

HARNESSING DIGITAL PEDAGOGIES AND SMART CLASSROOMS FOR FUTURE-READY BIOLOGY EDUCATION

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Abstract

As the society is being transformed technologically, every sector has been invaded by digital technologies, specifically, the education sector because education is the key to national growth and development. This study explored harnessing digital pedagogies and smart classrooms for future-ready Biology. This research is a position paper that advocates for the integration of digital pedagogies and smart classrooms as strategies for enhancing future-ready Biology Education. Drawing on current literature, educational and emerging global trends, the study highlighted the need to harness digital pedagogies and smart classrooms for future-ready Biology Education, which include achieving the sustainable development goals, blended learning opportunities, improved student-centered learning, promoting interactive classes and collaboration, enhancing experiential learning, enhancing engagement, promoting personalized learning, and leveraging virtual reality and augmented reality. Key features and components of digital pedagogies and smart classrooms were also identified, including technology integration, artificial intelligence-driven platforms, digital content delivery, interactive whiteboards and network virtual environment. The study further highlighted the challenges to harnessing digital pedagogies and smart classrooms for future-ready Biology Education in Nigeria such as technical, pedagogical, and socioeconomic challenges. The study concludes with recommendations for educators to harness digital pedagogies and smart classrooms to promote a future-ready Biology Education. Also, there should be continuous teachers' professional development and there should be sustained investment in digital infrastructures through adequate funding of the education by the government.

Keywords: Digital pedagogies, smart classroom, future-ready biology

Introduction

For any nation to develop, the knowledge of science and technology is required. Science and technology serves as tool for national growth and development. The bedrock upon which a nation is built is Science. Science is defined as a body of knowledge and processes studied for the possibilities it offers for the development and advancement of technology (Agboola, 2025). According to Michael (2023), science has found its usefulness in medicine, manufacturing industries, construction, engineering, agriculture, technology and communication. One of the branches of science whose role in developing individual and nation cannot be underrated is Biology. Biology is derived from Greek words "bios" meaning life and "logos" meaning study thus, Biology is the study of life. Green (2026) defined Biology as the study of living things and their vital processes. Green (2026) stressed further that Biology as a field of study cut across other disciplines, it overlaps with Chemistry, Medicine and Physics. It is therefore integrated with biochemistry, biomedicine and biophysics.

Hence, Biology is a multidisciplinary subject and its knowledge is applied in everyday life. It is an important subject that plays a major role in achieving Sustainable Development Goals in Nigeria through its various concepts. Febres (2024) submitted that the principles of biology are applied daily in healthcare, environmental conservation and

agriculture. In health care, Biology has been essential in developing medical treatments that save millions of lives. It has improved Agriculture through Biological research which has led to better crop yields, pest resistant plants and sustainable farming practices. Understanding ecosystems and biodiversity is crucial for conservation efforts, pollution control and the sustainable management of natural resources. The future of Biology shows that its role in the society is more crucial than ever, as the society faces global challenges like climate change, pandemics and biodiversity loss, advances in genetic engineering, conservation biology and synthetic biology hold promise for solutions to these challenge, highlighting the importance of continued investment in biological research (Febres, 2024). The application of the knowledge of Biology is important to individual and it is of a great value to the nation.

Although, in the present 9-3-4 Nigerian system of education, Biology is no longer a core subject yet its relevance in achieving the Sustainable Development Goals (SDGs) cannot be overemphasized and it is one of the required subjects to gain admission into higher institution to study health sciences (Medicine, nursing, dentistry, physiotherapy), biological sciences (microbiology, genetics, marine biology, biotechnology), environmental studies (ecology, wildlife management, forestry and environmental pollution), biology education and other related courses. This is supported by Ndayambaje et al (2021) that Biology is a worthwhile subject which prepares students to face real world of work through numerous career paths such as medicine, pharmacy, agriculture, nursing, food science, environmental studies and many others. Therefore, it is not a gain saying that Biology is relevant.

However, despite the importance of Biology to the individual as well the nation, there has been report on the poor performance of the students in Biology. Biology students' in both WASSCE and SSCE has become a great concern to various stakeholders. Persistence in poor performance in Biology have been reported (Gana et al, 2023). Parents in particular are worried about frequent poor performance of the students in these public examinations (Egbunu, 2022). Findings of Ndayambaje et al (2021) revealed the root causes of students' poor performance in Biology to include use of English language as medium of instruction, insufficient laboratory equipment, insufficient teaching and learning materials, inappropriate teaching methodology, amount of content and time allocated, inadequate involvement of parents in learners' education, poverty, students' absenteeism and school environment. Other factor identified is the abstract nature of some concept in Biology (Michael-Aondoaseer et al, 2025) while Jamaludin et al (2024) reported the complex nature of the subject. Therefore, there is need to proffer solutions to these problem for teaching and learning of Biology to be effective. To proffer solutions to this problem, it is of necessities to consider the innovations for teaching biology which include harnessing digital pedagogies and smart class room for future Biology.

Agboola (2025) identified the key features of Science Pedagogy which as well affect Biology as a science subject as well. The pedagogies are Inquiry-based learning, hands-on experiments, interdisciplinary approach, use of technology, constructivist approach, collaborative learning, real world context and assessment for learning. Agboola (2025) further highlighted the goals of these pedagogies to include; developing scientific literacy, foster curiosity and creativity, enhance problem-solving skills and prepare for future challenges. From the foregoing, it is undeniable that harnessing digital technologies and smart classrooms is the key to achieve the goals of science pedagogies, for improvement in the future of Biology and for the nation's growth and development.

This position paper is significant because it provides evidence-based arguments for integrating digital technologies and smart classrooms into Biology education. It

contributes to promoting the ongoing discussions on digital classrooms and standard of education by highlighting practical strategies to improve Biology students' engagement, their digital literacy and their learning outcomes through harnessing digital pedagogies and smart classrooms. Therefore, the study is expected to benefit both the teachers and the students. It also benefits the school administrators by providing insights on continuous teachers' professional development and it will also be of benefit to the researchers by contributing to the available knowledge on digital pedagogies, smart classrooms and future-ready Biology Education.

Digital education is defined as the use of digital technologies and resources to facilitate learning and teaching processes. It encompasses various methods, including online courses, virtual classrooms, and educational software UNESCO (2026). On the other hand, smart classrooms integrate physical and digital infrastructures to create environments that respond adaptively to teaching and learning processes (Panda et al, 2025). Similarly, SchoolnetIndia (2024) defined smart classrooms as an advanced digital learning environment that enhances conventional teaching methods with modern technology. Therefore, harnessing digital technologies and smart classrooms for future-ready Biology education is the application of digital tools and resources together with conventional teaching method in an advanced digital learning environment to enhance and improve teaching and learning of Biology.

Needs to Harness Digital Pedagogies and Smart Classrooms for Future-Ready Biology Education

There is need to harness digital pedagogies and smart classrooms for future-ready Biology Education because as technology is not enough. Also, conventional teaching method alone is not enough. The following are the benefits and the needs to harnessing digital pedagogies and smart classrooms for future-ready Biology education:

Achievement of the sustainable development goals: Harnessing digital pedagogies and smart classrooms will promote the achievement of the sustainable development goals. Digital technologies through evolution has been found to network tools and programmes that connect people and things across the world, and it helps to address personal and global challenges. Digital innovation has potential to complement, enrich, transform education and speed up the progress towards Sustainable Development Goal 4 (SDG 4) which is quality education (UNESCO, 2026). Febres (2024) submitted that the principles of biology is applied daily in healthcare, environmental conservation and agriculture. In health care, Biology has been essential in developing medical treatments that save millions of lives. It has improved Agriculture through Biological research which has led to better crop yields, pest resistant plants and sustainable farming practices. Understanding ecosystems and biodiversity is crucial for conservation efforts, pollution control and the sustainable management of natural resources.

Therefore with many benefits of Biology, the future-ready Biology is capable of achieving Sustainable Development Goal SDG 1, no poverty through its knowledge on sustainable management of natural resources and improved agriculture through biological research; SDG 2, zero hunger with improved Agriculture through Biological research; SDG 3, good health and wellbeing through its principles being applied daily in healthcare; SDG 6, clean water and sanitation with application of Biology knowledge in health care and pollution control; SDG 7, affordable and clean energy with knowledge of environmental conservation in Biology, SDG 8, decent work and economic growth through application of Biological research for improved Agriculture and sustainable management of resources; SDG 13, climate action with understanding ecosystems and biodiversity which is necessary for conservation efforts; SDG 14, life below water through understanding

ecosystems and biodiversity which is crucial for conservation efforts and SDG 15, life on land with the knowledge of ecosystems and biodiversity that is crucial for conservation efforts.

Students' engagement: Digital pedagogies and smart classrooms enhance students' engagement. The study of Panda et al (2025), smart classrooms increased participation, particularly during collaborative projects and problem-solving activities. Hence, digital pedagogies and smart classrooms captivates students' attention and thus improve students-centered learning with interactive content, multimedia presentations, and real time feedback making learning more enjoyable and dynamic. Therefore, it promote interactive class, hands-on, active learning and collaboration.

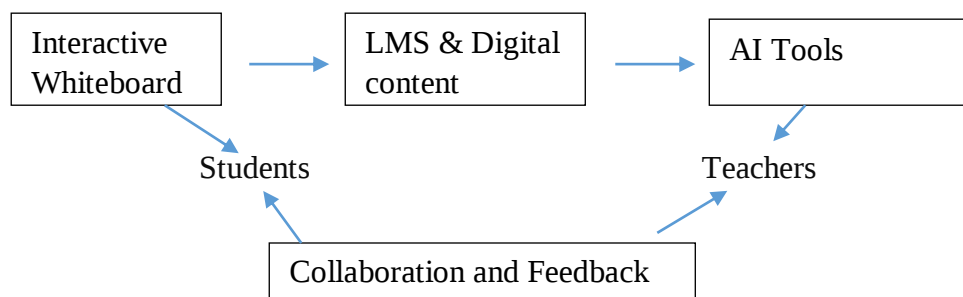
Personalized learning: With digital pedagogies and smart classrooms lessons can be tailored to meet learners' needs and individual learner can learn at their own pace and style. This is supported by Haleem et al (2022) that digital technologies promote convenient teaching and learning and it also makes classroom instructions interesting.

Virtual reality and augmented reality: Digital pedagogies and smart classrooms promote virtual reality and augmented reality through virtual labs which enable students to perform many experiments that are difficult to perform in real laboratories. With virtual labs, students perform the practical experiments related to the theoretical courses, which promote their engagement and the learning process. It also protects students and teachers from hazards, since there won't be direct contact with toxic or radioactive chemicals (Muhamed, 2025).

Blended learning opportunities: Harnessing digital pedagogies and smart classrooms promotes blended learning with the combination of offline and online learning.

Enhances experiential learning: Studies have shown that modern technology plays a pivotal in enhancing experiential learning by providing tools and platforms that enable hands-on, interactive, and immersive educational experiences (Ranjan, 2026). Therefore, harnessing digital pedagogies and smart classrooms will enhance experiential learning in future-ready Biology education.

Key features and Components of Digital Pedagogies and Smart Classroom: The key features and components of digital pedagogies and smart classrooms include blended learning, flipped classrooms, gamification, adaptive learning, interactive whiteboards, Learning Management Systems (LMS), Artificial Intelligence (AI)-powered tutoring systems, Virtual Reality (VR) and Augmented Reality (AR) tools, and networked virtual environments. Together, these technologies and instructional approaches enhance teaching and learning by promoting interactive, personalized, collaborative, and technology-driven educational experiences.



Components of digital pedagogies adapted from Panda et al (2025)

Challenges to Harnessing Digital Pedagogies and Smart Classrooms for Future-Ready Biology Education in Nigeria

The major challenges to harnessing digital pedagogies and smart classrooms for future-ready biology education in Nigeria include the digital divide, technical challenges, and pedagogical challenges. The digital divide refers to unequal access to technology and digital resources across socioeconomic and geographical groups (McEwan, 2023). Technical challenges include inadequate technological facilities, poor internet connectivity, and system failures, while pedagogical challenges involve inadequate teacher training and the gap between the availability and effective utilization of digital technologies in teaching.

Conclusion

Harnessing digital pedagogies and smart classrooms for future-ready Biology Education is the solution to the problems of Biology as well as societal problems because it focuses achievement of the sustainable development goals (SDGs), blended learning opportunities, improved student centered learning, promoting interactive class and collaboration, enhances experiential learning, enhances engagement, personalized learning, virtual reality and augmented reality. However, there are challenges to harnessing digital pedagogies and smart classroom for future-ready Biology Education in Nigeria such as technical, pedagogical, and socioeconomic challenges. Therefore, to overcome these challenges, policymakers are to prioritize development of infrastructure and continuous professional development.

Recommendations

To address these challenges, collaborative efforts among schools, government, local councils, and private organizations should be strengthened to provide adequate digital infrastructure and ensure equitable access to technology. Policymakers should prioritize the development of digital infrastructure and the provision of necessary facilities. In addition, continuous professional development should be provided for teachers to enhance their digital competencies, while institutional policies should promote access to digital technologies and provide adequate technical support to encourage the effective use of digital pedagogies and smart classrooms.

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