REVIEW OF LITERATURE ON INTEGRATION OF AI TOOLS IN CURRICULUM DESIGN AND CONTENT DELIVERY IN CHEMISTRY EDUCATION

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Abstract
Artificial Intelligence (AI) is transforming chemistry education by supporting curriculum design, instructional material development, personalized learning, assessment, virtual laboratories, simulations, and immediate feedback. In Nigeria, AI can help students understand difficult chemistry concepts and enable teachers to improve teaching efficiency and learner engagement. However, its effective use is limited by challenges such as poor electricity and internet connectivity, high data costs, inadequate teacher training, limited institutional support, financial constraints, academic integrity concerns, inaccurate AI-generated information, data privacy, and unequal access to digital devices. Nigerian studies, including research from Rivers State, show growing interest in AI and its potential to improve students' learning outcomes. The article concludes that AI should complement rather than replace chemistry teachers, laboratory practicals, and inquiry-based learning. Effective integration requires continuous teacher training, improved digital infrastructure, responsible AI policies, curriculum reform, better assessment practices, and collaboration among government, schools, universities, and technology providers. When appropriately implemented, AI can improve chemistry education in Nigeria and help develop students' scientific, digital, critical-thinking, and problem-solving skills.

Keywords: *Artificial Intelligence, AI Integration, Curriculum Design, Content Delivery, Chemistry Education*

Introduction
Artificial Intelligence (AI) has emerged as an important technology in contemporary education, influencing curriculum development, lesson preparation, personalized learning, assessment, instructional support and educational administration. AI-powered and generative AI tools can assist teachers in preparing lesson plans, generating instructional materials, developing assessment questions, providing explanations and supporting learners with immediate feedback. According to Ugosor et al. (2026), AI presents considerable opportunities for improving chemistry education in Nigeria, particularly through personalized learning, digital resources and innovative approaches to teaching and learning. Similarly, Chukwunwogor et al. (2025) observed that AI tools can support chemistry teachers and learners, although their effective application requires appropriate teacher preparation and institutional support.

The relevance of AI is particularly significant in science education because science subjects require learners to understand abstract concepts, interpret representations and apply theoretical knowledge to practical situations. Chemistry, in particular, involves movement between macroscopic observations, microscopic explanations and symbolic representations. Students may therefore experience difficulties with concepts such as atomic structure, chemical bonding, stoichiometry, thermodynamics, equilibrium, electrochemistry and organic reaction mechanisms. Bugaje and Madaki (2025) noted that AI applications such as simulations, virtual laboratories, molecular modelling and personalized learning can provide alternative ways of representing

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difficult chemistry concepts and supporting students' understanding. In the Nigerian context, such technologies could supplement conventional explanations, especially where schools have limited access to specialized instructional resources.

The Nigerian educational environment, however, presents circumstances that require AI integration to be approached differently from its implementation in highly developed digital-learning environments. Nigerian schools and higher institutions differ considerably in their access to electricity, internet connectivity, computers, mobile devices, digital platforms and laboratory facilities. Ugosor et al. (2026) identified inadequate infrastructure, limited digital competence, financial constraints, data-related concerns and regulatory challenges among the major issues affecting AI adoption in Nigerian chemistry education. Similarly, Nosakhare (2025) reported that poor internet connectivity, high data costs and limited institutional support constitute important barriers to the effective use of AI tools among Chemistry Education students at the University of Benin. Thus, the availability of an AI application does not necessarily mean that every Nigerian teacher or learner can use it consistently.

Evidence from Rivers State provides a useful local perspective on the emerging application of AI in chemistry education. Zudonu et al. (2024) investigated the accessibility and applicability of AI among chemistry teachers in secondary schools in Rivers State, involving 81 chemistry teachers from 76 senior secondary schools. Their study demonstrates that AI has become an issue of practical relevance to chemistry teachers within the state. In a related investigation, Zudonu et al. (2024) examined the effect of AI on the achievement and conceptual change of Senior Secondary School II Chemistry and Physics students in heat change in Rivers West Education Zone. The study involved 160 students from 16 senior secondary schools. These findings are particularly relevant because Rivers State is an important educational and industrial environment in Nigeria, where chemistry can be connected to petroleum processing, environmental pollution, water quality, energy and other issues affecting communities in the Niger Delta.

Evidence from other parts of Nigeria further demonstrates the growing interest in AI-supported chemistry education. Ahmed and Ibrahim (2026) investigated chemistry teachers in Kwara State and reported generally positive perceptions of AI, although practical utilization remained relatively limited in areas such as automated assessment, learner monitoring and virtual simulations. This finding suggests that awareness of AI does not automatically translate into effective classroom application. Teachers may recognize the potential value of AI while lacking the training, infrastructure, time or institutional support required to integrate it into everyday chemistry instruction. Consequently, Chukwunwogor et al. (2025) emphasized the importance of addressing implementation challenges alongside the potential benefits of AI in chemistry education.

Research in Nigerian universities and colleges of education also indicates increasing student and teacher engagement with AI. Nosakhare (2025) examined the use of AI tools among Chemistry Education students at the University of Benin and reported the use of applications such as ChatGPT and Google Gemini in students' learning activities. The study also identified connectivity, data costs and institutional support as important considerations. Similarly, Adejo (2025) examined the effectiveness and challenges of AI tools in chemistry instruction at the Federal University of Education, Zaria, while Ikokwu (2026) investigated AI integration in chemistry teaching and learning in colleges of education in Anambra and Ebonyi States. These studies indicate that AI is no longer simply a theoretical possibility in Nigerian chemistry education; it is becoming part of the learning and teaching experiences of students and educators in different parts of the country.

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The integration of AI into chemistry education is also relevant to teacher education because today's student teachers will become tomorrow's chemistry teachers. If prospective teachers are not adequately prepared to evaluate and use AI, they may enter Nigerian classrooms without the skills required to manage AI-supported learning. Ikokwu (2026) therefore provided an important perspective by examining AI integration within colleges of education in South-East Nigeria. Similarly, Chukwunwogor et al. (2025) argued that teacher competence is central to the effective use of AI in chemistry education. Professional development should consequently move beyond basic knowledge of AI applications and include prompt development, verification of AI-generated scientific information, AI-supported assessment, digital ethics, academic integrity and learner-centred pedagogy.

At the policy level, the Nigerian government has also acknowledged the increasing importance of digital technologies and AI in education. The Federal Ministry of Education (2023), through the National Digital Learning Policy, identifies issues including personalized learning, digital content development, learning outcomes, e-safety, data privacy and cybersecurity as important considerations in the digital transformation of education. The policy therefore provides a basis for considering AI not simply as a classroom tool but as part of a broader national digital-learning ecosystem. The Federal Ministry of Education (2025) has also identified infrastructure, connectivity, teacher digital competence, financing, governance and responsible technology use as important elements of Nigeria's emerging educational technology strategy.

The use of AI in Nigerian chemistry education must therefore be understood within the realities of the Nigerian classroom. For example, a chemistry teacher in Rivers State may use AI to develop a lesson on hydrocarbons and connect the topic with crude-oil production and environmental pollution in the Niger Delta. A teacher in an agricultural community may use AI to develop learning activities relating soil chemistry to fertilizer use, while a teacher in an urban school may use molecular visualization tools to help students understand chemical bonding and molecular geometry. Such examples demonstrate that the value of AI does not lie merely in introducing sophisticated technology into the classroom; rather, its value depends on how effectively the technology is connected to the curriculum, learners' experiences and real-life Nigerian problems.

Despite these opportunities, AI should not be regarded as a replacement for chemistry teachers or practical laboratory experiences. Ugosor et al. (2026); Bugaje and Madaki (2025) emphasized the need to address ethical, infrastructural, technical and pedagogical concerns associated with AI adoption. Teachers remain responsible for verifying scientific information, guiding students' reasoning, ensuring academic integrity and facilitating practical laboratory experiences. AI can simulate an experiment or provide an explanation of a chemical reaction, but it cannot completely replace the physical experience of handling laboratory equipment, observing chemical changes, recording experimental data and responding to unexpected experimental outcomes.

Against this background, this article examines the application of Artificial Intelligence in chemistry curriculum design and content delivery in Nigeria. The discussion focuses on how AI can support curriculum planning, instructional material development, personalized learning, assessment, simulations and virtual laboratory experiences while considering the realities of Nigerian schools and higher institutions. Particular attention is given to evidence from Rivers State and other parts of Nigeria, as well as challenges relating to infrastructure, teacher competence, affordability, academic integrity, data privacy and equitable access. The article argues that responsible, context-sensitive and teacher-led integration of AI can strengthen chemistry education

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in Nigeria while preserving the central importance of teachers, practical laboratory work, inquiry-based learning and independent scientific thinking.

Understanding Artificial Intelligence in Education

Artificial Intelligence (AI) refers broadly to computer-based systems designed to perform tasks that are commonly associated with aspects of human intelligence, including learning, pattern recognition, language processing, prediction, classification, problem-solving and decision-making. In education, AI encompasses a range of technologies, including adaptive learning systems, intelligent tutoring systems, learning analytics, automated assessment, conversational AI, generative AI, speech and language technologies, computer vision and simulation systems. Ugosor et al. (2026) explained that AI is increasingly relevant to chemistry education because it can support personalized learning, instructional delivery, assessment and access to educational resources. Similarly, Bugaje and Madaki (2025) identified applications such as computer simulations, virtual laboratories, molecular modelling and automated assessment as emerging uses of AI in Nigerian chemistry education.

One of the most significant recent developments is generative Artificial Intelligence, which can produce new content such as text, questions, explanations, lesson plans, summaries, images and computer code in response to user prompts. Examples include ChatGPT, Google Gemini, Microsoft Copilot and Claude. These tools can assist chemistry teachers in preparing explanations and learning activities on topics such as chemical bonding, stoichiometry, electrochemistry, organic chemistry and thermochemistry. Chukwunwogor et al. (2025) noted that generative AI can provide opportunities for improving chemistry teaching and learning, particularly by assisting educators with instructional resources and supporting students' learning. However, the availability of these tools does not eliminate the teacher's responsibility for determining whether the generated material is appropriate for the learners and consistent with the approved chemistry curriculum.

The issue of accuracy is particularly important in chemistry because AI-generated information may occasionally contain scientific errors. An AI system may generate an incorrect chemical equation, molecular formula, oxidation state, numerical calculation or explanation of a reaction mechanism while presenting the information with considerable confidence. Bugaje and Madaki (2025) therefore emphasized the importance of validation and critical evaluation when AI tools are applied to chemistry education. For example, if a Nigerian chemistry teacher asks an AI system to generate ten questions on electrochemistry, the teacher should independently verify the chemical equations, numerical values, units, answer keys and level of difficulty before presenting the questions to students. Human verification is consequently an essential component of responsible AI-supported chemistry instruction.

The need for human supervision also applies when students use AI for learning. A student studying stoichiometry may use an AI tool to obtain a worked example, but the teacher should encourage the learner to understand the reasoning behind each step rather than simply copy the final answer. Nosakhare (2025) in a study involving Chemistry Education students at the University of Benin, examined students' engagement with AI tools and highlighted the increasing role of applications such as ChatGPT and Google Gemini in students' learning experiences. This development creates opportunities for independent learning but also reinforces the need to teach students how to evaluate AI-generated information and use AI as a learning aid rather than a substitute for independent thinking.

AI should therefore be regarded primarily as a support technology rather than an autonomous replacement for the chemistry teacher. Teachers remain responsible for identifying

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appropriate learning objectives, selecting relevant content, designing meaningful learning experiences, evaluating students' progress and ensuring scientific accuracy. Ugosor et al. (2026) argued that AI has considerable potential in Nigerian chemistry education but that effective implementation requires attention to teacher competence, infrastructure, ethics and responsible use. In practical terms, AI can help a teacher prepare a lesson on chemical equilibrium, but the teacher must decide whether the explanation is suitable for Senior Secondary School students and how it should be combined with demonstrations, experiments, questioning and problem-solving activities.

The Nigerian context makes human oversight even more important because AI adoption occurs within an educational system characterized by differences in infrastructure, digital competence and access to technology. Zudonu et al. (2024**)** investigated the accessibility and applicability of AI among chemistry teachers in secondary schools in Rivers State, demonstrating the importance of examining teachers' actual capacity to access and use AI rather than assuming that the availability of AI tools automatically results in classroom adoption. Ahmed and Ibrahim (2026) similarly reported generally positive perceptions of AI among chemistry teachers in Kwara State but identified limitations in practical classroom utilization. These findings suggest that AI competence must include not only knowledge of AI tools but also the ability to integrate them appropriately into chemistry pedagogy.

For chemistry education in Nigeria, this human-centred approach is particularly important because chemistry is both theoretical and practical. AI can provide explanations, generate practice questions, visualize molecular structures and simulate selected laboratory procedures, but students still need opportunities to handle apparatus, observe chemical reactions, collect data, interpret experimental results and develop laboratory safety skills. Bugaje and Madaki (2025) emphasized the potential of virtual laboratories and simulations while also identifying technical and ethical considerations that must be addressed. Consequently, AI should be integrated with classroom discussion, practical laboratory work, inquiry-based learning and teacher-guided problem-solving.

AI and Chemistry Curriculum Design in Nigeria

Curriculum design involves identifying educational goals, selecting relevant content, sequencing learning experiences, determining appropriate instructional strategies and establishing assessment procedures for achieving intended learning outcomes. In chemistry education, curriculum design must go beyond the transmission of scientific facts to include conceptual understanding, laboratory and practical skills, scientific reasoning, problem-solving, creativity and the application of chemistry to everyday life and national development. Ugosor et al. (2026) argued that AI provides opportunities for strengthening chemistry education through personalized learning, improved instructional resources and innovative approaches to teaching and learning. Similarly, Chukwunwogor et al. (2025) emphasized that AI can contribute to the improvement of chemistry teaching and learning when its use is supported by appropriate pedagogical practices.

One important contribution of AI to chemistry curriculum design is its capacity to support the analysis of learners' needs. AI-supported learning analytics can process information generated from quizzes, assignments, online activities and other forms of digital assessment to identify patterns in students' performance. Such information can help teachers identify specific concepts that students understand well and those that require additional attention. Bugaje and Madaki (2025) identified personalized learning and AI-supported assessment as important applications of AI in chemistry education because they allow instructional activities to be better aligned with learners' individual needs.

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For example, if students in a Nigerian secondary school repeatedly perform poorly in mole calculations, an AI-supported learning system could help the teacher identify stoichiometry as a significant learning gap. However, poor performance in mole calculations may have different causes. Some students may have difficulty with mathematical operations, while others may not understand relative atomic mass, molar mass, mole relationships or the interpretation of chemical formulae. AI-assisted analysis can help the teacher distinguish among these difficulties and provide targeted remedial activities. Nosakhare (2025) demonstrated the growing relevance of AI tools to chemistry learning among Nigerian Chemistry Education students, suggesting that such technologies can provide additional opportunities for learners to engage with academic content and receive support.

The application can be made particularly relevant to the Nigerian secondary-school classroom. For example, a chemistry teacher in Rivers State could administer a short digital diagnostic test before introducing stoichiometry. The assessment could include questions on relative atomic mass, balancing chemical equations, mole-mass relationships and simple quantitative calculations. If the results show that most students can balance equations but struggle to convert mass to moles, the teacher could devote additional instructional time to that specific skill instead of repeating the entire topic. Where digital infrastructure is available, AI-supported analytics could assist in identifying these patterns more quickly. This approach is consistent with findings from Zudonu et al. (2024), who examined the accessibility and applicability of AI among chemistry teachers in Rivers State and demonstrated the growing relevance of AI to chemistry teaching within the state.

AI-supported learner analysis can also help teachers recognized differences among individual students. For instance, in a mixed-ability Senior Secondary School chemistry class, some learners may already understand chemical bonding while others may still struggle to distinguish ionic, covalent and metallic bonding. An AI-supported platform could recommend additional explanations, practice questions or molecular visualizations for students requiring further assistance while providing enrichment activities for students who have already demonstrated mastery. Ugosor et al. (2026) identified personalized learning as one of the potential benefits of AI integration in Nigerian chemistry education.

Development of Learning Outcomes

AI can assist teachers and curriculum developers in developing clear, measurable and learner-centred learning outcomes for chemistry. Rather than relying on broad statements such as “students should understand chemical bonding,” AI can help teachers transform general curriculum goals into specific outcomes that describe what learners should be able to know, demonstrate or apply after instruction. Ugosor et al. (2026) identify curriculum support and personalized learning as important areas in which AI can contribute to chemistry education, while Chukwunwogor et al. (2025**)** emphasized the potential of AI to support the planning and delivery of chemistry instruction. AI can also help teachers differentiate learning outcomes according to students' levels of ability. For example, basic learners may be expected to identify different types of chemical bonds, while more advanced learners may be expected to explain, compare, predict and apply knowledge of bonding to unfamiliar situations. This supports the development of learning experiences that accommodate differences among learners. Bugaje and Madaki (2025**)** similarly identified personalized learning and adaptive instructional approaches as important opportunities presented by AI in chemistry education.

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The Nigerian context can be incorporated into the formulation of these outcomes. For example, rather than teaching chemical bonding entirely through abstract examples, a chemistry teacher in Rivers State could develop an outcome requiring students to relate the properties of materials used in petroleum processing, construction, water treatment or household products to the types of chemical bonding present in those materials. Such an approach helps students connect abstract chemical principles with their local environment and demonstrates the relevance of chemistry to Nigerian economic and social activities. Zudonu et al. (2024) highlighted the growing relevance of AI to chemistry teaching in Edo State, providing a basis for exploring context-sensitive applications of AI within the state's schools.

AI can further assist teachers in checking whether proposed learning outcomes are specific, measurable and appropriate for the learners' level. For instance, an AI system may identify that the verb *"understand"* is difficult to measure directly and suggest more observable verbs such as identify, explain, calculate, compare, predict, analyze or evaluate. The teacher can then use these outcomes to design appropriate classroom activities and assessment tasks. Nosakhare (2025) demonstrated the increasing use of AI tools among Nigerian Chemistry Education students, indicating the growing need for both teachers and learners to develop the capacity to use such tools critically.

Selection and Updating of Chemistry Content

Chemistry is a dynamic discipline, and its curriculum must continually respond to developments in science, technology, industry and society. Emerging areas such as green chemistry, nanotechnology, biotechnology, renewable energy, environmental chemistry, materials science and sustainable chemical processes are increasingly important to contemporary scientific and economic development. AI can support curriculum developers by helping them identify emerging scientific themes, review large amounts of scientific and educational information, and consider how new knowledge can be connected to existing chemistry topics. Bugaje and Madaki (2025**)** identified AI-supported access to contemporary scientific information, simulations and digital resources as opportunities for strengthening chemistry education, while Ugosor et al. (2026) emphasized the potential of AI to make chemistry education more responsive to contemporary scientific and technological developments.

For example, the topic of environmental chemistry can be connected to oil pollution in the Niger Delta. A chemistry teacher in Rivers State could use AI to develop learning activities that require students to investigate the chemical properties of crude oil, sources of water contamination, effects of hydrocarbons on aquatic ecosystems, methods of detecting pollutants and possible approaches to environmental remediation. Students could analyze a simplified dataset on the quality of water from different locations and use AI-supported tools to identify patterns and formulate possible explanations. In this way, concepts such as solubility, hydrocarbons, organic compounds, pH, pollution and chemical analysis become connected to an environmental problem that students may already know from their communities. This approach is particularly relevant to the findings of Zudonu et al. (2024) concerning the growing accessibility and applicability of AI among chemistry teachers in Rivers State.

The same approach can be applied to petroleum chemistry, which has particular relevance to Rivers State and the wider Niger Delta. Traditionally, the teaching of hydrocarbons may focus heavily on naming compounds, drawing structural formulae and identifying homologous series. AI can help teachers extend these activities by developing context-based learning tasks on crude-oil composition, fractional distillation, petroleum refining, combustion, greenhouse-gas emissions, oil

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spills and the environmental consequences of petroleum exploitation. For instance, students could be asked to compare the chemical processes involved in petroleum refining with alternative energy technologies and evaluate the environmental implications of continued dependence on fossil fuels**.** Ugosor et al. (2026) highlighted the potential of AI to support contemporary and contextually relevant chemistry learning in Nigeria.

A teacher could use AI to generate case studies involving water treatment, hardness of water, dissolved substances, pH, microbial contamination and the chemical principles underlying purification processes. In a Rivers State community where concerns about water quality are relevant, students could investigate why water may require treatment before consumption and examine the chemical principles involved in coagulation, filtration, disinfection and pH adjustment. AI could assist the teacher in producing differentiated activities for students at different levels of ability. However, the scientific accuracy of AI-generated explanations must be verified by the teacher before they are used. Bugaje and Madaki (2025) stressed the importance of validation and responsible use when AI-generated information is incorporated into chemistry education.

AI in Chemistry Content Delivery

AI is increasingly changing how chemistry content can be presented, explained, practiced and assessed. Traditional chemistry instruction often depends on teacher explanations, textbooks, board illustrations, laboratory demonstrations and written exercises. While these approaches remain important, AI can provide additional ways of presenting content through personalized explanations, interactive simulations, molecular visualization, intelligent tutoring, virtual laboratories, automated formative assessment and immediate feedback. Ugosor et al. (2026) identified personalized learning, digital resources and innovative instructional approaches among the major opportunities associated with AI in Nigerian chemistry education. Similarly, Bugaje and Madaki (2025) highlighted simulations, virtual laboratories, molecular modelling and automated assessment as emerging applications of AI in chemistry teaching.

One of the major contributions of AI to chemistry content delivery is its ability to support personalized learning. Students in the same classroom do not necessarily have the same prior knowledge, learning pace or level of conceptual understanding. An AI-supported learning system can analyze students' responses to questions and recommend additional explanations, examples, exercises or learning resources according to their identified needs. Nosakhare (2025) provided Nigerian evidence of students' growing engagement with AI tools such as ChatGPT and Google Gemini, demonstrating the increasing role of AI-supported resources in students' learning experiences.

Chemistry contains many concepts that students cannot easily observe directly. For example, learners cannot see atoms, ions, molecular orbitals or the movement of electrons during a chemical reaction with the naked eye. AI-supported visualization and interactive technologies can help represent these invisible processes in forms that students can explore. A Nigerian teacher can also connect these visualizations to familiar materials. During a lesson on molecular structure, for example, students could examine the structures of substances found in household products, agricultural chemicals, fuels or pharmaceutical products. This can help bridge the gap between abstract chemical representations and students' everyday experiences.

AI can also support chemistry learning through intelligent tutoring systems. These systems are designed to provide learners with explanations, hints, questions and feedback based on their responses and progress. Unlike a conventional textbook, an intelligent tutoring system can provide

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different levels of assistance depending on the learner's performance. Chukwunwogor et al. (2025) emphasized the potential of AI to improve chemistry teaching and learning, while also stressing the importance of addressing the challenges associated with its implementation. In Nigeria, intelligent tutoring systems could be particularly useful for students who need additional practice outside normal classroom hours, provided that they have reliable access to the required digital devices and internet services.

Laboratory work is central to chemistry education because students need to develop practical skills in observation, measurement, experimentation, data collection, analysis and laboratory safety. However, some Nigerian schools experience shortages of laboratory equipment, chemicals, electricity, water and other resources. AI-supported virtual laboratories and simulations can provide additional opportunities for students to explore experimental procedures where physical resources are limited.

AI can also improve the delivery of chemistry content by supporting continuous formative assessment. Teachers can use AI tools to generate practice questions, quizzes and short assessment activities and to analyze students' responses. Students can receive immediate feedback, allowing them to identify misconceptions while learning is still taking place.This approach can make assessment part of the learning process rather than something that occurs only at the end of a topic. Nosakhare (2025) demonstrated the growing engagement of Nigerian Chemistry Education students with AI tools, while Ugosor et al. (2026) highlighted AI's potential to support personalized learning and instructional improvement.

Generative AI can function as an additional preparation and instructional resource for chemistry teachers. A teacher may use an AI tool to generate lesson introductions, examples, discussion questions, revision exercises, laboratory questions, case studies and differentiated activities. For example, a teacher preparing a lesson on environmental chemistry in Rivers State could ask an AI system to suggest activities linking hydrocarbon pollution, gas flaring, water contamination and chemical remediation to concepts in the secondary-school chemistry curriculum.

Benefits of AI Integration in Nigerian Chemistry Education

The integration of Artificial Intelligence (AI) into Nigerian chemistry education offers opportunities to improve curriculum implementation, content delivery, assessment, learner engagement and access to learning resources. AI can help teachers respond to differences among learners while providing students with additional opportunities to practice concepts, receive feedback and explore chemistry beyond the traditional classroom. Ugosor et al. (2026) identified personalized learning, innovative instructional approaches, improved access to resources and enhanced learning experiences among the potential benefits of AI in Nigerian chemistry education. Similarly, Chukwunwogor et al. (2025**)** argued that AI can contribute to improving chemistry teaching and learning when appropriately integrated into educational practice.

Improved Understanding of Abstract Chemistry Concepts

One of the major benefits of AI is its capacity to make abstract chemistry concepts easier to visualize and understand. Chemistry requires students to move between what they can observe experimentally, what happen at the molecular or atomic level, and the symbolic language used to represent chemical processes. AI-supported simulations, molecular models, animations and interactive visualizations can help students make connections among these different levels of representation. Bugaje and Madaki (2025) identified molecular modelling, computer simulations

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and virtual learning environments as important applications of AI for supporting chemistry learning.

1. ***Personalized Learning:*** AI can support personalized learning by adjusting learning activities according to individual students' performance and learning needs. Students within the same Nigerian chemistry classroom may differ considerably in prior knowledge, learning pace, language proficiency and academic ability. An AI-supported learning platform can analyze students' responses and recommend additional explanations, practice questions or enrichment activities.
2. ***Increased Student Engagement and Motivation:*** AI can make chemistry learning more interactive by providing conversational tools, simulations, games, immediate feedback and opportunities for students to explore questions independently. Instead of passively listening to a teacher throughout a lesson, learners can interact with digital resources, test ideas and receive immediate responses. Nosakhare (2025) investigated AI-tool use among Chemistry Education students at the University of Benin and reported the increasing use of applications such as ChatGPT and Google Gemini. This indicates that AI is already becoming part of students' learning practices in Nigerian higher education. When properly guided, such tools can encourage students to ask questions, explore unfamiliar concepts and engage more actively with chemistry content.
3. ***Improved Access to Learning Resources:*** AI can increase access to educational resources, particularly where students have limited access to textbooks, specialized teachers or supplementary learning materials. A student can use an AI-supported learning tool to request explanations, examples, practice questions or revision materials outside normal classroom hours. However, this benefit depends on access to electricity, internet connectivity and suitable digital devices. Nosakhare (2025) identified poor internet connectivity and high data costs as barriers to students' use of AI tools. Consequently, expanding AI-based educational opportunities must be accompanied by efforts to improve digital access.
4. ***Enhanced Teacher Productivity****:* AI can reduce the amount of time chemistry teachers spend on repetitive preparation tasks. Teachers can use AI to generate draft lesson plans, worksheets, quizzes, discussion questions, revision exercises and differentiated learning activities. This may allow teachers to devote more time to classroom interaction, laboratory supervision, individual learner support and professional development. The important point is that AI-generated resources should remain draft materials, not automatically approved teaching materials. The teacher must verify their scientific accuracy, relevance and appropriateness.

Strategies for Effective AI Implementation in Nigerian Chemistry Education

The successful integration of Artificial Intelligence (AI) into Nigerian chemistry education requires more than simply providing teachers and students with access to AI applications. It requires coordinated attention to teacher competence, infrastructure, curriculum alignment, assessment, ethics, data protection, funding and institutional support. Nigerian studies indicate that although teachers and students are increasingly aware of AI tools, practical implementation is still affected by connectivity problems, high data costs, limited digital competence and inadequate institutional support (Zudonu et al., 2024; Nosakhare, 2025; Ugosor et al., 2026). Therefore, AI implementation should be gradual, context-sensitive and guided by educational objectives rather than technology alone.

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1. ***Continuous Professional Development for Chemistry Teachers:*** The first and most important strategy is continuous professional development. Chemistry teachers need more than basic knowledge of how to operate ChatGPT, Gemini or other AI applications. They need to understand how to select appropriate AI tools, write effective prompts, evaluate AI-generated information, design AI-supported learning activities, protect students' data and integrate AI with established chemistry pedagogy. Professional development could be organized through workshops, seminars, online courses, professional learning communities and teacher-training programmes. For example, a chemistry teachers' workshop in Rivers State could demonstrate how AI can be used to develop lesson plans on hydrocarbons, generate differentiated stoichiometry exercises, create formative assessments and design environmental-chemistry case studies based on oil pollution in the Niger Delta. Teachers should also be trained to identify incorrect AI-generated chemical equations, calculations and explanations before using them with students.
2. ***Improvement of Electricity and Digital Infrastructure:*** AI-supported chemistry education depends heavily on reliable electricity, internet connectivity and access to digital devices. However, infrastructure remains a significant challenge in many Nigerian schools. Nosakhare (2025) identified poor internet connectivity and high data costs as barriers to students' use of AI tools, while Ugosor et al. (2026) highlighted inadequate digital infrastructure as one of the major constraints to AI adoption in Nigerian chemistry education.

   Government and educational institutions should therefore invest in reliable electricity, internet connectivity, computers, tablets, projectors, smart classrooms and appropriate digital laboratory facilities. In schools where internet access is unreliable, institutions could explore educational platforms that provide offline or low-bandwidth functionality. This is particularly important for rural and underserved schools, where AI should not become another source of educational inequality.
3. ***Context-Sensitive Curriculum Integration:*** AI should be integrated into the existing Nigerian chemistry curriculum rather than introduced simply as an additional technological activity. Curriculum developers should identify topics where AI genuinely improves learning outcomes and determine how it can complement existing instructional strategies. Bugaje and Madaki (2025) identified applications such as simulations, molecular modelling, personalized learning and virtual laboratories as useful areas for AI integration in chemistry.

Conclusion

Artificial Intelligence presents significant opportunities for improving chemistry education in Nigeria. It can support curriculum design, learner-needs analysis, personalized learning, lesson preparation, molecular visualization, intelligent tutoring, virtual laboratories, formative assessment and immediate feedback. These applications can help address some of the difficulties students encounter when learning abstract chemistry concepts. However, AI is not a substitute for effective chemistry teachers or practical laboratory experiences. Nigerian evidence demonstrates that positive perceptions of AI coexist with substantial barriers, including poor connectivity, high data costs, inadequate infrastructure, limited teacher competence and insufficient institutional support. The most appropriate model is a human-AI partnership in which teachers provide professional judgement, students engage actively in learning, AI provides additional instructional support, and laboratory experiences remain central to chemistry education. With appropriate

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infrastructure, teacher preparation, curriculum reform, ethical safeguards and institutional support, AI can contribute meaningfully to improving chemistry teaching and learning in Nigeria.

Suggestions

Based on the review, the following recommendations are proposed:

1. Government should develop and implement clear national and state-level guidelines for responsible AI use in education.
2. Teacher education programmes should integrate AI literacy into chemistry education courses so that future chemistry teachers are prepared for AI-supported classrooms.
3. Chemistry curricula should be contextualized to Nigerian problems, including oil pollution, water quality, agriculture, energy, waste management and environmental sustainability.
4. AI-generated chemistry content should always be verified by qualified teachers before being used for instruction or assessment.
5. Schools should develop clear academic-integrity policies explaining acceptable and unacceptable uses of generative AI.
6. Assessment methods should be diversified to include practical work, oral questioning, supervised tests, projects, demonstrations and problem-solving activities.
7. AI should complement rather than replace laboratory practicals. Virtual laboratories should be used as preparation, reinforcement or supplementary experiences where appropriate.

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