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INTEGRATING ARTIFICIAL INTELLIGENCE INTO SCIENCE EDUCATION FOR SUSTAINABLE DEVELOPMENT IN NIGERIA

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ABSTRACT

The integration of Artificial Intelligence (AI) into science education has emerged as a transformative tool for promoting critical thinking and problem-solving skills among students and educators in the science classroom, reshaping science education by enriching how scientific concepts are taught, understood, and applied. One significant contribution of AI to Science education is its support for inquiry-based learning and experimentation. This paper examines the concept of Artificial Intelligence, Science Education, in Nigeria schools and how it can improve Sustainable development. It also discusses how AI provides innovative opportunities in enhancing students learning outcomes. It further examines key challenges such as accessibility, digital literacy and resistance to technology. The paper highlights the importance of equipping educators and learners with the skills and knowledge necessary to engage critically and ethically with AI systems. It concluded that effective Science Education in the country is the key to Sustainable development particularly as the country endeavors towards building equitable, tolerant, sustainable and knowledge-based societies.

Keywords: Integration, Artificial Intelligence, Science Education, Sustainable development Education,

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INTRODUCTION

Education is equally the process of facilitating learning or the acquisition of knowledge, skills, values, beliefs and habits (Iweala, 2012). It is through education that science can be explored and shared. Science education is well recognized as a distinct field within education, and is concerned with the teaching and learning of science and the discrete science disciplines. Science plays a vital role in nation building, which has driven every country to yearn for advancement in science and

technology which can only be achieved through education. Science education could be seen as the field concerned with sharing science content and process with individuals not traditionally considered part of the scientific community (Adolphus, 2022). Science Education is that aspect of education that leads to the acquisition of practical and applied skills as well as basic scientific knowledge (Garba, 2009). Science education involves the in-depth study of verified scientific concepts and principles. According to Lewis (2015), science education identifies natural phenomena appropriate to child's interest and skills. This implies that science education equips teachers, learners and the society with knowledge, skills, equipment and freedom to perform noble task useful for improving socio-economic standard. Thus, the goal of science education is to produce a sufficient number and diversity of skilled and motivated future scientists, engineers, and other science-based professionals. In addition, he added that science education courses are designed to produce capable scientists who contribute meaningfully to academic excellence of the society to raise the economic level of nations. Despite the importance of science education to national development, Nigeria lacked sustainable science education since its independence and as a result, science education has not been able to move the country into industrialization and above poverty level. as observed by Okonkwo (2010), science education has failed to produce skilled human resources needed for transformation into national prosperity. This implies that most of Nigeria's development in the direction of modernization has been haphazard leading to acquisition of obsolete technology. Sustainable science education development therefore represents a catalytic process for social educational, training and public awareness – the values, behavior and lifestyles required for a sustainable future.

WHAT IS ARTIFICIAL INTELLIGENCE? (AI)

AI refers to computer or machine that are designed to perform tasks that usually require human intelligence. This includes learning, understanding language, recognizing patterns or solving problems, and making decisions based on algorithms and data. (Kamalov et al., 2023; Käser & Alexandron, 2023; Zador et al., 2023). Similarly, AIs are programmes or tools created for technology devices like the computer system to simulate the human intelligence by analysing massive amount of data and recognising patterns, much like how students learn from textbooks, examples and repetitions (Russell & Norvig, 2020). These programmes are intelligent learning systems that are developed to adapt to particular or specific learning abilities to lead to improved learning outcomes and hands-on activities. The introduction of AI to the educational system will be of great importance to the system on how educational contents are delivered, assessed and interacted with by the users (students and teachers). Mohammed and Watson (2019) defined artificial Intelligence as the skillful manner of machines or technologies programmed to imitate humans. Consequently, Popenici and Kerr (2017) posited that artificial Intelligence is advancing faster in the services and educational systems. It is geared toward automated individualized education to support students of all levels of education through virtual engagement at the student's convenience and time. Raja and Nagasubramani (2018) added that it is much more interactive, making knowledge transfer easy and convenient, demonstrating that reliance and dependency on this technology make life easier and smoother, among other things. Artificial Intelligence (AI) has infiltrated every aspect of human activity, including education, and hence, the areas of science education are not exempted to its effect.

SCIENCE EDUCATION AND EDUCATION FOR SUSTAINABLE DEVELOPMENT

Science Education aims to grow scientifically literate individuals who have an understanding of science content, can draw conclusions from scientific issues and know how to evaluate scientific cases (Adolphus, 2022). Science Education has evolved through 100 years. During the early years of the 20th century, it was influenced by the education philosophers like John Dewey. Because of the influence of Dewey's educational perspective, it was accepted that Science Education and education in general were more related to social life, thus the role of Science Education was set as to teach individuals to be effective in a social world; in other words, the target of Science Education was to integrate scientific knowledge to real life activities. Today, industrial and economic developments digital technologies have been influencing Science Education. Therefore, the aim of Science Education is described as to develop scientifically and technologically informed citizens (UNESCO, 2008). As stated by Carter (2008), science has changed in recent decades with economic and technological developments and the effects of globalization. These rapid changes in science and technology brought changes in human life as well (Choi, Shin, Kim & Krajcik, 2011). Today it is possible to travel long distances by plane at cheaper costs but also this causes declining oil supplies and an increase in the amount of greenhouse gases and contributes to climate change (Levinson, 2010). Therefore, there is a need to educate citizens who are aware of the problems in the world and could make critical decisions for the environment and society (Choi et al., 2011). Hence, science could be set as a bridge to understand these issues and take action. In terms of changes in the environment and society in the 21st century the purpose of science education could be redefined by considering the current state of the earth. At the same time, as Isa and Usman (2021) stated, the purpose of science education in the 21st century has been set as to help students make critical judgments about science and increase their engagement to work for a more socially just, equitable and sustainable world. More recently, a discussion started to integrate sustainability to science teacher education as it is realized that sustainability problems are complex and need an integrated understanding by considering three aspects of sustainability (social, environmental and economic) (Feldman & Nation, 2015).

CONCEPT OF SUSTAINABLE DEVELOPMENT

Historically, sustainable development (SD) The sustainable development goals are a new, universal set of goals, targets and indicators that UN member states expect to use to frame their agendas and political policies until 2050. The SDGs are a vision of progress towards a safe, just, egalitarian and sustainable society for all human beings to effectively thrive and survive on earth. The UN is to achieve these goals within a set period of 15 years, which terminates in the year 2050. The underlining reason for the UN to move for sustainable development is the one identified by Ndukwe (2000) in Mbara (2019), which was about the cooperative relationship between growth and protection of the environment. In September 2015 at the 70th session of the General Assembly of the United Nations, member states met and adopted a new global development agenda, which gave birth to what is today termed sustainable development goals (SDGs).

In the same vein, Okwelle (2019) defined sustainable development as the management and conservation of the natural resources base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generation. So, sustainable development describes improvement and changes that aim to achieve a more sustainable development situation, and sustainability focuses on meeting the needs of the present without compromising their needs. In essence, sustainable

development of individual and that of the economy. In this regard, science education is viewed as an indispensable instrument for sustainable development because it equips individuals with the necessary skills for sustainable development of a nation.

THE PLACE OF SCIENCE EDUCATION IN ATTAINING SUSTAINABLE DEVELOPMENT IN THE COUNTRY

Sustainable development is as about the development of individual and that of the economy. In this regard, science education is viewed as an indispensable instrument for sustainable development because it equips individuals with the necessary skills for sustainable development of a nation. Some of the area's science education can assist in the attainment of the sustainable development are:

Science Education Promotes Sustained and Responsible Citizens

Students who have learned to think critically and have a healthy dose of skepticism can better make their own, informed decisions, which can make them more enlightened, informed voters and stronger consumers. Also, the sense of responsibility and caution that science provides - along with the understanding of how things work (be they chemical reactions, human development, or nutritional needs) - can help future parents to provide safe, healthy environments for their own children, and be more responsible pet owners and neighbors.

Promote a Strong Economy

Nigeria's scientific, technological, industrial, and economic growth can only be assured on the foundation of an effective science and technology education. For this reason, curricula contents and intended learning objectives of science education are directed at achieving core national aspirations capable of producing the goods and services needed for the economy's growth and sustained society. science education is necessary to substantiate the claim it has been argued that: science education can single-handedly solve the problem of poverty, lack of availability of food, issues of superstition, and deadening customs and traditions in Nigerian societies. The future belongs to those who make friends with science (Lawal and Usman .2018). Also, students who have a solid knowledge base in science will later be more open to emerging technologies and ideas that can boost businesses and stimulate the economy.

Promote Critical Thinking and Informed Citizens That Impact the World

Science Education is by inculcating critical thinking in the student's mind. Critical thinking can lead to meaningful results through creative ways of understanding and willingness to consider views where necessary, Solomon et al., (2018). His study has its basis in the National Policy on Education, which states that the major goal of education is to train and prepare people who will cultivate inquiry habits, acquire knowledge and rational minds, conduct a good life and produce scientists for national development. Some researchers, such as (Cottrel, 2011) and Brookhart (2010), state that critical thinking is a means of scientific and reflective thinking in pursuing relevant and reliable knowledge about the world. Critical thinking should be reflective, responsible, skillful, and focused on deciding what to believe or not. It is also seen as higher-order thinking and involves the formation of sound conclusion. As a matter of necessity, science and education should be activity and inquiry-based, at a level where the younger generation is to be nurtured.

HOW AI PROVIDES INNOVATIVE OPPORTUNITIES IN ENHANCING STUDENTS LEARNING OUTCOMES IN SCIENCE EDUCATION

Artificial Intelligence (AI) is transforming Science education by reshaping how students engage with content, receive personalized instruction, and develop problem-solving skills essential for the strategies needed to succeed in an increasingly complex and technology-driven economy. Through intelligent systems and adaptive technologies, AI enhances the learning experience, making Science education subjects more interactive, inclusive, and effective. The following are some AI innovative opportunities in science education as outlined in (Madume, Otuturu &Ekineh, 2025).

1. **Enhancing Learning**

AI-driven tools such as intelligent tutoring systems, educational chatbots, and gamified learning platforms promote active learning and sustained engagement. By incorporating real-time feedback and interactive elements, these tools cater to students' curiosity and maintain motivation. For instance, platforms like Carnegie Learning and Squirrel AI offer AI-based tutoring that simulates human-like feedback, fostering deeper engagement in mathematical and computational thinking (Holstein et al., 2019). Moreover, AI-supported virtual labs and simulations allow learners to explore scientific concepts in immersive environments, making abstract concepts more concrete and enjoyable (Zawacki-Richter et al., 2019).

2. **Supporting Personalized Learning**

AI enables differentiated instruction by analyzing individual learner data and adjusting content delivery accordingly. Adaptive learning systems can identify students' strengths and weaknesses, provide instant feedback and guidance, and offer customized pathways to address specific learning gaps. Chen et al. (2020) state that AI-powered platforms adapt questions, pace, and instructional methods based on student responses, ensuring that learners receive support aligned with their needs. This level of personalization is particularly critical in science subjects where foundational understanding is essential for higher-level reasoning.

3. **Fostering Problem-Solving and Critical Thinking**

AI provides students with tools to learn and apply problem-solving skills through dynamic simulations, coding platforms, and intelligent feedback systems. By presenting real-world challenges and modeling alternative answers, AI motivates learners to experiment, reflect, and update their ways. AI-powered tools present open-ended problems and encourage creative solutions. According to research, AI can help learners solve complex problems by offering structured clues, step-by-step breakdowns, and quick corrective feedback (Luckin et al., 2016). This encourages analytical thinking and increases confidence in completing difficult science problems.

4. **Improved Engagement**

AI-powered interactive simulations and virtual labs provide immersive learning experiences by bringing students to 3D worlds. Role-playing exercises allow students to explore concepts while improving their understanding and motivation. AI-driven tools stimulate creative problem-solving, enabling science students to experiment with real-world simulations and build solutions.

5. **Enhanced Career Readiness**

AI-powered Science education prepares students for an AI-driven future. AI literacy and computer science courses equip students with skills for the modern workplace, while hands-on AI projects allow students to build AI prototypes, create personalized AI assistants, and develop critical thinking and problem-solving competencies.

6. Inclusivity and Accessibility

AI-powered tools promote inclusivity in science education by breaking down barriers for underrepresented groups. Personalized learning platforms tailor lessons to individual learning styles, providing opportunities for diverse students. AI also helps translate materials into multiple languages, overcoming language barriers.

Challenges in Implementing AI in Science Education

1. Data Privacy and Ethical Concerns

AI systems require vast amounts of personal and behavioral data to function effectively. This raises questions regarding student privacy, data security, and ethical use of information. Therefore, safeguarding this information is critical for maintaining the confidentiality of the students There is growing worry about how data is collected, handled, and shared, especially when third-party suppliers are involved. Slade & Prinsloo (2013) state that without defined regulatory frameworks, educational institutions risk breaching students' rights and exposing sensitive data to misuse. Implementation of solid data encryption methods and very severe access controls, along with keeping to regulations such as the General Data Protection Regulation (GDPR), is required for safeguarding student data (Pardo & Siemens, 2014).

2. Unequal Access to Technology

Access to digital infrastructure, such as gadgets, fast internet, and smart educational platforms, is a vital requirement for AI-enhanced learning. Unfortunately, there is a digital divide because many kids do not have access to these necessities, especially those who live in rural or low-income areas. van Dijk (2020) states that this worsens already-existing educational disparities and produces unequal learning opportunities. Schools with limited budgets may also struggle to adopt and maintain AI tools, especially if they require expensive subscriptions or ongoing technical support.

3.Teacher Training and Resistance

Many teachers are not familiar with AI tools or feel unprepared to use them effectively in their classrooms, which leads to resistance to adoption, especially when technology is perceived as complex, intrusive, or threatening to the teacher's autonomy (Holmes et al., 2021).

Suggestions

1. The government should Invest in Infrastructure and Accessibility, and prioritize the recruitment of AI experts to train educators There should be training courses arranged for teachers on how to use AI tools optimally in teaching Science subjects. Government and Educational institutions should ensure that science teachers have access to necessary hardware (computers, tablets) and software. Address issues of digital divide by providing equitable access to technology for all. Incorporate tools like virtual labs, simulations, and educational apps to make teaching and learning more engaging.

2. Data privacy and ethical considerations should be emphasized by developers and educators to keep student information secure and remove bias from AI algorithms. important to design AI systems with ethical considerations, ensuring transparency, accountability and fairness. Teachers

and policymakers must discuss the ethical aspects of using AI by making guidelines and frameworks to promote the ethical practices of AI, in education.

CONCLUSION

In this discourse, it was observed that Science Education in the country is the key to Sustainable development particularly as the country endeavors towards building equitable, tolerant, sustainable and knowledge-based students in the society that depends directly on its level of scientific literacy. Artificial Intelligence (AI) is gradually dominating the education system with very high speed while transforming the landscape of science domains. AI-equipped platforms and tools are automatically able to enable teachers to provide personalized learning experiences, enhance creativity, and build critical thinking skills in learners. Nevertheless, educational systems across the globe are encountering challenges in ensuring universal access to education, equipping graduates with essential knowledge and skills for dynamic markets ansd complex living environments preparing students for future occupations for sustainable development.

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