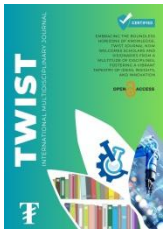
DOI 10.5281/twist.10049652#569

TWIST, 2026, Vol. 21, Issue 1, pp. 222-227

TWIST

Journal homepage: www.twistjournal.net



An Exploratory Study of Artificial Intelligence in Promoting Creative and Sustainable Science Education

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Abstract
This study explores the role of Artificial Intelligence (AI) in promoting creative and sustainable science education. As educational systems face increasing pressure to adapt to rapid technological advancements and address environmental challenges, AI offers promising solutions for transforming science learning. By reviewing existing literature and case studies, the researcher examines how AI-driven tools such as adaptive learning systems, intelligent tutoring systems (ITS), and virtual labs can enhance both creativity and sustainability in science education. These AI tools enable personalized learning experiences, support creative problem-solving, and foster deeper engagement with scientific concepts while reducing reliance on physical resources through resource-efficient methods. The study also addresses the challenges of AI integration, particularly the digital divide in developing regions, and emphasizes the importance of interdisciplinary collaboration among educators, policymakers, and technology developers. Thus, AI's role in curriculum design and resource optimization is discussed, providing a framework for creating future-ready education systems that prepare students for the demands of an increasingly complex world. The study concludes that AI enhanced critical thinking, creativity, and sustainability literacy among students, which offers valuable insights for advancing science education in both developed and developing settings.

Keywords
artificial intelligence, creativity in education, sustainable science education, technological advancements, innovative learning

INTRODUCTION

Sustainability is at the core of emerging issues in the 21st century, as rapid technological advancements have significantly reshaped the global education. Among the recurring innovations in the current age is Artificial Intelligence (AI). AI stands out as one of the most transformative, given its emerging possibilities for enhancing learning experiences (Gruetzemacher and Whittlestone, 2022). AI is not just a tool for automation or computational tasks but is increasingly seen as a potential game changer in fostering creativity and sustainability within education, particularly in sciences. Given the urgency to adapt education to the needs of a rapidly evolving and increasingly complex world, the integration of AI into science education offers a promising avenue for preparing students to meet the challenges of the future (Oluwayemisi, 2023).

This study explores the connection of AI technology with science education. It focuses on how AI can foster creativity and sustainability. As traditional education models face criticism for being overly rigid and detached from real-world applications, particularly in the STEM fields (Ejiwale, 2013; Tytler, Anderson and Williams, 2023). AI presents a novel approach to addressing these gaps with a view to promoting individualized learning experiences, encouraging creative problem-solving, and embedding sustainability into the curriculum and the potential to revolutionize how science is taught and learned.

AI is a recent innovation in field of computer science. It is refers to as the development of computer systems or machines that can perform tasks typically requiring human intelligence (Khaleel, Jebrel, and Shwehdy, 2024; Copeland, 2024). These tasks include problem-solving, understanding natural language, recognizing patterns, learning from experience, and making decisions. Its scope operations includes machine learning, natural language processing, computer vision and robotics which is applicable in different fields of human endeavour.

Early research in AI started in 1960s and 1970s, with pioneering computer-assisted instruction systems like PLATO and TICCIT (Doroudi, 2022). These tools offered a glimpse of a more interactive learning experience (esoftskills.com, 2024). The rise of information systems and machine learning paved way for intelligent tutoring systems (ITS), which provide students with personalized feedback and guidance, tailoring the learning process to their individual needs (Rizvi, 2023). Sophisticated AI-powered learning platforms can adapt to each student's pace and preferences, transforming how to approach education and training entirely (Lin, Huang, and Lu, 2023).

The use of AI in promoting creative and sustainable science education aligns with Technology Enhanced Learning (TEL) approach. The approach posits that technology can be used to enhance learning outcomes and experiences, as it focuses on the role of AI in education (EA-TEL, n.d.). It is a pedagogical approach that leverages technology to enhance teaching and learning. It encompasses a wide range of educational technologies, from simple tools like word processors and spreadsheets to more complex systems like learning management systems (LMS) and intelligent tutoring systems (ITS) (Dron, 2022; Shan et al., 2024). The strength of the approach is that it is learner-centred. It allows students take an active role in their learning and can personalize their educational experiences. It allows the integration of technology into the learning process, ensuring that it supports and enhances, rather than hinders, learning objectives. This makes learning more engaging and interactive, leading to increased student motivation and participation. However, digital divides and technical issues can be a challenge, particularly in developing countries. This can disrupt the learning process and frustrate students and teachers. With the advent of AI, learning can be personalised which allows learner to learn at their own pace.

The integration of AI into science education aligns with broader educational goals aimed at developing students' critical thinking and problem-solving skills (Olatunde-Aiyedun, 2024). These skills are essential for addressing global challenges like climate change, resource scarcity, and technological disruption. AI-driven educational tools, such as adaptive learning systems, intelligent tutoring systems, and virtual simulations, can cater for the diverse learning needs. This can done by offering personalized and dynamic learning experiences that encourage students to explore complex scientific concepts creatively (Almasri, 2024; Farahani, and Ghasemi, 2024). At the same time, AI can optimize educational practices to promote sustainability, minimizing the environmental impact of science education through resource-efficient methods like virtual labs and simulations (Almasri, 2024).

Being a novel approach, research in AI driven creative and sustainable science education has received little attention especially within Nigeria context. Hence, this study lays the foundation for a deeper exploration of how AI can be utilized not only to enhance the creative aspects of science education but also make it more sustainable. In this study, we will examine various AI-driven educational interventions and their implications for fostering creativity and sustainability in science classrooms. The study will explore best practices, potential obstacles, and opportunities for leveraging AI to transform science education into a forward-thinking, interdisciplinary, and environmentally conscious discipline.

PURPOSE OF THE STUDY

The broad aim of this study is to investigate the potential of Artificial Intelligence (AI) to enhance creative and sustainable approaches in science education. That is how AI can be integrated into science education to promote creativity and sustainability, thereby enriching students' learning experiences and preparing them for the demands of a rapidly evolving world. Thus, the study will specifically provide answer to the following questions:

1. What are the potential of AI to enhance creative and sustainable approaches in science education?
2. How can AI be integrated into science education to promote creativity and sustainability?

MATERIALS AND METHOD

This study employed a qualitative research approach, focusing on an extensive review of existing literature and case studies to explore the role of Artificial Intelligence (AI) in promoting creativity and sustainability in science education. The materials used in this research included peer-reviewed academic articles, empirical studies, theoretical frameworks, and interdisciplinary perspectives from education, cognitive science, and AI research.

To gather comprehensive data, databases such as Google Scholar, JSTOR, and PubMed were utilized to collect relevant literature on AI integration in education, with a particular focus on science education. Keywords such as "AI in education," "creativity in science education," "sustainable learning," "intelligent tutoring systems," and "AI-driven curriculum design" were used to filter the most relevant sources. The selection criteria prioritized recent studies (published within the last five years), with particular attention to real-world applications of AI technologies in educational settings, especially within STEM (Science, Technology, Engineering, and Mathematics) disciplines.

The methodology involved a systematic analysis of case studies highlighting AI-driven educational interventions and their implications for fostering creativity and sustainability. This included examining best practices, challenges, and opportunities related to AI-enhanced science education. The data was synthesized into thematic categories such as adaptive learning systems, AI-enabled virtual labs, resource optimization, and AI's impact on personalized education.

The insights from these studies were used to develop a conceptual framework that outlines the potential benefits and challenges of integrating AI in science education.

RESULTS AND DISCUSSION

What is the potential of AI in enhancing creative and sustainable approaches in science education?

AI has the potential to enhance creativity and sustainability in science education through various innovative tools and approaches. Adaptive learning systems analyze student performance to personalize instruction, helping educators identify strengths and weaknesses while allowing students to learn at their own pace (Robert, Potter, & Frank, 2024).

Intelligent Tutoring Systems (ITSs) provide real-time feedback and adaptive learning experiences, improving problem-solving skills and scientific understanding (Thomas et al., 2024). Research shows AI tutors enhance learning effectiveness in K-12 classrooms compared to traditional methods.

AI also fosters creativity by aiding in experiment design, hypothesis generation, and data analysis (Chih-Pu & Fengfeng, 2022). Additionally, AI-generated simulations and virtual labs make abstract concepts more engaging.

Sustainability is promoted through AI-driven resource optimization, reducing material waste, and predictive analytics that identify at-risk students for timely interventions. AI also supports curriculum design by integrating sustainability topics like renewable energy and conservation (Hider & Saleem, 2024).

Inclusivity is improved through AI-powered language translation and assistive technologies, ensuring accessibility for non-native speakers and students with disabilities (Dubey, 2024). AI-powered collaboration platforms further enhance learning by connecting students globally for shared projects and peer interactions.

Finally, AI aids educators' professional development by providing up-to-date teaching strategies and scientific advancements (Fakhar et al., 2024; Ou, 2024), fostering a sustainable and innovative approach to science education.

How can AI be integrated into science education to promote creativity and sustainability

AI can enhance science education by fostering creativity and sustainability through adaptive learning platforms, virtual labs, and AI-assisted curriculum design. AI-powered adaptive systems personalize instruction, tailoring content to individual learning styles and pacing (Chih-Pu & Fengfeng, 2022; Groenewald et al., 2024). Virtual simulations and labs allow students to conduct experiments in resource-efficient digital environments, promoting sustainable learning practices (Groenewald et al., 2024).

AI also aids in curriculum development by analyzing educational trends and integrating sustainability themes—such as renewable energy and climate science—into science lessons (Olatunde-Aiyedun, 2024; Chen et al., 2023). Additionally, AI-generated interactive content, including visualizations and multimedia resources, helps students grasp complex concepts creatively (Budwig, 2015; Rødnes & Dolonen, 2022).

Project-based learning is further enhanced by AI, which supports students in sustainability-focused research by aiding in data analysis, idea generation, and real-time feedback (Olatunde-Aiyedun, 2024). AI-driven collaboration platforms also connect students globally, facilitating cross-cultural teamwork on sustainability projects through translation tools and shared workspaces (Meng et al., 2022).

By leveraging these AI-driven strategies, science education can become more engaging, inclusive, and aligned with global sustainability goals.

AI-powered assessment tools can evaluate not only knowledge but also creativity and problem-solving skills in sustainability-related tasks (Yakar-Pritchard et al., 2024). By analyzing open-ended responses, AI provides tailored feedback that encourages deeper exploration. Instant feedback on assignments and experiments (Sabrina et al., 2024) allows students to refine their ideas iteratively, fostering innovation in sustainable science solutions.

AI supports teacher training through personalized modules on integrating creativity and sustainability into science lessons (Lin, Huang, & Lu, 2023). AI-powered platforms enable educators to share resources, lesson plans, and strategies (Ai-Chu et al., 2024), with recommendations tailored to individual teaching goals.

AI optimizes resource use in science education by managing lab equipment, reducing waste, and suggesting eco-friendly alternatives (Wu, Burdina, & Gura, 2023). For instance, AI can recommend virtual labs over physical setups when feasible, lowering environmental impact. Additionally, AI analyzes student performance and resource data to identify efficient, sustainable teaching methods without compromising learning quality (Lin et al., 2023).

By integrating AI in these areas, science education becomes more adaptive, resource-efficient, and aligned with sustainability goals.

AI enhances problem-based learning by simulating real-world sustainability challenges (Nishant et al., 2020). Students can analyze real-time data, model different scenarios, and explore creative solutions to environmental issues. These AI-powered simulations help learners understand complex systems and assess the consequences of various actions, fostering critical thinking about sustainable scientific solutions.

AI supports continuous education by providing students with up-to-date research, sustainability trends, and innovative scientific developments (Fidalgo & Thormann, 2024). Personalized AI learning pathways adapt to individual interests in sustainability and creativity (Jian, 2023), encouraging ongoing exploration beyond the classroom.

By integrating AI in these ways, science education cultivates both creative problem-solving and a lasting commitment to sustainability, equipping students to address future environmental challenges effectively.

CONCLUSION

This study highlights the transformative potential of AI in promoting creativity and sustainability in science education. The potential benefits of AI in science education are multifaceted, as it encourages creativity by enabling students to engage in hands-on, exploratory learning. AI tools has facilitated innovative approaches to experimentation and scientific inquiry. This allows students to test hypotheses, analyze data, and even generate new knowledge in ways that would be difficult in traditional classroom settings. Moreover, AI has enhanced sustainability by promoting resource optimization and reducing reliance on physical materials, which aligns with the global push towards more environmentally responsible education systems. Through AI-driven adaptive learning systems, intelligent tutoring, and resource-efficient virtual labs, students can engage with scientific concepts in innovative and personalized ways. AI's capacity to optimize educational resources aligns with the global push for sustainability, ensuring that education not only prepares students for the demands of the future but does so in an environmentally conscious manner. Furthermore, the interdisciplinary collaboration between educators, policymakers, and AI developers will be crucial in maximizing these benefits, fostering an inclusive, innovative, and sustainable approach to science education. The findings of this research provide a foundation for efforts in integrating AI into educational systems, ensuring that AI serves as a catalyst for cultivating creativity, critical thinking, and sustainability literacy among students.

ACKNOWLEGMENT

Special appreciation goes to all the authors whose works serve as primary source of information to this research work.
This research has not received external funding.

FUNDING INFORMATION

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

DECLARATION OF CONFLICT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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