities for the purpose of training teachers who are digitally literate and capable of handling virtual instruction; facilitating the development of pre-service teachers' entrepreneurial knowledge, attitudes, and abilities; helping pre-service teachers develop their science process and manipulative skills; and helping graduates develop their scientific literacy to solve societal issues. The following 21st-century skills will be acquired and developed as a result: problem-solving and digital skills; quantitative reasoning skills; self-reliance and initiative; critical and creative thinking skills; research and interrogative questioning skills; creativity, curiosity, imagination, and innovation skills; and IT and health and safety skills. Graduates in chemistry education would get the abilities required to create electronic resources for successful chemical instruction in this digital age. Therefore, integrating new technologies, such as AI, is a creative way to accomplish the goal of CCMAS.

The incorporation of AI in Chemistry education programmes at tertiary institutions has become an increasingly important focus for educational innovation and development. As AI technologies rapidly advance, their impact on various industries and disciplines has necessitated a corresponding evolution in educational curricula. A lot of students are already aware of how to utilise the products of AI in their various educational activities, as AI tools are readily available on their phones and laptops. Therefore, it has become paramount to recognise the capabilities and attributes of

artificial intelligence beyond researching assignments and school projects.

Artificial Intelligence (AI), according to Chen et al. (2020), is a computing system that can learn, adapt, synthesis, self-correct, and use data for intricate computation tasks, all of which are human-like activities. It is an evolving computer system used to perform tasks such as decision making, solving problems and reasoning to improve how humans get information and other services. For Dergunova et al. (2022), AI is an intelligent machine that has the capacity to use computers to mimic memory, aptitude, learning, analysis, and even creativity. It is a fast-emerging area of computer science that typically requires human intellect. That is, it is a machine or programme that exhibits intelligence that can make decisions, translate between different languages. And recognise speech to complete tasks. It is the simulation of human intelligence, like the representation of information, self-correction, preparation, movement, thinking, imagination, and manipulation by technology. The idea, according to Hashem et al. (2023), is to utilise pattern recognition and algorithms that learn from human behaviour to offer machines independence and intelligence.

In Africa, including Nigeria and South Africa, AI-driven tools have been used to transform the educational system through the growth of inventive ideas. These AI-driven tools are used in teaching and learning in higher institutions, providing a new opportunity to improve the value of instruction. It has changed and developed new social interaction areas of interest. Some examples of leveraging AI in instruction are evident in adaptive learning management systems, learning analytics dashboards, human-computer interactions, machine translation tools, teaching robots, and intelligent tutoring systems (Kaur, 2021; Cleopas, 2023; Chen et al., 2020). It provides support to the students and enhances learning. Similarly, Hasanov et al. (2019) believed that the teacher uses AI techniques as models to facilitate teaching. Suggestion systems are computer programs that make recommendations for practical things that someone could find interesting. They are based on machine learning and information extraction methods (Syed & Zoga, 2018).

The use of AI tools has transformed several industries and fields like social media (Udeze et al., 2015); banking and entertainment (Karaca, 2020); film (Obiora & Adikuru, 2024); communication (Shadrach & Adikuru, 2023); and education (Nwodu, 2025; Egara & Mosimege, 2024). According to Lin (2022), AI tools



in education can be described as educational technologies that are used to enhance teaching effectiveness. These tools will promote the understanding of the students and enhance differentiated instructions. Recent AI tools can be used to make accurate predictions and solve problems (Holmes et al, 2023); assist lecturers in providing more precise instruction and providing more scientific practice ideas (Lin, 2022). For some researchers like (Lo, 2023; Uzunboylu et al., 2022; Ogurlu & Mossholder, 2023; Baker, 2021), AI-powered tools such as Canva, ChapPDF, Quillionz, ChatGPT, Quillbot, Turnitin, Socrative can be used to ensure and/or enhance designs, generate ideas, research purpose, paraphrase, writing, check the originality of students' or researcher's work, understand educative documents, and create quiz questions and assessment. Moreover, some of the merits of AI in the education sector include access to information, distance learning, personalized learning, tracking of students attendance, assessment of students learning progress (Nalbant, 2021; Abid, 2019;). According to Gracia-Martinez et al. (2023), studies on AI and computational sciences have aroused a growing interest in education, giving rise to improved student achievement.

The recent explosion in AI technology has made it so that businesses, organisations and institutions of learning have had to adapt to the changes brought about by these developments. As AI permeates daily life more and more, it is critical to assess how it will affect education (Asirit & Hua, 2023), including possible challenges encountered in the process. Some of these challenges according to Omobolanle (2024) are inability to interpret and utilize AI generated data for teaching, concerns about the privacy, lack of institutional support, insufficient resources for implementing AI in teaching, struggles to integrate AI seamlessly into the existing teaching methods and curriculum, and administrators to the adoption of AI in teaching. Interestingly, these barriers notwithstanding, studies in South Africa, Kenya, Egypt, and Rwanda (Folorunso et al., 2024; Tawil & Miao, 2024; Ifenthaler et al., 2024; Gikunda, 2023) have reported a positive influence of AI on students' engagement and achievement. Also, existing research (Shahsavar & Choudhury, 2023) highlights that awareness and AI-enhanced teaching can vary significantly among lecturers and students influenced by factors such as access to information, institutional support, and disciplinary differences. This could be due to the lack of AI in the curriculum and the lack of AI knowledge,

as most lecturers do not have the capabilities of AI technologies and cannot actively incorporate them into their teaching practices, while others may be hesitant or unaware of the potential benefits. While universities in developed nations are making notable strides in AI, universities in Africa seem to be confined to conventional teaching. Though some students know the importance of AI within education, its integration into university programmes like Chemistry education is still far-fetched, as most universities have yet to fully integrate ICT into their learning, not to mention AI integration. To achieve the demands of the modern world, undergraduate chemistry education students in Nigerian and South African universities need to know how to use AI. They also need to possess the necessary skills and abilities to analyse information using AI-enhanced tools. Studies have suggested the need to comprehensively integrate AI into university programmes; however, the extent of this integration in programmes like Chemistry education is empirically unknown. Consequently, this study explored students' perceptions on the extent to which AI is integrated into Chemistry education programmes in universities in Nigeria and South Africa, along with the challenges faced by these institutions in integrating AI into their programmes.

Rogers' Diffusion of Innovation (DOI) Theory (1962), which attempts to explain how, why, and at what pace new ideas and technologies spread, serves as the theoretical foundation for this investigation. It aids in understanding how innovations and new technologies proliferate in a society and how to guarantee their uptake. It explains how a new concept, behaviour, or product develops traction over time and diffuses (or spreads) among a specific population or social system, ultimately leading to individuals embracing it as a component of that system. Adoption is the act of someone doing something different from what they used to do (e.g., learning and performing a new behaviour, skill, etc., or purchasing or utilising a new product). The main factor influencing adoption is whether or not a person thinks the idea, action, or product is creative or original, which permits diffusion. When marketing an invention, behaviour, skills, habits, and knowledge—all of which are essential components of human life—it is imperative to understand the characteristics of the target audience that will either help or hinder the adoption of the innovation (such as artificial intelligence). The theory offers a conceptual structure for grasping and appreciating the process of diffusion and social change to those who are interested



in the diffusion of innovation. This theory underpins the study because the innovations of using digital technologies, such as Artificial intelligence, are important for delivering instructions in Chemistry education. The use and adoption of AI usually originates from the teachers and educational administrators and then spreads or diffuses to the students and schools at an incremental level. Through this, the students acquire a level of skills and apply the innovations (artificial intelligence) in solving many problems through the use of better innovative practices and techniques. The application of this theory of innovation is of importance to this research work and the development of human capacity in not just Chemistry education but science education.

Research Questions

The research questions that guided the study include;

1. What is the extent of AI integration in Chemistry education programmes as perceived by the lecturers and students?
2. What is the influence of artificial intelligence on chemistry education students' learning outcomes?
3. What are the challenges encountered by institutions in integrating artificial intelligence into Chemistry education programmes?

Hypothesis

The study was guided by one null hypothesis and tested at a 0.05 level of significance.

HO₁: There is no significant difference between the mean response of the lecturers and students on the extent of AI integration in Chemistry education programmes.

Methodology

The study utilised a quantitative approach, specifically, a descriptive survey research design. Descriptive survey research involves the collection of data from a sample of the population considered a representative of the entire group (Nworgu, 2018). This design is considered fitting because the views of the

respondents (lecturer & students) were collected and analysed to determine the extent of AI integration in Chemistry education programmes. The participants included the 224 3rd year undergraduate students and 15 lecturers at the: Department of Mathematics, Natural Science and Technology Education, University of the Free State, South Africa (59 natural science students & 3 lecturers); Department of Science Education, Chukwuemeka Odumegwu Ojukwu University, Igbariam, Anambra State, Nigeria (75 Chemistry education students & 6 lecturers); and Department of Science Education, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria (75 Chemistry education students & 6 lecturers). A questionnaire entitled "Integration of Artificial Intelligence in Chemistry Education Programmes (IAICEP)" made by the researchers was used for data collection. The Google form link of the questionnaire was sent to the students and lecturers through their WhatsApp numbers, of which only 224 respondents (209 students & 15 lecturers) filled the form and submitted it. Following validation by three experts, the internal consistency of IAICEP was determined using Cronbach alpha to be 0.86. The study issues were addressed using the mean and standard deviation, and the hypothesis was tested at the 0.05 level of significance using the independent sample t-test. "A" and "B" were the two sections of the questionnaire. While Section "A" contained the respondents' biographical information, Section "B" contained 23 items organised according to a modified four-point Likert scale: Agree (A) = 3, Disagree (D) = 2, and Strongly Disagree (SD) = 1. Three experts performed the face validation of the instrument. Cronbach Alpha was used to calculate the internal consistency, and the result was an estimate of 0.89. The study issues were addressed using mean and standard deviation, and the hypothesis was tested at the 0.05 level of significance using the independent sample t-test in SPSS Version 25. Any item with a mean rating of 2.5 and above indicated a positive response or agreement (high extent), while items with a mean rating of 2.49 and below indicated a negative response or disagreement (low extent).

**Results****Table 1: Mean and standard deviation of the extent of AI integration in Chemistry education programmes as perceived by the lecturers and students**

S/N	Items	Mean	SD	Decision
1.	Deep Learning classes are part of the chemical education program at my school.	2.17	0.92	Low Extent
2.	Early program introductions to artificial intelligence courses are introduced early in my school to provide me with lots of opportunities to learn more about the subject.	1.95	0.86	Low Extent
3.	The chemistry education curriculum includes robotics assignments and projects as part of the core course assignments.	2.16	0.97	Low Extent
4.	The programme of study for Chemistry Education is designed to use computer vision and concepts.	3.11	0.79	High Extent
5.	In order to meet industrial demands, the Chemistry Education program in my institution is designed to use big data technology.	2.16	0.78	Low Extent
6.	We have sufficient lecturers with AI expertise to teach AI and related courses	2.25	0.79	Low Extent
7.	The chemistry education programmes at my university have sufficient computing resources and software tools for hands-on AI instruction.	1.89	0.76	Low Extent
8.	Specialised AI courses like AI for social good and AI safety are covered in the chemical education programmes.	2.38	0.93	Low Extent
9.	One of the topics covered in the chemistry education curriculum is the ethical implications of artificial intelligence.	2.21	0.82	Low Extent
10.	As part of the chemistry curriculum, my school offers classes on Natural Language Processing (NLP) and other topics linked to AI.	2.26	0.84	Low Extent
11.	Data science assignments and projects are a component of the chemistry education program's fundamental course.	2.81	0.77	High Extent
12.	Research projects utilising artificial intelligence programming and techniques frequently employed in AI advancements are encouraged by the Chemistry Education programmes in my school.	2.31	0.95	Low Extent
13.	My institution's chemistry education programmes have sufficient access to datasets for hands-on AI instruction.	2.06	0.95	Low Extent
	Clustered mean	2.29	0.45	Low Extent

Table 1 shows that items 1, 2, 3, 5, 6, 7, 8, 9, 10, 12 and 13 were to a low extent, while items 4 and 11 were to a high extent. Moreover, 2.29 and 0.45 were obtained as the cluster mean and standard deviation,

respectively. This reveals that artificial intelligence is integrated into chemistry education programmes to a low extent.



Table 2: t-tests Analysis of the difference between the mean response of the lecturers and students' perceptions on the extent machine learning is integrated into Chemistry education programmes

Respondents	N	Mean	SD	t-value	df	P-value	Dec.
Lecturers	15	2.45	0.52	1.428	222	.155	NS
Students	209	2.27	0.44				

SD = standard deviation, Dec. = Decision, NS = Not Significant

Table 2 reveals that (t-value = 1.428, df = 222, P-value = 0.397). Hence, the null hypothesis is not rejected, which indicates that there is no significant difference between the mean response of the lecturers and students on the extent of AI integration in

Chemistry education programmes. This implies that both lecturers and students share the same opinion on the extent AI is integrated into Chemistry education programmes.

Table 3: Mean and standard deviation of the influence of artificial intelligence on chemistry education students' learning outcomes

S/N	Items	Mean	SD	Decision
14.	Chatbots and tutoring systems are examples of AI-powered solutions that have enhanced my access to educational materials.	3.65	0.54	Agreed
15.	My learning results have improved thanks to the tailored feedback that AI-based solutions offer.	3.16	0.71	Agreed
16.	AI-powered platforms increase the interactivity and interest of learning.	3.09	0.84	Agreed
17.	My ability to solve problems has improved because of AI's interactive and adaptive learning activities.	3.22	0.82	Agreed
18.	My academic achievement has improved as a result of AI.	3.28	0.63	Agreed

Table 3 shows that the AI influences chemistry education students' learning outcomes, including improving their accessibility to educational materials ($\bar{x} = 3.65$, SD = 0.54), enhancing effective feedback ($\bar{x} = 3.16$, SD = 0.71), increasing the

interactivity and interest of learning ($\bar{x} = 3.09$, SD = 0.84), improving their ability to solve problems ($\bar{x} = 3.22$, SD = 0.82) and academic achievement ($\bar{x} = 3.28$, SD = 0.63).

Table 5: Mean and standard deviation of the challenges encountered by institutions in integrating artificial intelligence into Chemistry education programmes

S/N	Items	Mean	SD	Decision
19.	High cost of AI tools	3.88	0.32	Agreed
20.	Insufficient resources	3.50	0.61	Agreed
21.	Poor training of teachers and students	3.31	0.73	Agreed
22.	Difficulty in integrating AI into the existing curriculum.	3.70	0.49	Agreed
23.	Poor knowledge of the ethical considerations of AI	3.31	0.68	Agreed

Table 4 reveals that the challenges encountered by institutions in integrating artificial intelligence into Chemistry education programmes include the high cost of AI tools ($\bar{x} = 3.88$, SD = 0.32), insufficient resources ($\bar{x} = 3.50$, 0.61), poor training of teachers

and students ($\bar{x} = 3.31$, SD = 0.73), difficulty in integrating AI into the existing curriculum ($\bar{x} = 3.70$, 0.49) and poor knowledge of the ethical considerations of AI ($\bar{x} = 3.31$, SD = 0.68). This is because their mean scores were above the mean cut-off point of 2.50.



Discussion

The investigation showed that both lecturers and students opined that artificial intelligence is integrated into chemistry education programmes to a low extent. It's revealed that the use of AI programming and tools is commonly not encouraged, there are few lecturers with expertise in AI, and there are no courses on AI and chemistry education. The finding of the study supports those of Nwodu (2025) and Ibrahim et al. (2024), who acknowledged in their respective studies that the use of AI is still in its nascent stage in most Nigerian and African universities due to many challenges, such as a lack of AI resources and expertise among the academic communities. Also, in line with the result, Tundrea (2020) disclosed that due to the inherent barriers to AI in schools, many universities in South Africa lack the ability to ensure a successful integration of AI into university programmes. Conversely, the findings of the study are against those of Kong et al. (2021) and Lérias et al. (2024), who reported a high integration of AI in Chinese and Portuguese universities, respectively. Similarly, the study negates the finding of Touretzky et al. (2022) that AI courses are taught in K-12, computer science and science curricula in the United States of America. The difference between the results could be due to the availability of AI-driven tools in schools in the mentioned countries.

The study showed that artificial intelligence influences chemistry education students' learning outcomes by improving their accessibility to educational materials, enhancing effective feedback, increasing the interactivity and interest of learning, improving their ability to solve problems and their academic achievement. This could be because AI provide an opportunity for personalised learning. The findings of the study corroborate with Egara and Mosimege (2024) and Lin (2022), who revealed in their various studies that AI-driven tools help in enhancing students' academic achievement, engagement, understanding, interaction, teaching effectiveness and personalised learning. This indicates that both the lecturers and students benefit from AI towards the all-around achievement of the educational objectives. The finding is in agreement with Gracia-Martinez et al. (2023), who showed that AI has the potential to arouse the general interest in education, given rise to improved student achievement. Similarly, Yahya & Mohamed (2024) and Pati et al. (2023) affirmed that AI has the prospective to increase students' abilities in

communication, provide real-time feedback, promote critical thinking, teamwork, and adaptive learning. Also, Goodfellow et al. (2016) averred that embedding AI-powered educational tools into learning enhanced teacher-student interactions, personalised learning, and accessibility to quality education.

The challenges encountered by institutions in integrating artificial intelligence into Chemistry education programmes are costly AI tools, deficient resources, poor training of teachers and students, difficulty in integrating AI into the existing curriculum and poor knowledge of the ethical considerations of AI. These findings corroborate with those of Omobolanle (2024), which revealed that the implementation of AI in Africa is affected by a lack of institutional support, insufficient AI resources, concerns about ethical considerations and teachers' and students' inability to effectively utilise AI-generated data and tools. This finding is also in agreement with Ogunode (2020) and Edinoh et al. (2024), who in their various studies revealed that the challenges to the implementation of AI in developing countries are poor infrastructure, poor knowledge of AI by both the teachers and students and lack of institutional support. Also, the finding aligns with Pansoni et al. (2023) and Ogunode and Agwor (2021) that due to a shortage of funds, a lack of AI-driven tools, cultural resistance, and poor internet connectivity

Conclusion

The researchers concluded based on the findings that AI influences the learning outcome of Chemistry education students, but the adoption of AI in chemistry education programmes is to a low extent. Moreover, the challenges encountered by institutions towards incorporating AI into the chemistry education programmes are the costly AI tools, deficient resources, poor capacity building of teachers and students, difficulty in integrating AI into the existing curriculum and poor knowledge of the ethical considerations of AI. There is therefore an urgent need for institutions in Nigeria to provide students with AI dexterity for success and prioritise the development of a comprehensive AI programme and possible integration of AI into existing programmes towards the preparation of students for future careers in a technology-driven world.



Recommendations

1. Institutions should collaborate with industry experts to develop a curriculum that incorporates practical applications of artificial intelligence.
2. Lecturers should undergo professional development training focused on the latest advancements in AI to enhance their teaching effectiveness.
3. Educational policymakers should allocate funding for AI research initiatives and infrastructure improvements within science education departments which house the chemistry education programmes.
4. Institutions should establish partnerships with technology companies to provide students with internship opportunities that focus on AI projects.
5. Academic leaders should promote interdisciplinary courses that integrate AI with other fields, such as healthcare, agriculture, and business, to broaden the scope of education and real-world applications.

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