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Reimagining Science Education in the Era of Artificial Intelligence

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Abstract

Artificial intelligence (AI) is increasingly transforming the nature of knowledge production, scientific inquiry and educational practice. Science education, traditionally characterised by teacher-centred instruction, textbook-based learning, memorisation, practical experiments and conventional assessment, now requires significant rethinking in response to the capabilities of AI. The emergence of generative AI and other intelligent technologies provides opportunities to personalise science learning, enhance scientific experimentation, support data analysis, improve assessment and develop students' scientific and digital competencies. The Organisation for Economic Co-operation and Development (OECD, 2025) argues that the development of powerful AI requires education systems to reconsider the competencies, knowledge, skills and attitudes that learners need, including the goals and experiences embedded in existing curricula. UNESCO (2024) similarly emphasises that AI is changing the traditional teacher–student relationship into a teacher–AI–student relationship and calls for teachers to develop competencies in AI ethics, AI foundations, AI pedagogy and professional learning. This paper examines the need to reimagine science education by integrating AI with scientific inquiry, experimentation, curriculum development, assessment and teacher professional development. It argues that AI should complement rather than replace science teachers, laboratory experiences and students' cognitive engagement. The paper concludes that responsible integration of AI can make science education more personalised, innovative, inquiry-oriented and relevant to contemporary society when supported by adequate infrastructure, teacher competence, ethical safeguards and appropriate curriculum reform.

Keywords: Artificial intelligence, science education, scientific inquiry, AI literacy, science curriculum, digital learning

1. Introduction

Science education occupies a central position in the development of scientifically literate individuals capable of understanding natural phenomena, solving problems, evaluating evidence and contributing to technological and socioeconomic development. Through subjects such as Biology, Chemistry, Physics and Environmental Science, learners acquire knowledge and skills for interpreting the natural world and addressing societal challenges. However, the rapid development of artificial intelligence is changing the context within which science is taught and learned. AI can now generate explanations, analyse data, produce

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simulations, identify patterns, support prediction and assist in scientific problem-solving. Consequently, science education can no longer be organised exclusively around the transmission and memorisation of established scientific information. The traditional science classroom has often relied on teacher explanation, textbooks, chalkboards, laboratory demonstrations, practical exercises and conventional examinations. These approaches remain important, particularly because scientific learning requires direct observation, experimentation and interaction with physical materials. However, excessive dependence on conventional approaches may limit opportunities for personalised learning, rapid feedback, large-scale data analysis and exposure to emerging scientific technologies. The OECD (2025) observes that increasingly capable AI requires education systems to reconsider fundamental questions about what students should learn, which competencies should receive emphasis and how learning experiences should be organised.

The emergence of AI therefore provides an opportunity to reimagine rather than simply digitise science education. Reimagining involves reconsidering the objectives of science education, the role of the teacher, the nature of classroom activities, assessment methods and the competencies students require in an AI-driven society. OECD's work on science education in a future of powerful AI identifies the importance of teaching students how science works, where scientific knowledge comes from, how scientific claims can be evaluated and how science contributes to societal decision-making. This suggests that science education should increasingly emphasise scientific reasoning and epistemic understanding rather than the mere accumulation of facts. One important area of transformation is personalised science learning. Conventional classrooms frequently provide the same lesson, examples and exercises to students despite differences in ability and prior knowledge. AI-supported educational systems can potentially provide differentiated explanations, exercises and feedback based on students' learning needs. A learner struggling with a concept in Physics, for example, could receive additional explanations and examples while another learner could be challenged with more advanced problems. Nevertheless, personalisation must remain under teacher guidance because AI-generated information can be inaccurate and because effective science education requires pedagogical judgement.

According to Nwisagbo, Ihua-Jonathan and Sam-Leeloo, (2024), AI also creates new possibilities for scientific experimentation and simulation. Virtual laboratories and AI-supported simulations can provide students with opportunities to investigate scientific phenomena that may be difficult, expensive or dangerous to reproduce in conventional classrooms. These technologies can complement physical laboratories by allowing students to manipulate variables, observe simulated outcomes and repeat investigations. However, digital simulations should not eliminate hands-on laboratory experiences. Students still need opportunities to handle equipment, observe real materials, collect evidence and experience the uncertainty associated with authentic scientific investigation. Another major implication concerns the role of the science teacher. The increasing availability of AI-generated educational content means that teachers are no longer the only immediate source of information available to students. Rather than diminishing the importance of teachers, this development requires teachers to perform higher-level professional functions such as designing learning experiences, evaluating information, facilitating inquiry, supervising practical activities and developing students' scientific reasoning. UNESCO (2024) identifies 15 teacher AI competencies across five dimensions: human-centred mindset, ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional learning.

This transformation requires science teachers to become AI-literate professionals. A science teacher should be capable of evaluating the accuracy of AI-generated explanations, identifying fabricated scientific claims, recognising algorithmic limitations and teaching students how to verify AI outputs against credible scientific evidence. UNESCO emphasises that meaningful interaction between teachers and students and human flourishing should remain at the centre of education, stressing that teachers should not be replaced by technology. AI also has implications for science assessment. Traditional examinations often focus heavily on students' ability to recall information and provide predetermined answers. In an environment where AI can readily generate answers, such assessment approaches may provide an incomplete picture of genuine learning. Assessment should increasingly examine students' ability to formulate scientific questions, design investigations, interpret evidence, evaluate competing explanations and defend conclusions. AI can support formative assessment and feedback, but students must still demonstrate their own scientific reasoning.

Furthermore, science education needs to incorporate AI literacy and data literacy into its curriculum. Students should understand not only scientific concepts but also how AI systems use data to generate predictions, recommendations and other outputs. UNESCO's AI competency framework advocates progressive development of learners' abilities to understand, apply and create with AI while maintaining ethical and human-centred principles. This is particularly important because future scientists, engineers, teachers, health professionals and policymakers will increasingly work alongside AI systems. Reimagining science education should also strengthen scientific inquiry and problem-solving. Instead of using AI merely to obtain ready-made answers, students can be encouraged to use AI as an object of investigation and as a research assistant. For instance, students could examine an AI-generated explanation of climate change, identify unsupported claims, compare them with peer-reviewed scientific evidence and formulate a corrected explanation. Such activities develop both scientific literacy and critical AI literacy.

However, AI integration presents important challenges. These include unequal access to digital infrastructure, inadequate teacher training, data privacy concerns, algorithmic bias, misinformation, academic dishonesty and excessive dependence on technology. The OECD (2025) stresses that education systems must think beyond incremental AI adoption and reconsider curriculum content and learning experiences. UNESCO similarly places human agency, ethical use and teachers' rights at the centre of AI integration.

For Nigeria, these considerations are particularly significant. Science education institutions need reliable electricity, internet connectivity, digital devices, functional laboratories and adequately trained teachers. AI should therefore be introduced as part of a broader strategy for strengthening science education rather than as a substitute for basic educational infrastructure. The objective should be to combine human expertise, practical science, digital technology and artificial intelligence to produce scientifically competent and technologically responsible citizens. The central argument is that the future of science education should not be based on a choice between the traditional teacher and artificial intelligence. Instead, the goal should be to develop a productive relationship between the science teacher, learner, laboratory and AI. AI can provide computational power and rapid information processing, while teachers provide pedagogical judgement, scientific interpretation, ethical guidance and human interaction.

2. Conceptual Terms

Concept of Science Education

Below are four distinct, academically useful definitions of science education, presented in review

Yager (1984) defines science education from a broader societal perspective as a discipline concerned with the interaction between science and society, including the impact of science on society and the influence of society on science. This definition moves science education beyond the mere transmission of scientific facts. It positions science as a social enterprise whose knowledge, discoveries and applications influence human life, while societal needs and values also influence the direction of scientific development. Canlas and Karpudewan (2020) define science education as the teaching and learning of science and its allied disciplines at all levels of schooling, including university science courses, with the broader objective of achieving scientific literacy. They further explain that science education develops scientific knowledge and understanding, science-process skills and curiosity that individuals can apply in everyday life.

The National Science Teaching Association (NSTA) presents science education as a field aimed at developing learners' capacity to understand science, engage in scientific inquiry and apply scientific knowledge to real-world problems. NSTA emphasises that effective science education should enable students to frame scientific questions, evaluate complex issues, seek relevant data and scientific arguments, and communicate their understanding and conclusions. UNESCO describes science education within the broader STEM education context as education that develops knowledge and competencies needed to address global challenges and drive innovation. UNESCO emphasises that science-related education fosters critical thinking, problem-solving and creativity, while contributing to sustainable development and the capacity to transform knowledge into solutions for societal challenges.

Concept of Artificial Intelligence

Artificial Intelligence is the branch of computer science that focuses on creating machines capable of performing tasks that typically require human intelligence, such as learning, reasoning, problem-solving, and decision-making (Russell & Norvig, 2021; Nwisagbo & Wodi, 2025). In organizational contexts, AI is deployed for predictive analytics, automation of routine processes, data-driven decision-making, and enhancing operational efficiency. Ogunode and Ukozor (2023) conceptualized AI as programs designed with human-like intelligence and structured in the forms of computers, robots, or other machines to aid in the provision of any kind of service or tasks to improve the social economic and political development of the society. Artificial Intelligence is an application or program constructed to carry out tasks with human-like intelligence. Artificial intelligence (AI) as simulation of human intelligence by software-coded heuristics. Artificial Intelligence is a branch of science producing and studying the machines aimed at the stimulation of human intelligence processes (Frankenfield 2023).

3. Result and Discussion

Reimagining Science Education in the Era of Artificial Intelligence

The emergence of artificial intelligence (AI) is changing how scientific knowledge is produced, taught, learned and assessed. In science education, the issue is not simply whether AI should be introduced into classrooms, but how science educators can redesign teaching and learning so that AI strengthens scientific reasoning, experimentation, creativity and problem-solving without replacing authentic intellectual engagement. The OECD argues that education systems need to rethink teaching and learning as AI capabilities develop, particularly because AI is increasingly capable of performing tasks involving scientific reasoning.

AI-Supported Personalised Science Teaching and Learning

One important way of reimagining science education is through personalised learning supported by AI. Conventional science classrooms often require teachers to teach relatively large groups of learners using common lesson plans, instructional materials and assessment tasks. This approach may make it difficult to respond adequately to differences in students' abilities, interests, learning speeds and misconceptions. AI can assist science teachers by analysing learners' responses and identifying areas where individual students require additional explanation or practice. AI-supported systems can generate differentiated learning activities, explanations, examples, quizzes and simulations according to learners' needs. The OECD identifies personalisation as one of the potential benefits of digital technologies and AI in education. For example, a science teacher teaching genetics could use AI to develop different explanations of genetic inheritance for learners with varying levels of prior knowledge. Students could also interact with simulations that allow them to explore scientific concepts that are difficult to observe directly. However, personalisation should not mean allowing AI to determine everything a learner studies. The teacher remains responsible for determining learning objectives, selecting scientifically accurate materials and ensuring that AI-generated content is appropriate. The OECD's 2026 Digital Education Outlook warns that generative AI can improve performance on tasks without necessarily producing genuine learning when it is used without sound pedagogical guidance. Thus, the appropriate model is AI-assisted personalised science education, in which AI provides additional instructional support while the science teacher remains the pedagogical authority.

Transforming Science Experiments Through AI, Simulation and Virtual Laboratories

A second major area is the transformation of practical science education through AI-powered simulations, virtual laboratories and intelligent learning environments. Practical experimentation is central to science because learners need opportunities to observe phenomena, formulate hypotheses, collect evidence, analyse results and draw conclusions. In many educational institutions, however, practical science teaching is constrained by inadequate laboratory facilities, expensive equipment, large class sizes, safety concerns and limited access to specialised apparatus. AI-supported virtual environments can complement physical laboratories by allowing students to simulate experiments and investigate scientific phenomena that may otherwise be difficult or expensive to reproduce. For example, students may use digital simulations to investigate chemical reactions, ecological systems, planetary motion or genetic processes. AI can potentially provide feedback during these activities and help learners identify relationships between variables.

Importantly, virtual experimentation should complement rather than completely replace physical experimentation. Science education requires learners to handle materials, operate equipment, make observations and encounter the unpredictability of real-world phenomena. AI should therefore extend access to experimentation while preserving authentic laboratory experiences. This approach is consistent with the OECD's emphasis on using AI as a tutor, partner and assistant rather than simply outsourcing learning tasks to generative AI.

Reimagining the Role of the Science Teacher and Developing AI Competence

AI is also changing the professional role of the science teacher. Traditionally, the teacher has been the major source of scientific information, while students largely depend on textbooks, classroom explanations and laboratory activities. With AI systems capable of generating explanations, questions, examples and other educational resources, the teacher's role is increasingly shifting from being primarily a transmitter of information to a designer, facilitator, evaluator and critical guide of learning. UNESCO's AI Competency Framework for Teachers identifies 15 competencies across five dimensions: human-centred mindset, ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional learning. These competencies are particularly important for science teachers because science requires accuracy, evidence, critical reasoning and responsible interpretation of information. A science teacher should therefore be able to evaluate AI-generated scientific explanations, identify factual errors, recognise potential bias and teach students how to verify information using credible scientific evidence. The teacher should also know when AI is pedagogically useful and when students need to work independently without technological assistance. Teacher education programmes should incorporate AI literacy, scientific information verification, AI ethics, prompt development, digital experimentation and AI-supported pedagogy. The objective is not to make teachers dependent on AI but to enable them to use AI critically and professionally (Ogunode, et al 2023).

Developing Scientific Inquiry, Critical Thinking and AI Literacy

The fourth area involves using AI to strengthen, rather than weaken, scientific inquiry and critical thinking. Science education should enable students to ask questions, formulate hypotheses, gather evidence, analyse data, evaluate explanations and communicate conclusions. If students simply ask AI to provide answers to scientific problems, they may obtain correct-looking responses without developing the reasoning processes necessary for scientific understanding. The OECD and European Commission's 2026 AI Literacy Framework for Primary and Secondary Education argues that learners need knowledge, skills and attitudes that enable them to understand how AI works, critically evaluate its outputs and use it ethically and creatively. Science teachers can therefore redesign assignments so that students critique AI-generated scientific claims rather than simply reproduce them. For instance, students could be given an AI-generated explanation of climate change, photosynthesis or evolution and asked to identify inaccuracies, compare the claims with scientific sources and construct a scientifically supported correction. This approach transforms AI from an answer-producing machine into an object of scientific investigation and critical inquiry. Students learn both science and how to evaluate the technology through which scientific information is increasingly communicated. Such an approach is particularly important because AI-generated information may contain errors or unsupported claims. Students must therefore develop the capacity to ask: What evidence supports this claim? Is the source credible? Can the result be reproduced? Does the explanation conform to established scientific knowledge?

Science education in the AI era should consequently produce learners who are not merely users of AI, but scientifically literate individuals capable of critically interrogating AI-generated information.

Reorienting Science Curriculum Towards AI, Data Literacy and Emerging Scientific Competencies

A major dimension of reimagining science education is the reorientation of the science curriculum to incorporate AI literacy, data literacy, computational thinking and emerging scientific competencies. Traditionally, science curricula have concentrated on established bodies of knowledge in subjects such as Biology, Chemistry, Physics and Environmental Science. While these remain essential, the increasing influence of AI on scientific research and everyday life requires students to understand how intelligent technologies generate, process and interpret information. The OECD (2025) argues that the rapid development of AI requires education systems to reconsider the competencies, knowledge, skills and attitudes that learners need for life and work. The organisation specifically argues that curriculum designers should consider whether some existing emphases need to change and whether new competencies should be introduced.

Similarly, UNESCO's AI Competency Framework for Students identifies AI techniques and applications, AI system design, ethics and a human-centred mindset as important competencies for learners. It recommends that students should progress from understanding AI to applying and creating with it (Miao et al., 2024). For science education, this means that students should increasingly encounter activities involving data interpretation, computational modelling, AI-assisted scientific investigation and evaluation of AI-generated scientific information. A Biology student, for example, could examine how AI is used in disease prediction or genomics, while a Physics student could explore AI applications in modelling physical systems. Consequently, science curriculum should move beyond what scientific knowledge is to include how scientific knowledge is generated, analysed, validated and applied in an AI-driven society.

AI-Enhanced Science Assessment and Feedback

Another important area is the transformation of science assessment and feedback. Conventional assessment often relies on written examinations, assignments, laboratory reports, quizzes and teacher marking. Although these methods remain valuable, they can place considerable demands on teachers, particularly where science classes are large. AI can support teachers by analysing students' responses, identifying recurring misconceptions, generating formative questions and providing preliminary feedback. For instance, an AI-supported learning platform could identify that a group of students consistently misunderstands the concept of chemical equilibrium and provide additional exercises addressing that misconception. The OECD (2026) reports that generative AI can support education when it is used as a tutor, partner or assistant and when its use is guided by clear pedagogical principles. However, the OECD also cautions that successful completion of tasks using GenAI does not automatically result in genuine learning. This distinction is particularly important for science assessment. A student may use AI to produce an impressive laboratory report without actually understanding the experiment. Therefore, reimagined science assessment should evaluate reasoning, experimentation, interpretation of evidence, problem-solving and scientific communication, rather than merely the quality of the final written product. AI should consequently support formative assessment, while teachers remain responsible for interpreting students' learning and making high-stakes assessment decisions. The teacher's professional judgement remains indispensable because AI-generated feedback may itself contain errors or misunderstand the learner's reasoning (Ogunode, Idoko, & ThankGod, 2024).

Promoting Scientific Research, Problem-Solving and Innovation Through AI

AI provides opportunities for science education to become more strongly oriented towards research, innovation and real-world problem-solving. Instead of students merely memorising established scientific facts, they can use AI-supported tools to investigate authentic problems, analyse datasets, formulate hypotheses and explore possible solutions. The OECD's analysis of science education in a future shaped by powerful AI emphasises that science education should help learners understand how science works, where scientific knowledge comes from and how to evaluate scientific knowledge. It also stresses the importance of helping students understand the social relevance and limitations of scientific knowledge. This has important implications for science teaching. Students could, for example, use AI-supported data-analysis tools to examine environmental pollution, climate patterns, biodiversity, public health or agricultural productivity. Rather than receiving ready-made answers, learners can be challenged to formulate research questions, analyse evidence and defend their conclusions. Such an approach can transform science classrooms into miniature research environments where students become investigators rather than passive recipients of information. AI can assist with data processing and modelling, while students remain responsible for questioning assumptions, evaluating evidence and explaining their conclusions. The ultimate goal is therefore not simply to produce students who know how to operate AI tools, but students who can use AI to investigate scientific problems creatively and responsibly (Ogunode, Okolie, & Chinedu, 2023).

Strengthening Ethical, Safe and Sustainable Science Education in the AI Era

The fourth additional dimension is the development of an ethical and human-centred approach to AI-supported science education. AI presents significant opportunities, but it also raises concerns relating to academic integrity, misinformation, privacy, bias, unequal access and excessive dependence on technology. UNESCO (2023) emphasises that the use of generative AI in education should be human-centred, ethical, safe, equitable and meaningful. It specifically highlights the importance of data privacy, appropriate regulation and pedagogical and ethical validation of AI tools. For science education, ethical AI use is especially important because students must learn that scientific claims should be supported by evidence. AI can generate scientifically plausible but inaccurate explanations, fabricated references or misleading interpretations. Students therefore need to develop the ability to verify AI-generated scientific information against credible evidence.

UNESCO's AI Competency Framework for Teachers (2024) provides a useful foundation by identifying five areas of teacher competence: human-centred mindset, ethics of AI, AI foundations and applications, AI pedagogy, and AI for professional learning. Science teachers should consequently teach students not only how to use AI but also when not to use it, how to question its outputs and how to use it ethically. Students should understand issues such as plagiarism, fabricated scientific information, data privacy, algorithmic bias and responsible attribution of AI assistance. AI adoption should not deepen educational inequality. Schools with limited electricity, internet connectivity, devices or trained teachers may be disadvantaged. A responsible approach to reimagining science education must therefore ensure that AI complements rather than replaces essential laboratory facilities, teachers and hands-on scientific experiences.

4. Conclusion and Recommendation

Artificial intelligence presents both a challenge and an unprecedented opportunity for science education. The traditional model based predominantly on teacher exposition, textbook knowledge, memorisation and conventional assessment is increasingly insufficient for an environment in which AI can generate information, analyse data, simulate phenomena and support scientific problem-solving. Reimagining science education therefore requires a shift towards personalised learning, inquiry-based science, AI-supported experimentation, data literacy, critical thinking, innovative assessment and ethical technology use. The OECD (2025) emphasises that powerful AI requires education systems to reconsider what students should learn and how learning experiences should be organised.

However, AI should not replace science teachers or authentic scientific experiences. UNESCO (2024) places human agency and meaningful teacher–student interaction at the centre of AI-supported education and specifically states that teachers should not be replaced by technology. The most appropriate future is therefore a human-centred AI-enhanced science education system in which technology strengthens, rather than diminishes, scientific reasoning and human creativity. For Nigeria, successful implementation will require investment in infrastructure, teacher training, curriculum reform, laboratory facilities, digital resources and ethical governance. When these conditions are satisfied, AI can contribute substantially to producing science learners who are not merely knowledgeable but also critical thinkers, scientific investigators, innovators and responsible users of emerging technologies.

Based on the findings, the study recommends the followings:

1) Science curricula should be reviewed and redesigned. Curriculum planners should incorporate AI literacy, data literacy, computational thinking, scientific reasoning and emerging applications of AI into Biology, Chemistry, Physics and related science programmes.

2) Science teachers should receive continuous AI professional development. Teacher-training institutions should provide practical training in AI pedagogy, AI ethics, verification of AI-generated information, data literacy and appropriate use of AI in science instruction. UNESCO's competency framework provides a useful foundation for this development.

3) AI should complement physical laboratory experiences. Schools should develop virtual laboratories and simulations where appropriate, but these should supplement rather than replace hands-on experimentation and authentic scientific investigation.

4) Assessment should focus more strongly on scientific reasoning. Schools should reduce excessive dependence on recall-based examinations and incorporate research projects, experiments, problem-solving, evidence evaluation, oral presentations and other approaches that demonstrate genuine understanding.

5) Students should be taught to critically evaluate AI-generated scientific information. Science teachers should train learners to verify AI outputs using textbooks, scientific databases, credible websites, laboratory evidence and peer-reviewed literature.

6) Institutions should establish ethical guidelines for AI use. Policies should address academic integrity, data privacy, plagiarism, misinformation, responsible use of generative AI and appropriate attribution of AI-assisted work.

7) Government should strengthen science and digital infrastructure. Nigerian educational institutions require reliable electricity, internet connectivity, computers, laboratory facilities and technical support before AI-based science education can be implemented equitably.

8) AI should be used to promote scientific inquiry rather than cognitive dependence. Students should be encouraged to formulate questions, test hypotheses, analyse evidence and defend conclusions themselves. AI should function as a support tool rather than an automatic answer provider.

9) Science teacher education should embrace the teacher–AI–student model. Teacher-training programmes should prepare future science teachers to work effectively alongside AI while maintaining their professional judgement and responsibility.

10) AI adoption should remain human-centred and equitable. Policymakers and educational institutions should ensure that AI strengthens teachers and learners rather than widening existing inequalities or replacing meaningful human interaction. UNESCO's framework explicitly places human-centredness, ethics and human agency at the core of responsible AI adoption.

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