

AI-Assisted Biology Learning and Environmental Literacy for Sustainable Development among Secondary School Students in Imo State

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ABSTRACT

Imo State faces serious environmental challenges, including gully erosion, flooding, oil pollution in parts of the state, deforestation, biodiversity loss and poor urban waste management. Responding to these challenges requires citizens who are environmentally literate: who understand ecological systems, recognize environmental problems, and are disposed and able to act sustainably. Secondary school biology is a natural foundation for such literacy, yet it is often taught through rote learning that leaves students unable to connect classroom concepts to their own environment. Artificial intelligence (AI) tools, such as image-recognition apps for identifying plants and animals, generative AI tutors, adaptive learning platforms, and AI-supported data analysis, now offer new ways to make biology learning interactive, local and action-oriented. This conceptual paper examines how AI-assisted biology learning can promote environmental literacy for sustainable development among secondary school students in Imo State. Anchored on constructivism, experiential learning theory, and the theory of planned behavior, the paper clarifies key concepts, describes applications of AI across the senior secondary biology curriculum, and maps them to local environmental issues and the Sustainable Development Goals. It discusses challenges, including infrastructure gaps, cost, teacher capacity, inaccurate AI output, data privacy, and the risk of replacing field experience with screens, and proposes strategies to address them. The paper argues that AI should serve as a bridge between biology concepts and students' lived environment, not a substitute for direct engagement with nature. Recommendations target the Imo State Ministry of Education, schools, teachers, and researchers.

Keywords: artificial intelligence; biology education; environmental literacy; education for sustainable development; Imo State.

Introduction

Sustainable development, meeting present needs without compromising the ability of future generations to meet theirs, is a global priority expressed in the United Nations' 2030 Agenda and its seventeen Sustainable Development Goals (SDGs) (United Nations, 2015). Education is central to this agenda: SDG target 4.7 calls for all learners to acquire the knowledge and skills needed to promote sustainable development. UNESCO (2017, 2020) has urged countries to embed education for sustainable development (ESD) across curricula, so that learners understand environmental problems and are empowered to act on them.

Imo State illustrates why such education matters. Gully erosion has destroyed farmland, roads and homes in many communities. Seasonal flooding affects riverine and urban areas. Oil exploration in parts of the state has been associated with pollution of soil and water, while deforestation, bush burning and unsustainable farming practices threaten biodiversity and soil fertility. In Owerri and other growing towns, solid waste disposal and drainage are persistent problems. These issues affect students' health, livelihoods and futures, yet many young people have limited understanding of their causes and of what they can do about them.

Biology, the science of living things and their interactions with the environment, is the secondary school subject most directly concerned with these issues. The senior secondary biology curriculum covers ecology, ecosystems, nutrient cycling, pollution, conservation and the relationship between organisms and their habitats. However, biology is frequently taught through lectures and memorisation, with limited fieldwork, so students may pass examinations without becoming environmentally literate.

Artificial intelligence offers new possibilities. Smartphone apps can identify plants, insects and birds from photographs; generative AI tutors can explain ecological concepts in simple language and in response to students' own questions; adaptive platforms can personalise practice; and AI tools can help students analyse environmental data they collect. Used purposefully, these tools could help students connect biology concepts to the environment around them.

Statement of the Problem

Despite the environmental challenges confronting Imo State, secondary school students' environmental literacy appears limited, and biology teaching has not fully realised its potential to build it. Teaching is often abstract, laboratories and field trips are scarce, and the link between classroom biology and local environmental problems is rarely made explicit. AI tools that could

make biology learning more interactive and locally relevant are increasingly accessible, but there is little guidance on how they might be used to promote environmental literacy in Imo State's secondary schools, or on the risks such use might carry.

Purpose of the Paper

The purpose of this paper is to examine how AI-assisted biology learning can promote environmental literacy for sustainable development among secondary school students in Imo State. Specifically, the paper (a) clarifies key concepts, (b) presents a theoretical framework, (c) describes applications of AI in biology learning and maps them to local environmental issues, (d) discusses challenges and strategies, and (e) offers recommendations.

Conceptual Clarification

AI-assisted biology learning. This refers to the use of artificial intelligence tools to support the teaching and learning of biology. Relevant tools include image-recognition applications that identify organisms from photographs (Wäldchen & Mäder, 2018), generative AI chatbots that explain concepts and answer questions (Kasneci et al., 2023), adaptive learning systems that adjust content to learners' progress, and AI-supported tools for analysing and visualising data (Holmes et al., 2019; Luckin et al., 2016).

Environmental literacy. Environmental literacy is the capacity to understand environmental systems and to make informed decisions and take responsible action regarding the environment (Roth, 1992). Hollweg et al. (2011) describe it as comprising knowledge (of ecological concepts and environmental issues), dispositions (attitudes, values, sensitivity and sense of responsibility), competencies (skills to identify, analyse and resolve environmental issues) and environmentally responsible behaviour. Environmental literacy therefore goes beyond knowing facts; it includes caring and acting.

Education for sustainable development. ESD is education that empowers learners to make informed decisions and take responsible actions for environmental integrity, economic viability and a just society, for present and future generations (UNESCO, 2020). Environmental literacy is a central outcome of ESD.

Theoretical Framework

Constructivism. Constructivist theory holds that learners construct knowledge by connecting new experiences with prior understanding, often through social interaction (Vygotsky, 1978). AI tools that let students investigate organisms and environmental conditions in their own surroundings support this construction by grounding biology concepts in familiar contexts.

Experiential learning theory. Kolb (1984) described learning as a cycle of concrete experience, reflection, conceptualisation and active experimentation. AI-assisted field activities, such as photographing and identifying plants around a school, measuring local conditions and discussing findings, provide concrete experiences that feed this cycle.

Theory of planned behaviour. Ajzen (1991) proposed that behaviour is predicted by intention, which is shaped by attitudes toward the behaviour, perceived social norms and perceived behavioural control. Kollmuss and Agyeman (2002) showed that environmental knowledge alone rarely produces pro-environmental behaviour; attitudes, values and perceived ability to act matter. The theory suggests that AI-assisted biology learning will promote environmental literacy most effectively if it also builds positive attitudes, shared norms and students' confidence that their actions can make a difference, for example through projects that lead to visible change in

the school or community. Hungerford and Volk (1990) similarly argued that environmental education should develop ownership of issues and empowerment to act.

Applications of AI in Biology Learning for Environmental Literacy

Biodiversity identification and local field studies. Image-recognition apps allow students to photograph plants, insects, fungi and birds and receive suggested identifications. Students can survey biodiversity around their school, farms and streams, build class species lists, and compare disturbed and undisturbed sites. Participation in citizen science platforms connects these observations to wider scientific databases, which has been shown to build scientific knowledge and skills (Bonney et al., 2009). Students should be taught that AI identifications are suggestions to be checked with keys, textbooks and teachers.

Generative AI tutoring on ecological concepts. AI tutors can explain difficult concepts such as energy flow, nutrient cycles, succession and pollution in simple language, using local examples when prompted. Students can ask follow-up questions in their own words, practise with AI-generated quizzes and receive feedback. Teachers can use AI to prepare locally relevant lesson materials, such as case studies of erosion or pollution in Imo communities.

Data collection and analysis. Students can collect simple environmental data, including rainfall, temperature, water clarity, waste types or erosion measurements, and use AI-supported spreadsheet and analysis tools to find patterns and create charts. This develops scientific inquiry skills and evidence-based reasoning about local environmental change.

Simulations and modelling. AI-enhanced simulations can model population dynamics, food webs, the effects of deforestation on soil, or the spread of pollutants, allowing students to test scenarios that cannot be observed directly in class.

Problem-solving and action projects. AI tools can support project-based learning in which students investigate a local issue, such as waste in their school or erosion near their community, research causes and solutions, and design and carry out an action plan, such as tree planting, waste sorting or awareness campaigns. This links knowledge to behaviour, as the theory of planned behaviour recommends.

Curriculum Mapping

Table 1. Mapping AI-assisted biology activities to curriculum topics, local environmental issues and SDGs

Biology topic		AI-assisted activity	Imo State environmental issue	Related SDGs	
Ecology ecosystems	and	Biodiversity survey with image-recognition apps; AI-generated food web analysis	Habitat loss and deforestation	SDG 15 (Life land)	on
Soil and cycling	nutrient	AI tutor: explanations of soil formation and erosion; data on soil	Gully erosion and loss of farmland	SDG 15, SDG 2 (Zero hunger)	2
Biology topic	AI-assisted activity	Imo State environmental issue	Related SDGs		
	loss at local gullies				

Water and habitats	aquaculture	Recording water clarity and organisms in local streams; AI-assisted data analysis	Water pollution, including oil pollution in affected areas	SDG 6 (Clean water), SDG 14 (Life below water)	
Pollution		AI-supported research on pollutants and their effects; case study preparation	Oil spills, gas flaring, open waste burning	SDG 3 (Good health), SDG 12 (Responsible consumption)	
Conservation natural resources	of	Simulations of resource use; AI-assisted planning of conservation projects	Over-exploitation of forests and wildlife	SDG 15	
Population and environment	the	Population growth modelling; analysis of urban growth data	Urban waste and drainage in Owerri	SDG 11 (Sustainable cities)	
Climate adaptation organisms	and of	AI tutor: exploration of climate change; analysis of local rainfall and temperature records	Flooding and changing rainfall patterns	SDG 13 (Climate action)	

This mapping shows that AI-assisted biology learning can be embedded in existing curriculum topics rather than added as a separate subject, while connecting each topic to an environmental issue students can observe and act on.

Challenges and Strategies

Infrastructure and access. Many public secondary schools in Imo State lack reliable electricity, internet access and computers, and not all students own smartphones. Strategy: schools can begin with teacher-led use of a single smartphone or laptop with a projector, group work around shared devices, and tools that function offline, such as downloaded simulations and apps with offline identification modes. Government and partners can provide solar-powered ICT kits to schools.

Cost. Some AI tools require paid subscriptions or significant data. Strategy: prioritise free and open tools, download materials in advance, and seek partnerships with telecommunications providers and development organisations for subsidised data.

Teacher capacity. Many biology teachers have little training in AI or ESD pedagogy. Strategy: the Imo State Ministry of Education and teacher professional bodies should run practical workshops on AI tools, field-based inquiry and project-based environmental education.

Accuracy and over-reliance. AI identification apps and chatbots can make errors, particularly for local species and contexts poorly represented in their training data. Strategy: teach students to treat AI output as a hypothesis to verify with keys, textbooks, teachers and local knowledge, which itself builds scientific thinking.

Screens replacing nature. There is a risk that AI activities substitute for direct experience of the environment. Strategy: use AI to enhance fieldwork, not replace it; most activities proposed here begin outdoors, with students observing and recording their own surroundings.

Data privacy and safety. Apps may collect location data and images, and fieldwork carries physical risks near gullies, rivers and polluted sites. Strategy: choose tools with clear privacy policies, avoid sharing students' personal data, obtain parental consent, and plan supervised, safe fieldwork.

Environmental cost of AI. Large AI systems consume considerable energy (Strubell et al., 2019). Strategy: use AI purposefully rather than indiscriminately, and discuss this trade-off with students as part of their environmental literacy.

Knowledge without action. Knowledge alone may not change behaviour (Kollmuss & Agyeman, 2002). Strategy: include action projects, school environmental clubs and community partnerships so that students practise sustainable behaviour and see its effects.

Conclusion

Imo State's environmental challenges call for a generation of young people who understand their environment, care about it and are able to act for its sustainability. Biology education is well placed to build this environmental literacy, and AI tools can strengthen it by making biology learning interactive, personalised and rooted in students' own surroundings. Image recognition can turn a school compound into a biodiversity laboratory, AI tutors can clarify ecological concepts, and data tools can help students investigate local environmental change. Grounded in constructivism, experiential learning and the theory of planned behaviour, AI-assisted biology learning is most powerful when it connects knowledge to attitudes and action. Its success, however, depends on addressing infrastructure, cost and teacher capacity, on teaching students to question AI output, and on ensuring that technology deepens rather than replaces students' direct engagement with nature.

Recommendations

The Imo State Ministry of Education should integrate AI-assisted, field-based environmental activities into the teaching of senior secondary biology, using the curriculum mapping in Table 1 as a guide.

Government, development partners and the private sector should provide schools with solar-powered ICT kits, including devices, projectors and offline resources.

Teacher professional development programmes should train biology teachers in using AI tools, verifying AI output and leading project-based environmental education.

Schools should establish environmental clubs that use AI tools for biodiversity surveys, environmental monitoring and community action projects, in partnership with local communities and environmental agencies.

Schools should adopt guidelines on safe fieldwork and on the privacy and responsible use of AI tools.

Researchers should conduct empirical studies in Imo State secondary schools to measure the effect of AI-assisted biology learning on students' environmental knowledge, attitudes and behaviour.

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