Artificial Intelligence in Advancing Qualitative Education, Technology and Innovation for Sustainable National Development

Ogunlade Ibiyinka, Ola-Kadri Anjolaoluwa, Ogunlade Oluwatosin

AJP

Artificial Intelligence in Advancing Qualitative Education, Technology and Innovation for Sustainable National Development

Ogunlade Ibiyinka[1], Ola-Kadri Anjolaoluwa[2], Ogunlade Oluwatosin[3]

[1]Department of Chemical Sciences, BOUESTI, Ekiti State

[2]Department of Science Education, Ajayi Crowther University, Oyo, Oyo State

[3]Department of Strategy and Leadership, University of East London, UK
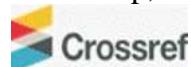
Crossref

Abstract

Purpose: The paper aims to examine the role of Artificial Intelligence (AI) as a driving force in transforming qualitative education, fostering innovation, and accelerating technological development globally. It seeks to highlight how AI facilitates technology transfer and promotes sustainable development across multiple sectors, including education, healthcare, agriculture, and governance.

Materials and Methods: The study adopts a descriptive and analytical approach, drawing from secondary data sources and contemporary examples of AI applications. It reviews existing literature and policy frameworks to assess how AI-driven data analytics supports decision-making and strategic planning among key stakeholders such as government bodies, educational institutions, and healthcare providers.

Findings: The paper finds that AI significantly enhances the capacity of institutions to identify emerging trends and respond rapidly to societal and technological changes. It underscores AI's applicability in: Education, Agriculture, Healthcare and Governance. The study acknowledges that risks such as bias and ethical challenges persist despite all its benefits. However, ongoing strategies and frameworks are mitigating these limitations to ensure AI's sustainable integration into national development agendas.

Unique Contribution to Theory, Practice, and Policy: The paper contributes to understanding AI as not just a technological tool but a transformative agent in socio-economic and educational evolution. It also provides a practical perspective on how institutions can leverage AI-driven analytics to enhance efficiency, innovation, and service delivery across multiple sectors. The paper also emphasizes the need for adaptive frameworks and ethical guidelines that ensure responsible AI adoption, supporting data-informed governance and sustainable national development.

Keywords: *Artificial Intelligence (O33), Education (I25), Technology (O30, O32), Innovations (O32), Framework (O32).*

INTRODUCTION

Artificial Intelligence (AI) is the ability of machines to mimic human intelligence by performing tasks such as learning, reasoning, problem-solving and decision-making [1]. AI has become fundamental in innovation, technological advancement and sustainable development in the 21st century, due to the rapid pace of transformation in the digital world, revolutionizing how humans interact with technology and knowledge [2]. Many nations of the world are striving to tackle the challenges posed by; gender inequality, inaccessibility to quality education, food insecurity, poverty and inadequate healthcare facilities.

All these shortcomings can be efficiently addressed with the use of AI tools for sustainable development [3]. It was reported that recent advances in machine learning, nature language processing and predictive analytics have enabled AI to support decision-making, automate repetitive tasks and generate insights previously unattainable through conventional means [4]. This has made policymakers, researchers, educators and private sector stakeholders to leverage on it for long-term benefits of the society.

Existing literature has largely focused on sector-specific applications of AI, such as intelligent tutoring systems in education, predictive analytics in healthcare, industrial automation, and data-driven governance frameworks [5]. The integration of AI into qualitative education systems has the potential to transform teaching and learning processes, promote creativity, critical thinking and equip learners with skills for lifelong learning [5]. AI powers every technological thing ranging from weather forecasting to real-time language translation to planning of smart cities infrastructure, playing a central role in driving transformation in technology across industries. Governments are increasingly adopting AI to enhance service delivery, automate public administration and inform data-driven policy making [2].

However, despite these advancements, limited scholarly attention has been given to the integrated role of AI in advancing multiple Sustainable Development Goals (SDGs) - particularly SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), and SDG 17 (Partnerships for the Goals) - within developing economies.

Most existing studies examine these goals in isolation, overlooking how AI can simultaneously strengthen education systems, foster inclusive innovation, and enhance cross-sectoral partnerships for sustainable development.

However, some ethical, social and technical concerns in addition to algorithmic bias, data privacy, digital exclusion and workforce displacement remain insufficiently examined within an integrated SDG-driven AI framework, provoking critical reflection on the equitable use of AI technologies [6].

This study addresses these gaps by examining AI as a cross-cutting enabler of sustainable development, focusing on its interconnected contributions to education, innovation, and collaborative partnerships in developing contexts.

By adopting a holistic perspective, the study contributes to existing literature by demonstrating how AI can be strategically leveraged to advance multiple SDGs simultaneously while mitigating ethical and social risks.

SDG 4 and Importance of Quality Education

The Sustainable Development Goals (SDGs) adopted by the United Nations in 2015, provides a universal framework for addressing global challenges which includes access to education (SDG 4 - Ensure Inclusive and Promote Lifelong Learning Opportunities for all).

Figure 1: SDG 4 - Quality Education

The role of quality education in achieving of all other Sustainable Development Goals, cannot be overemphasized. It is an essential ingredient for acquisition of necessary skills needed to impact the society at large. Educated populations are more likely to promote sustainable practices, embrace innovation and contribute to social stability and economic growth [7].

The role of quality education in achieving all other Sustainable Development Goals cannot be overemphasized, as it is a foundational driver of sustainable development. *Drawing on Human Capital Theory*, education enhances individuals' knowledge, skills, and productivity, thereby increasing their capacity to contribute meaningfully to economic growth, social development, and technological progress [7] [8].

Barriers to Quality Education in Developing Countries

Achieving quality education remains a major challenge in many developing countries despite its importance, due to persistent structural and systemic barriers. These include inadequate educational infrastructure, shortage of trained teachers, limited funding, overcrowded classrooms, digital divide, socio-economic inequality, and restricted access to learning resources, particularly in rural and marginalized communities.

From a *Sustainable Development Theory* perspective, these challenges undermine long-term human and institutional capacity building, making educational systems less resilient and less capable of supporting inclusive development [9].

In recent times, access to quality education goes beyond the traditional classrooms, it includes accessibility to technology, digital literacy and ability to adapt to rapid change in technological innovations.

Artificial Intelligence and Innovation in Education

Artificial Intelligence offers innovative solutions to many of the challenges facing education systems in developing countries. Unlike traditional education models that rely heavily on physical infrastructure and uniform teaching methods, AI-enabled systems can provide personalized learning experiences, adaptive content delivery, automated assessment, and intelligent tutoring systems tailored to individual learner needs.

From the perspective of *Innovation Systems Theory*, AI strengthens education ecosystems by fostering collaboration between governments, educational institutions, technology providers, and development partners. AI-powered platforms enable scalable, cost-effective, and data-driven educational interventions that can reach underserved populations, reduce teacher workload, and improve learning outcomes even in resource-constrained environments [10].

By enhancing accessibility, inclusivity, and learning effectiveness, AI-driven educational solutions contribute directly to SDG 4 while also supporting other interconnected goals such as SDG 9 (Industry, Innovation and Infrastructure) and SDG 17 (Partnerships for the Goals). This positions AI as a critical enabler of sustainable, equitable, and resilient education systems in developing economies.

Technology as a Tool for Sustainable Development

The three goals of Sustainable Development Agenda that address AI and its application in driving educational and technological advancements are: SDG 4 - Quality Education, SDG 9 - Industry, Innovation and Infrastructure and SDG 17 - Partnership for the Goals.

AI for Sustainable National Development

Artificial Intelligence when integrated properly can bridge developmental gaps, create an adaptable digital economy, improve economic productivity, promote social equality and enhance quality of government policies. It could help improve the delivery of public services significantly. Services like; education, healthcare and security. Chatbots and virtual assistants could help with public inquiries, AI-powered diagnostic tools could aid in healthcare delivery and predictive policing systems could enhance public safety [2].

However, the use of predictive policing and surveillance technologies raises important ethical concerns, including the risk of data misuse, algorithmic bias, lack of transparency, and potential violations of civil rights. Without proper regulation and accountability frameworks, these systems may reinforce existing social inequalities and erode public trust. Therefore, ethical guidelines, human oversight, and strong data protection laws are essential to ensure responsible use of AI in public security.

AI applications in agriculture such as; precision farming and crop health monitoring, are also helping many developing countries secure food supplies while reducing environmental impact [11]. It also fosters innovations in industries by automating processes, reducing production costs and making production and logistics more efficient. Governance is enhanced by AI through improved decision-making based on real-time data analytics. Governments can plan public infrastructure better, allocate resources and deliver social services with greater efficiency. These capabilities help create smart, responsive governments that are vital for national resilience [2]. AI technologies could also help to monitor deforestation and optimize renewable energy systems, these innovations support a sustainable green economy. It is currently being used to develop early-warning systems for floods, droughts and wildfires, which would reduce disaster impact on vulnerable communities.

SDG 9 & SDG 17

SDG 9 - Industry, Innovation and Infrastructure: The 9th goal focuses on the building, promoting and fostering of infrastructure, industrialization and innovation. This applies to AI being a catalyst for innovation, thereby helping to create smart infrastructure, optimize manufacturing and develop intelligent systems that improve productivity and sustainability across industries [12] [13].

Figure 2: SDG 9 - Industry, Innovation and Infrastructure

Figure 3: SDG 17 - Partnerships for the Goals

SDG 17 - Partnerships for the Goals: SDG 17 underlines the importance of multi-stakeholder collaboration including governments, private sector companies, academic institutions and the society at large. The advancement of AI requires such partnerships to address issues like data governance, access to digital tools, ethical use of AI and inclusive deployment [14].

These partnerships operate through structured collaborative arrangements, each serving distinct but complementary roles in the AI innovation ecosystem. Public-private partnerships (PPPs)

play a central role by enabling governments to collaborate with technology firms to co-develop AI-driven public services, expand digital infrastructure, and scale innovative solutions while sharing financial, technical, and regulatory risks

Academia-industry linkages support AI advancement through joint research initiatives, innovation hubs, and skills development programs that align academic research with industry needs and workforce demands. Furthermore, international and cross-sector partnerships facilitate knowledge transfer, capacity building, and the diffusion of global best practices, particularly in developing countries.

These goals highlight the strategic role of AI in creating a more inclusive and innovative path in advancing education, technology and innovations.

AI In Solving Challenges Facing National Development

There are various challenges facing national development, including poverty, educational inequality, climate change, limited digital access, weak governance, and unemployment. While AI does not eliminate unemployment entirely, it has the potential to reshape labour markets by improving productivity, creating new categories of work, and supporting skills development when appropriately governed.

Integrating AI into education enhances personalized learning, improves educational outcomes, and helps reduce educational inequalities, thereby supporting the achievement of SDG 4 [5]. AI is currently being applied across multiple sectors, including education, healthcare, agriculture, governance and policy making, finance, and industry.

However, the integration of AI across these sectors inevitably transforms existing job roles and employment structures rather than simply replacing them. While AI-driven automation may displace certain routine or low-skilled jobs, it also creates demand for new roles in areas such as data analysis, AI system maintenance, digital services, and innovation-driven industries. The overall impact of AI on employment therefore depends on complementary investments in education, reskilling, and inclusive digital policies.

As a result, several implications must be carefully considered, including job displacement risks, data privacy and surveillance concerns, algorithmic bias and discrimination, the digital divide, and ethical and legal uncertainties.

Conceptual Framework

Intersection of AI with SDG 4, 9 and 17

AI and SDG 4: Artificial Intelligence contributes to SDG 4 by enabling equal and inclusive access to education through intelligent systems that adapt to the personal learning needs of an individual. It also supports lifelong learning by providing scalable digital education resources, bridging gaps in teacher shortages and geographic barriers [2].
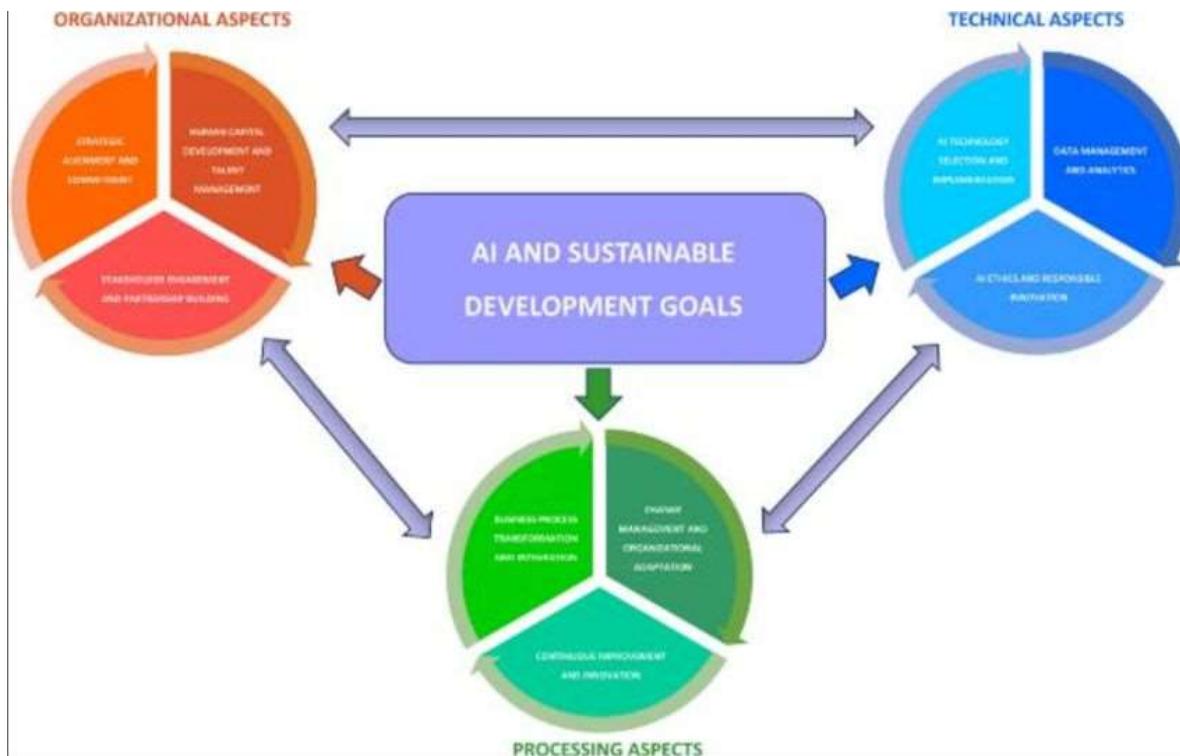
Figure 4: Conceptual Model for Integrating AI into Sustainable Development

Source: [15]

AI and SDG 9: Artificial Intelligence plays a revolutionary role in SDG 9 by driving automation, optimizing production processes and facilitating smart infrastructure development such as intelligent transport and energy systems [12]. AI also analyzes complex datasets using it to accelerate research, innovation and support technology based jobs.

AI and SDG 17: SDG 17 emphasizes the importance of multi-stakeholder partnerships because the successful deployment and governance of AI requires a collaborative effort between governments, private sectors and educational institutions. Shared research platforms, open source AI models and global initiatives such as UNESCO's AI policy guidelines, illustrate how AI can promote knowledge exchange and foster international cooperation for development [16].

AI In Advancing Qualitative Education

Artificial intelligence is changing the educational terrain by promoting equal access, personalization and innovation. In this context, "qualitative education" refers primarily to improved learning outcomes, inclusive pedagogy, and skills development. It acts as a strategic tool that analyzes the depth and quality of education across educational institutions.

In a rapidly advancing digital economy where lifelong learning is critical, AI empowers learning platforms like Coursera and Udemy, which track learner's progress across various fields and offer customized course recommendations. Studies on large-scale online learning platforms suggest that data-driven personalization can improve learner engagement and course completion rates, although these effects vary by context and learner motivation.

Platforms that have AI integrated, analyze and learn students' behavior and difference in knowledge to create a personalized learning structure for each of them. This additivity ensures that students' progress at their own pace thereby enabling mastery of concepts before moving

forward [5]. While mastery-based learning supported by AI is an emerging capability, current evidence indicates it is most effective when combined with teacher guidance and well-designed curricula.

Technologies powered by AI can make quality education more accessible by providing affordable remote learning opportunities. Translation systems like Google Translate which facilitates real-time translation and voiceovers, allowing educational content to reach students in local languages. Research on AI-assisted translation in education shows promising results for improving comprehension, though accuracy and cultural context remain ongoing challenges.

This is particularly valuable in underserved and rural communities where qualified teachers and infrastructure may be lacking [2]. Empirical studies from low-resource settings suggest that AI-supported distance learning can supplement, but not fully replace human instruction.

Tools like automated essay scoring, predictive analytics for student performance and AI-generated lesson plans would streamline teaching workflows and help identify students at risk of falling behind [17]. These applications are increasingly adopted in pilot programs, though concerns about bias and transparency require further empirical validation.

Government agencies and learning institutions can also use AI to collect data and analyze educational data on a large scale to identify trends and gaps that inform effective policies and interventions [14]. Evidence from education data-mining research indicates that such analytics can support policy decisions when paired with ethical data governance.

In the past, learners with special needs found it hard to have a proper education but with AI-powered tools like speech-to-text and image recognition systems, learners with disabilities find it easier. One example is Microsoft's Seeing AI app which helps visually impaired learners interpret their surroundings. Accessibility research increasingly recognizes these tools as supportive technologies rather than complete solutions.

AI can evaluate not just factual knowledge but also soft skills like creativity, collaboration and communication through Natural Language Processing (NLP) and behavioral data, thereby shifting the focus from traditional memorization for tests toward a more comprehensive and holistic approach to student assessment [5]. However, assessment of soft skills through AI remains an emerging area, with ongoing debate regarding validity and reliability.

AI-Driven Technological Innovations

AI is at the forefront of the Fourth Industrial Revolution (Industry 4.0), characterized by the integration of advanced digital technologies such as; Artificial Intelligence (AI), the Internet of Things (IoT), robotics and cloud computing into manufacturing and industrial processes. It represents a shift from traditional automation toward smart, interconnected and self-optimizing systems that can operate with minimal human intervention [18].

Urban areas in developed countries use AI to optimize traffic, manage energy consumption and improve the way waste is being managed.

Robotic surgery systems are making headway in the healthcare sector making healthcare more accessible. Wearable health monitors and AI-powered diagnostic tools are technological innovations that are also revolutionizing healthcare.

Fintech companies have adopted AI-driven tools in finance to automate calculation of credit scores, detection of fraud and algorithmic trading. These innovations make financial systems more secure and accessible, especially for populations with limited access to banking services [19].

In the agricultural sector, artificial intelligence is used to forecast weather, detect diseases in plants and guide unmanned farming equipment. These innovations reduce waste and contribute to food security especially vital in regions vulnerable to climate change [11].

Environmental science also utilizes artificial intelligence to detect deforestation, track wildlife and analyze climate patterns. Based on the analyzed climate data, AI systems help to manage renewable energy sources, which supports climate action and conservation efforts [20].

Case Studies and Their Benefits

The case studies of the use of AI tools are highlighted with their benefits in a developed and some developing countries. Where available, measurable outcomes such as adoption scale, learning gains, or productivity improvements are included to demonstrate impact.

Squirrel AI (China)

Squirrel AI, a Chinese EdTech (Educational Technology) company which has successfully implemented AI-driven adaptive learning platforms in over 2,000 centers across China serving millions of students [21]. Company-reported data indicate adoption by over 3 million learners. The system uses algorithms to track students' strengths and weaknesses in real time and adjusts lesson plans accordingly.

Benefits

i. Improved learning outcomes for students in rural areas. Internal reports suggest score improvements ranging from 10–30% in mathematics and science subjects.
ii. Supports SDG 4 (Quality Education) by providing inclusive and equitable quality education.

M-Shule (Kenya)

M-Shule is an AI-powered mobile learning platform based in Kenya. It delivers personalized educational content through SMS, specifically targeting primary school students in under-resourced areas. The platform has reached over 20,000 learners across multiple Kenyan counties, with pilot programs showing measurable learning gains.

Benefits

i. Reaches students even in areas with limited internet access, achieving high adoption rates due to compatibility with basic mobile phones.
ii. Supports SDG 4 (Quality Education)

Dr. CADx (Zimbabwe)

Dr. CADx is a Zimbabwean AI-powered diagnostic tool designed to assist medical professionals in interpreting medical images, such as x-rays, to improve early detection of diseases like tuberculosis and pneumonia. Pilot deployments in selected healthcare facilities have demonstrated increased diagnostic accuracy and reduced analysis time.

Benefits

i. Enhances diagnostic capabilities in rural healthcare facilities with limited specialists. Reported improvements include up to 25% faster diagnosis and higher early-detection rates.
ii. Supports SDG 3 (Good Health and Well-being) and SDG 9 (Industry, Innovation and Infrastructure)

Zenvus (Nigeria)

Zenvus is a Nigerian Agri-tech startup which uses AI and IoT to help farmers measure soil nutrients, moisture levels and optimize fertilizer usage [22]. Data collected from farms are analyzed with machine learning algorithms to improve productivity and reduce waste. The technology has been adopted by thousands of small-scale farmers across Nigeria.

Benefits

i. Increase in agricultural yields for small-scale farmers. Field reports indicate yield increases of approximately 15–25% while reducing input costs.
ii. Contributes to SDG 9 (Industry, Innovation and Infrastructure) and SDG 2 (Zero Hunger)

Limitations

However, there are limitations which include the following:

i. Digital Divide: One of the biggest challenges facing many developing countries is the lack of access to devices, reliable electricity and internet connectivity. This gap prevents equitable access to AI-driven solutions in rural and marginalized communities.
ii. Algorithmic Bias: AI systems can unintentionally be biased due to the biases that can be present in data used to train them. This could lead to unfair or discriminatory conclusions.
iii. Privacy and Security: AI systems require large volumes of data, both personal and institutional. Without vigorous data protection policies, breaches in data privacy could occur putting individuals and institutions at risk.
iv. Skills Gap: Many African nations face a shortage of skilled professionals in data science, programming and machine learning. Handling of AI technologies require technical expertise in these fields and since lots of developed nations have this in abundance, it limits local innovation, thereby increasing the skill gap.
v. High Costs: The development, deployment and maintenance of AI systems can be expensive, which can be a financial burden for developing nations.
vi. Environmental Concern: The training of large AI models requires significant computational power, contributing to carbon emissions, thereby causing environmental pollution and depletion of the ozone layer.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Artificial Intelligence has clearly been established as a force to be reckoned with capable of reshaping pathways to sustainable development around the world. As reviewed in this paper, AI presents a huge potential in advancing qualitative education, driving technology and innovations and the facilitation of sustainable national development.

Its application in education and the industry, bridges learning gaps, promotes lifelong learning and reinforces innovation and infrastructure which aligns with SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure) and SDG 17 (effective collaborations and partnerships).

However, despite the benefits and impacts, challenges like digital inequality, algorithmic bias and skills gap are very significant challenges which are more rampant in developing regions, especially Africa.

These challenges are not impossible to overcome. If done efficiently, then the integration of AI would be beneficial to all sectors of the economy and society.

Recommendations

The following recommendations provide a pathway towards a sustainable and impactful adoption of AI:

   i. Investment in digital infrastructure
  ii. Building of human and local talent
 iii. Support of local startups
 iv. Fostering of regional partnerships and collaborations
  v. Promotion of sustainable AI use
 vi. Increased awareness programs for digital education

REFERENCES

[1] Russell, S., & Norvig, P. (2020). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.

[2] UNESCO. (2021). AI and Education: Guidance for Policy-makers. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000376709

[3] Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., … & Nerini, F. F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. Nature Communications, 11(1), 233.

[4] Brynjolfsson, E., & McAfee, A. (2017). Machine, Platform, Crowd: Harnessing Our Digital Future. W. W. Norton & Company.

[5] Luckin, R., Holmes, W., Griffiths, M., & Forcier, L. B. (2016). Intelligence Unleashed: An Argument for AI in Education. Pearson Education.

[6] Crawford, K. (2021). Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press.

[7] UNESCO. (2020). Education for Sustainable Development: A Roadmap. https://unesdoc.unesco.org/ark:/48223/pf0000374802

[8] Becker, G. S. (1964). *Human Capital: A Theoretical and Empirical Analysis*.

[9] Sachs, J. D. (2015). *The Age of Sustainable Development*.

[10] Lundvall, B. Å. (1992). *National Systems of Innovation.*

[11] Kamilaris, A., Prenafeta-Boldú, F.X. (2018). Deep learning in agriculture: A survey. Computers and Electronics in Agriculture, 147, 70-90.

[12] World Bank. (2020). World Development Report: Trading for Development in the Age of Global Value Chains. https://www.worldbank.org/

[13] World Bank. (2020). Innovation, Technology, and Industry Report. https://www.worldbank.org/

[14] OECD. (2021). AI in the Public Sector. https://www.oecd.org/

[15] Iweuno, B., Orekha, P., Ojediran, O., Imohimi, E., Adutwum, H. (2020). Leveraging Artificial Intelligence for an inclusive and diversified curriculum. https://doi.org/10.30574/wjarr.2024.23.2.2440

[16] OECD. (2021). AI and the Future of Skills. https://www.oecd.org/

[17] Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial Intelligence in Education: Promises and Implications for Teaching and Learning. Center for Curriculum Redesign.

[18] Schwab, K. (2016). The Fourth Industrial Revolution. World Economic Forum.

[19] Arner, D. W., Barberis, J., & Buckley, R. P. (2016). The evolution of Fintech: A new post crisis paradigm? Georgetown Journal of International Law, 47(4), 1271–1319.

[20] Rolnick, D. et al. (2019). Tackling climate change with machine learning. arXiv preprint arXiv:1906.05433.

[21] Cui, W., Xue, Z., & Thai, K.-P. (2019). Performance comparison of an AI-based Adaptive Learning System in China. arXiv.

[22] Eze, S. C., & Chibuzo, C. O. (2021). "Smart Agriculture Adoption in Nigeria: Opportunities and Challenges." African Journal of Science, Technology, Innovation and Development, 13(7), 855–864.

License