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TRESEARCH

ARTIFICIAL INTELLIGENCE FOR AGRICULTURAL EDUCATION IN NIGERIAN PRIMARY SCHOOLS: TEACHERS' ASSESSMENT OF PUPILS' AGRICULTURAL LITERACY

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ABSTRACT

Agricultural literacy is increasingly recognised as essential for preparing young learners to understand food systems, environmental sustainability, climate change, and modern agricultural practices. However, conventional instructional approaches adopted in many primary schools continue to limit pupils' interest, engagement, and understanding of agricultural concepts. Artificial intelligence (AI) offers opportunities to enhance agricultural education through adaptive learning environments, intelligent tutoring systems, personalised instruction, and interactive educational technologies. Despite these prospects, empirical evidence regarding AI supported agricultural education in Nigerian primary schools remains limited. This study investigated artificial intelligence for agricultural education in Nigerian primary schools through teachers' assessment of pupils' agricultural literacy. Specifically, the study examined existing AI supported instructional practices, barriers affecting AI integration, the effectiveness of AI supported agricultural instruction, and strategies for strengthening AI integration in primary schools. Four research questions and four null hypotheses guided the study. A descriptive survey research design was adopted. Data were collected from 165 primary school teachers responsible for Agricultural Science and related subjects to assess their perceptions of AI supported agricultural learning and pupils' agricultural literacy. Mean and standard deviation answered the research questions, while Pearson Product Moment Correlation and multiple regression analysis tested the hypotheses at the 0.05 level of significance. The regression model was statistically significant and explained 69.9% of the variance in pupils' agricultural literacy. The findings indicate that effective implementation of AI supported agricultural education, supported by adequate infrastructure, teacher capacity development, and institutional commitment, can substantially enhance pupils' agricultural literacy. The study provides evidence for curriculum developers, policymakers, school administrators, and educational technology developers seeking to strengthen AI integration in primary education.

KEYWORDS: Agricultural education, agricultural literacy, artificial intelligence, Nigeria, primary schools, teachers' perceptions

1. INTRODUCTION

The increasing complexity of global food systems, climate change, environmental sustainability, and technological innovation has transformed the knowledge, skills, and competencies required of future generations. Agriculture is no longer regarded solely as a means of food production but as a multidisciplinary field that integrates environmental stewardship, technological innovation, entrepreneurship, nutrition, and sustainable resource management. Consequently, developing agricultural literacy from the primary school level has become an important educational priority for countries seeking sustainable agricultural transformation and food security (Food and Agriculture Organization [FAO], 2024). Agricultural literacy equips young learners with foundational knowledge, practical understanding, positive attitudes, and informed decision making regarding agriculture and food systems, thereby preparing them to participate meaningfully in sustainable development initiatives (National Research Council, 2023). Early exposure to agricultural concepts further strengthens pupils' appreciation of environmental conservation, responsible resource utilisation, and the role of agriculture in promoting national development (Ejiofor & Nwakile, 2016).

Recent advances in artificial intelligence (AI) have created significant opportunities for improving teaching and learning across educational systems. Artificial intelligence refers to computer systems capable of performing tasks that normally require human intelligence, including reasoning, problem solving, adaptive learning, language processing, and personalised instructional support (UNESCO, 2023). Within educational settings, AI powered technologies facilitate intelligent tutoring systems, adaptive learning platforms, automated feedback mechanisms, virtual simulations, conversational learning assistants, and personalised instructional pathways that respond to learners' individual needs and abilities (Holmes et al., 2022). These technologies have demonstrated considerable potential for enhancing learner engagement, academic achievement, knowledge retention, and higher order thinking across diverse educational contexts (OECD, 2024). Their capacity to personalise learning experiences and provide immediate instructional feedback has positioned AI as one of the most promising innovations for improving educational quality in the twenty first century.

Within agricultural education, artificial intelligence provides opportunities to transform conventional instructional approaches into more interactive, learner centred, and experiential learning experiences. Artificial intelligence supported agricultural learning involves the integration of intelligent digital technologies into agricultural instruction to improve

pupils' understanding of agricultural concepts through adaptive learning environments, intelligent simulations, virtual farms, image recognition systems for plants and animals, gamified agricultural learning platforms, conversational educational assistants, and adaptive assessment systems capable of providing immediate feedback according to learners' performance (FAO, 2024). These technologies enable pupils to visualise agricultural processes that may otherwise be difficult to observe within conventional classroom instruction while encouraging inquiry, experimentation, and active participation in learning (Luckin et al., 2022). Recent studies further indicate that AI supported learning enhances learners' scientific reasoning, environmental awareness, and problem solving abilities by providing authentic digital experiences that connect theoretical knowledge with practical applications (OECD, 2024). Consequently, artificial intelligence has emerged as an innovative instructional strategy capable of strengthening agricultural education and improving agricultural literacy among young learners.

Agricultural literacy represents a broad understanding of agriculture, food production, environmental sustainability, agricultural technologies, and the relationship between agriculture and society. It extends beyond factual knowledge to include practical skills, positive attitudes, environmental awareness, critical thinking, and informed participation in agricultural issues affecting communities and national development (Frick et al., 2022). Agricultural literacy enables learners to appreciate the importance of agriculture in economic development, food security, environmental conservation, and sustainable livelihoods. Pupils who develop strong agricultural literacy during their formative years are more likely to demonstrate positive attitudes towards agriculture, adopt environmentally responsible behaviours, and consider agriculture related careers later in life (National Institute of Food and Agriculture, 2023). Developing agricultural literacy at an early stage therefore provides an essential foundation for preparing future citizens who are capable of responding to emerging agricultural and environmental challenges.

Primary education occupies a strategic position in developing agricultural literacy because it establishes the cognitive and behavioural foundations upon which subsequent learning is built. During the primary school years, pupils develop curiosity, observational skills, scientific reasoning, and attitudes that influence lifelong learning and career aspirations. Agricultural science introduced at this stage provides opportunities for experiential learning through school gardens, classroom demonstrations, practical activities, and environmental projects (UNICEF, 2024). Integrating artificial intelligence into these learning experiences can further strengthen pupils' conceptual understanding by providing personalised instruction, immediate feedback, interactive visualisations, and engaging learning environments that accommodate individual learning differences (Zawacki Richter et al., 2023).

The Nigerian educational system has increasingly recognised the importance of digital transformation and technology enhanced learning as essential components of educational reform. National policies promoting digital education encourage schools to integrate emerging technologies capable of improving instructional quality, learner engagement, and educational outcomes. Nevertheless, many public primary schools continue to experience limited access to educational technologies, inadequate teacher preparedness, insufficient digital infrastructure, unreliable internet connectivity, and inadequate instructional resources required for the effective implementation of artificial intelligence supported learning (Federal Ministry of Education, 2024). These challenges are particularly evident within agricultural science, where instructional delivery remains predominantly teacher centred despite the practical and experiential nature of the subject (Nwachukwu et al., 2020). Consequently, many pupils receive limited exposure to innovative learning experiences that could strengthen their understanding of modern agricultural practices and enhance agricultural literacy required for sustainable national development.

Empirical evidence consistently demonstrates the positive contribution of artificial intelligence to teaching and learning across different educational contexts. Studies have reported that intelligent tutoring systems, adaptive learning platforms, and AI supported instructional environments improve learner engagement, academic achievement, conceptual understanding, and higher order thinking by providing personalised instructional support that accommodates individual learning differences (Holmes et al., 2022; OECD, 2024). Similar benefits have been reported within science and environmental education, where artificial intelligence enhances inquiry based learning, scientific reasoning, and environmental awareness through interactive simulations and immediate feedback mechanisms. Within agricultural education, emerging evidence suggests that AI supported simulations, virtual agricultural environments, and intelligent learning systems improve learners' understanding of agricultural production, sustainable farming practices, and environmental conservation by providing authentic and engaging learning experiences that extend beyond conventional classroom instruction (FAO, 2024). Although these studies collectively demonstrate the educational potential of artificial intelligence, they have largely been undertaken in developed educational systems or have focused on science education generally, thereby providing limited evidence regarding its application within agricultural education for primary school pupils in developing countries.

Within Nigeria, existing studies have primarily examined digital learning, educational technology adoption, teacher readiness, and ICT integration in schools (Nwachukwu et al., 2020; Okoli et al., 2020). While these investigations have contributed to understanding technology integration within Nigerian education, they provide limited empirical evidence regarding artificial intelligence supported agricultural learning and its contribution to agricultural literacy among primary school pupils. Furthermore, previous studies have generally examined educational technology adoption independently of agricultural literacy, making it difficult to understand how instructional practices, implementation challenges, and institutional support collectively influence agricultural learning outcomes. Consequently, educational policymakers,

curriculum developers, teachers, and school administrators possess limited evidence for designing effective strategies that integrate artificial intelligence into agricultural instruction at the foundational education level.

1.1 STATEMENT OF THE PROBLEM

Developing agricultural literacy among primary school pupils has become increasingly important because early agricultural education provides the foundation for lifelong understanding of food systems, environmental sustainability, and modern agricultural practices. Although artificial intelligence has demonstrated considerable potential for improving teaching and learning through personalised instruction, intelligent feedback, and interactive learning environments, its application within agricultural education at the primary school level remains insufficiently understood, particularly within the Nigerian context. Existing studies have focused largely on general educational technology, digital learning, or teacher readiness, with relatively little empirical attention devoted to artificial intelligence supported agricultural learning and its relationship with agricultural literacy among primary school pupils. Consequently, educational stakeholders have limited evidence regarding existing AI supported instructional practices, implementation barriers, instructional effectiveness, and strategies capable of strengthening artificial intelligence integration in agricultural education. This knowledge gap constrains evidence-based curriculum innovation, educational policy development, and instructional improvement aimed at preparing pupils for sustainable agriculture and food security. It is against this background that this study investigates artificial intelligence for agricultural education in Nigerian primary schools through teachers' assessment of pupils' agricultural literacy.

1.2 OBJECTIVES OF THE STUDY

The main objective of this study was to investigate artificial intelligence supported agricultural learning and the development of agricultural literacy among primary school pupils in Nigeria. Specifically, the study sought to:

1. Examine existing artificial intelligence supported agricultural learning practices implemented in primary schools for the development of agricultural literacy among pupils.
2. Identify the barriers affecting the integration of artificial intelligence technologies into agricultural learning among primary school pupils.
3. Assess the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy among primary school pupils.
4. Determine strategies for strengthening artificial intelligence supported agricultural learning for improved agricultural literacy among primary school pupils.

1.3 RESEARCH QUESTIONS

The following research questions guided the study:

1. What artificial intelligence supported agricultural learning practices are currently implemented in primary schools to promote agricultural literacy among pupils?
2. What barriers affect the integration of artificial intelligence technologies into agricultural learning among primary school pupils?
3. To what extent are artificial intelligence supported instructional approaches effective in promoting agricultural literacy among primary school pupils?
4. What strategies can strengthen artificial intelligence supported agricultural learning for improved agricultural literacy among primary school pupils?

1.4 RESEARCH HYPOTHESES

The following null hypotheses were tested at the 0.05 level of significance.

H01: Artificial intelligence supported agricultural learning practices have no significant influence on agricultural literacy among primary school pupils.

H02: Barriers to the integration of artificial intelligence technologies have no significant influence on agricultural literacy among primary school pupils.

H03: Artificial intelligence supported instructional approaches have no significant influence on agricultural literacy among primary school pupils.

H04: Strategies for strengthening artificial intelligence supported agricultural learning have no significant influence on agricultural literacy among primary school pupils.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

2.1 ARTIFICIAL INTELLIGENCE SUPPORTED AGRICULTURAL LEARNING AND AGRICULTURAL LITERACY

Artificial intelligence has become one of the most transformative technologies influencing educational systems worldwide. Educational institutions increasingly employ intelligent technologies to personalise instruction, improve learner engagement, facilitate adaptive learning, and strengthen knowledge acquisition across diverse subject areas (Nwakile et al, 2025). Within agricultural science, artificial intelligence offers opportunities for learners to interact with complex agricultural concepts through intelligent simulations, virtual environments, automated assessment systems, conversational agents, and adaptive instructional platforms that accommodate individual learning differences (UNESCO, 2023). These technologies provide learning experiences that extend beyond conventional classroom instruction by enabling pupils to visualise agricultural processes, receive immediate feedback, and participate actively in knowledge construction (Holmes et al., 2022). Consequently, artificial intelligence supported agricultural learning has emerged as an innovative instructional approach capable of improving educational quality and learner outcomes.

Artificial intelligence supported agricultural learning refers to the purposeful integration of intelligent digital technologies into agricultural instruction to facilitate personalised, interactive, and experiential learning. Such technologies include intelligent tutoring systems, adaptive learning software, virtual farms, image recognition applications, educational chatbots, predictive learning analytics, and immersive simulations that enable learners to explore agricultural concepts within authentic digital environments (Luckin et al., 2022). Unlike traditional teacher centred approaches, AI supported instruction continuously analyses learners' progress and adjusts instructional activities according to individual strengths, weaknesses, and learning preferences, thereby enhancing learning efficiency and knowledge retention (OECD, 2024). These adaptive capabilities make artificial intelligence particularly suitable for introducing practical agricultural concepts to young learners.

Agricultural literacy encompasses learners' understanding of agriculture, food production systems, environmental sustainability, natural resource management, agricultural technologies, nutrition, and the economic importance of agriculture. Agricultural literacy also involves developing positive attitudes towards agriculture, environmental responsibility, problem solving abilities, and informed decision making concerning agricultural issues affecting society (Frick et al., 2022). At the primary school level, agricultural literacy provides a foundation for lifelong learning by helping pupils appreciate the interdependence between agriculture, human wellbeing, and environmental sustainability. Early development of agricultural literacy has also been associated with improved environmental awareness, healthier food choices, and increased interest in agricultural careers (National Institute of Food and Agriculture, 2023).

Artificial intelligence contributes to agricultural literacy by transforming abstract agricultural concepts into meaningful learning experiences. Through interactive simulations, pupils can observe crop growth, weather patterns, soil management practices, pest identification, livestock production, and sustainable farming techniques without requiring expensive physical resources. Intelligent systems further promote inquiry-based learning by encouraging pupils to ask questions, explore multiple solutions, and receive immediate instructional feedback tailored to their individual needs (FAO, 2024). These personalised learning experiences enhance conceptual understanding and encourage active participation in agricultural science, thereby strengthening agricultural literacy among young learners (Zawacki Richter et al., 2023).

Recent empirical evidence supports the growing contribution of artificial intelligence to educational improvement across different disciplines, although the reported outcomes vary according to educational context, learner characteristics, and the level of technological integration. Chen et al. (2023) found that AI supported adaptive learning significantly improved learners' academic achievement and conceptual understanding across science related disciplines through personalised instructional support. Similarly, Crompton and Burke (2023) concluded that intelligent educational technologies enhanced learner motivation, collaboration, and higher order thinking by promoting learner centred instructional experiences. Within agricultural education, emerging evidence reported by the FAO (2024) indicates that intelligent digital technologies strengthen learners' practical understanding of agricultural systems, sustainable farming practices, and environmental stewardship through interactive and experiential learning activities.

Although these studies consistently demonstrate the educational benefits of artificial intelligence, important differences exist in their scope and methodological orientation. Most previous investigations focused on science education, educational technology, or general digital learning environments, while relatively few specifically examined artificial intelligence within agricultural education. Furthermore, many studies were conducted in developed countries characterised by advanced technological infrastructure and stronger institutional support, making it difficult to generalise their findings to developing countries such as Nigeria, where schools continue to experience infrastructural limitations, inadequate teacher preparedness, and unequal access to educational technologies (Federal Ministry of Education, 2024). Existing studies also tend to examine AI adoption or learning outcomes independently rather than considering how instructional practices collectively influence agricultural literacy.

The present study extends previous research by examining artificial intelligence supported agricultural learning within the Nigerian primary school context using teachers' assessments of pupils' agricultural literacy. By focusing on agricultural education at the foundational level, the study provides context specific evidence capable of informing curriculum innovation,

educational policy, and instructional practice in environments where artificial intelligence adoption remains at an emerging stage. Based on the reviewed literature, the following hypothesis was formulated.

H01: Artificial intelligence supported agricultural learning practices have no significant influence on agricultural literacy among primary school pupils.

2.2 BARRIERS TO ARTIFICIAL INTELLIGENCE INTEGRATION AND AGRICULTURAL LITERACY

Despite the increasing global adoption of artificial intelligence within education, numerous barriers continue to hinder its effective implementation, particularly within developing countries. Artificial intelligence integration requires adequate technological infrastructure, reliable internet connectivity, digital instructional resources, financial investment, institutional commitment, and teachers capable of effectively utilising intelligent educational technologies (UNESCO, 2023). Where these conditions are absent, the educational benefits associated with artificial intelligence become difficult to achieve, thereby limiting opportunities for improving teaching quality and learner outcomes (OECD, 2024).

One of the major barriers affecting artificial intelligence implementation is inadequate technological infrastructure. Many primary schools continue to experience shortages of computers, smart devices, stable electricity supply, internet connectivity, and appropriate digital learning environments required for AI supported instruction (UNICEF, 2024). These infrastructural deficiencies significantly reduce opportunities for pupils to interact with intelligent educational technologies, particularly within rural communities where digital resources remain scarce (World Bank, 2024). Consequently, disparities in technological access continue to widen educational inequalities and limit the development of agricultural literacy through innovative instructional approaches.

Teacher preparedness represents another significant challenge affecting artificial intelligence integration within agricultural science. Effective implementation requires teachers to possess adequate digital competence, pedagogical knowledge, technological confidence, and positive attitudes towards educational innovation. However, many teachers have received limited professional development regarding artificial intelligence applications within classroom instruction, making them reluctant or insufficiently prepared to integrate AI technologies effectively (Holmes et al., 2022). Inadequate teacher competence often results in underutilisation of available technologies, thereby reducing their educational effectiveness (European Commission, 2023).

Financial constraints also constitute an important barrier limiting artificial intelligence adoption in primary schools. Procuring intelligent educational software, digital infrastructure, hardware devices, maintenance services, and teacher training programmes requires considerable financial investment that many educational institutions cannot sustain (World Bank, 2024). These financial limitations are particularly pronounced within developing countries where educational funding remains inadequate relative to increasing technological demands (UNESCO, 2024). Consequently, schools frequently prioritise basic instructional needs over advanced technological innovations such as artificial intelligence.

Empirical evidence consistently indicates that reducing technological, institutional, and human resource barriers is fundamental to the successful implementation of artificial intelligence in education. Bond et al. (2024) reported that schools with stronger technological infrastructure, continuous teacher professional development, and effective institutional leadership achieved more successful educational technology integration than schools with limited organisational support. Similarly, Chen et al. (2023) found that administrative commitment, teacher competence, and infrastructure availability significantly predicted successful artificial intelligence implementation and improved instructional effectiveness. These studies collectively suggest that artificial intelligence implementation depends on the interaction of technological, organisational, and human resource factors rather than on the availability of digital technologies alone.

Despite this consensus, previous studies differ in their emphasis and methodological focus. While some investigations primarily attribute implementation challenges to inadequate infrastructure and financial constraints, others identify teacher competence, institutional readiness, and leadership support as the most influential determinants of successful AI adoption. Furthermore, most empirical studies have examined general educational technology or artificial intelligence implementation across broad educational settings, with comparatively limited attention devoted to agricultural education, particularly at the primary school level. These differences indicate that implementation barriers are context dependent and may vary according to educational policies, resource availability, and institutional capacity.

Within the Nigerian context, persistent challenges such as inadequate technological infrastructure, unreliable electricity supply, poor internet connectivity, limited government funding, and insufficient teacher preparedness continue to constrain the effective integration of artificial intelligence into classroom instruction (Federal Ministry of Education, 2024). Consequently, there remains limited empirical evidence regarding how these barriers collectively influence agricultural literacy among primary school pupils. The present study addresses this gap by examining the influence of implementation barriers within agricultural education, thereby providing evidence capable of informing educational policy, institutional planning, and technology integration strategies. Based on the reviewed literature, the following hypothesis was formulated.

H02: Barriers to the integration of artificial intelligence technologies have no significant influence on agricultural literacy among primary school pupils.

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2.3 ARTIFICIAL INTELLIGENCE SUPPORTED INSTRUCTIONAL APPROACHES AND AGRICULTURAL LITERACY

Artificial intelligence supported instructional approaches have fundamentally changed contemporary educational practice by providing learner centred, adaptive, and data driven learning experiences capable of improving academic performance across different educational levels. Unlike conventional instructional methods that deliver uniform content to all learners irrespective of their abilities, AI supported instructional approaches personalise learning according to pupils' cognitive needs, prior knowledge, learning pace, and individual progress. These approaches utilise intelligent tutoring systems, adaptive learning environments, conversational educational agents, automated assessment platforms, learning analytics, and immersive simulations to create interactive educational experiences that promote deeper conceptual understanding (Holmes et al., 2022). Consequently, artificial intelligence has become an important instructional innovation for improving the quality of teaching and learning in both developed and developing educational systems (OECD, 2024).

Artificial intelligence supported instructional approaches are particularly relevant to agricultural science because agriculture involves numerous practical concepts that may be difficult to demonstrate effectively using traditional classroom instruction alone. Topics such as crop production, soil management, livestock husbandry, climate adaptation, pest management, food processing, and environmental conservation require experiential learning opportunities that allow pupils to observe processes, manipulate variables, and examine the consequences of different agricultural decisions. Artificial intelligence technologies provide virtual learning environments where pupils can explore these concepts through interactive simulations, virtual farms, augmented visualisations, intelligent animations, and predictive modelling without the limitations imposed by time, cost, weather, or physical resources (FAO, 2024). These technologies therefore strengthen pupils' understanding of agricultural systems while making learning more engaging and meaningful (Luckin et al., 2022).

Personalised learning represents one of the most significant contributions of artificial intelligence to agricultural instruction. AI powered learning platforms continuously collect information regarding pupils' performance, identify areas requiring improvement, and automatically recommend learning activities appropriate to each learner's ability level. Immediate feedback enables pupils to correct misconceptions before they become firmly established, while adaptive instructional pathways ensure that learners receive sufficient practice according to their individual learning needs (Zawacki Richter et al., 2023). Such personalised instruction improves learners' confidence, motivation, and academic achievement because pupils progress according to their own pace rather than following rigid classroom schedules that may not accommodate individual differences (UNESCO, 2023).

Artificial intelligence also promotes inquiry based and problem centred learning by encouraging pupils to investigate authentic agricultural challenges through intelligent decision making activities. Learners may analyse crop diseases using image recognition technologies, predict weather conditions affecting agricultural production through intelligent forecasting systems, identify appropriate farming practices using virtual advisory systems, or examine sustainable agricultural solutions through scenario-based simulations. These learning experiences strengthen critical thinking, creativity, problem solving abilities, and scientific reasoning, which are essential components of agricultural literacy and environmental responsibility (Food and Agriculture Organization, 2024). Consequently, pupils become active participants in knowledge construction rather than passive recipients of information.

Recent empirical investigations consistently demonstrate that artificial intelligence supported instructional approaches improve learning outcomes across science and technology education, although the magnitude of these improvements varies according to instructional design, technological infrastructure, and teacher competence. Chen et al. (2023) reported that adaptive intelligent learning environments significantly enhanced learners' conceptual understanding, classroom engagement, and academic performance through personalised instructional support tailored to individual learning needs. Likewise, Crompton and Burke (2023) observed that AI supported instructional systems increased learner motivation, collaboration, and higher order thinking while reducing learning anxiety by providing continuous feedback and adaptive learning experiences. Similarly, a systematic review by Zawacki Richter et al. (2023) concluded that artificial intelligence positively influences learning achievement when implemented within learner centred pedagogical frameworks supported by adequately trained teachers and appropriate technological infrastructure.

Although these studies consistently report positive educational outcomes, important differences remain regarding the conditions under which artificial intelligence produces the greatest instructional benefits. Most previous investigations have concentrated on science, mathematics, or general educational technology, while relatively few have examined agricultural education specifically. In addition, many studies employed experimental or quasi experimental designs within technologically advanced educational settings, making it difficult to generalise their findings to developing countries where infrastructural deficiencies, limited teacher preparedness, and inadequate institutional support continue to constrain effective AI implementation. These methodological and contextual differences suggest that the effectiveness of artificial intelligence supported instructional approaches depends not only on the technology itself but also on the educational environment in which it is implemented.

Within Nigeria, artificial intelligence supported instructional approaches remain at an emerging stage of adoption, particularly in primary education. Although educational reforms increasingly encourage digital transformation, many schools continue to depend largely on conventional instructional methods because of inadequate technological

infrastructure, unreliable electricity supply, limited teacher competence, and insufficient instructional resources (Federal Ministry of Education, 2024; Nwachukwu et al., 2020). Consequently, empirical evidence regarding the contribution of AI supported instructional approaches to agricultural literacy among primary school pupils remains limited. The present study therefore extends previous research by examining this relationship within the Nigerian agricultural education context, thereby providing evidence capable of informing curriculum innovation, instructional improvement, and educational policy. Based on the reviewed literature, the following hypothesis was formulated.

H03: Artificial intelligence supported instructional approaches have no significant influence on agricultural literacy among primary school pupils.

2.4 STRATEGIES FOR STRENGTHENING ARTIFICIAL INTELLIGENCE SUPPORTED AGRICULTURAL LEARNING

Successful integration of artificial intelligence into agricultural science requires coordinated institutional, technological, pedagogical, and policy interventions capable of supporting sustainable educational innovation. Artificial intelligence implementation extends beyond acquiring technological devices because effective utilisation depends on curriculum alignment, teacher competence, infrastructure availability, leadership commitment, financial investment, continuous technical support, and supportive educational policies (UNESCO, 2024). Consequently, strengthening artificial intelligence supported agricultural learning requires comprehensive strategies that address both technological and human dimensions of educational transformation (OECD, 2024).

Curriculum innovation represents one of the most important strategies for promoting artificial intelligence supported agricultural learning. Agricultural science curricula should be revised to incorporate digital agricultural technologies, artificial intelligence applications, computational thinking, environmental sustainability, and emerging agricultural innovations appropriate for primary school learners. Integrating intelligent learning activities into existing agricultural science lessons enables pupils to acquire technological competence alongside agricultural knowledge while promoting interdisciplinary learning that connects science, technology, agriculture, and environmental education (FAO, 2024). Curriculum reforms further ensure that artificial intelligence becomes an integral component of instructional practice rather than an isolated technological initiative (UNESCO, 2023).

Teacher professional development remains equally important for strengthening artificial intelligence implementation within agricultural science. Teachers require continuous training programmes focusing on artificial intelligence literacy, digital pedagogies, instructional design, classroom technology integration, ethical considerations, and effective utilisation of intelligent educational platforms. Professional development opportunities improve teachers' confidence, competence, and willingness to integrate emerging technologies into classroom instruction while encouraging innovative pedagogical practices capable of enhancing learner engagement (Holmes et al., 2022). Evidence indicates that educational technology initiatives are considerably more successful when teachers receive continuous institutional support and professional learning opportunities (European Commission, 2023).

Investment in digital infrastructure constitutes another essential strategy for promoting artificial intelligence supported agricultural learning. Schools require reliable electricity, broadband internet connectivity, computers, interactive displays, intelligent learning software, digital agricultural resources, and technical maintenance services to ensure sustainable implementation of artificial intelligence technologies (World Bank, 2024). These infrastructural investments should prioritise equitable access for both urban and rural schools to minimise educational inequalities associated with digital transformation. Adequate infrastructure further enables teachers to integrate practical agricultural simulations, intelligent assessment systems, and personalised learning environments into everyday classroom instruction (UNICEF, 2024).

Collaboration among educational institutions, government agencies, universities, agricultural research institutes, technology companies, and development organisations also strengthens artificial intelligence implementation within agricultural science. Such partnerships facilitate access to educational technologies, curriculum development expertise, teacher training opportunities, research findings, and financial support necessary for sustainable programme implementation (FAO, 2024). Collaborative innovation ecosystems further encourage development of culturally appropriate artificial intelligence applications that address local agricultural challenges while supporting national educational priorities (World Bank, 2024).

Recent empirical investigations consistently demonstrate that successful integration of artificial intelligence in education depends on comprehensive institutional strategies rather than isolated technological interventions. Bond et al. (2024) reported that institutional leadership, teacher capacity development, technological infrastructure, and stakeholder collaboration collectively predicted successful digital transformation across schools. Similarly, the OECD (2024) emphasised that coordinated educational policies, curriculum innovation, continuous teacher professional development, and sustained technological investment are essential for effective implementation of artificial intelligence and improved learner outcomes. These findings indicate that successful AI integration requires a balanced combination of technological, pedagogical, organisational, and policy related interventions.

Despite this broad agreement, previous studies differ in the strategies they identify as most influential. While some investigations emphasise investment in technological infrastructure and digital resources as the primary drivers of successful implementation, others argue that teacher competence, curriculum alignment, institutional leadership, and supportive

educational policies exert a greater influence on sustainable technology adoption. Furthermore, much of the existing evidence has been generated from developed educational systems where adequate funding, reliable digital infrastructure, and continuous professional development opportunities are more readily available. Consequently, the applicability of these findings to developing countries, particularly within primary agricultural education, remains uncertain because implementation strategies are shaped by differences in educational policy, institutional capacity, and resource availability.

Within Nigeria, strengthening artificial intelligence supported agricultural learning requires coordinated efforts involving government agencies, curriculum developers, school administrators, teacher education institutions, and technology providers. Persistent challenges relating to infrastructure, funding, teacher preparedness, and policy implementation continue to limit the effective integration of artificial intelligence into agricultural instruction (Federal Ministry of Education, 2024; UNESCO, 2024). Despite increasing interest in digital transformation, empirical evidence identifying the strategies most likely to strengthen AI supported agricultural education in Nigerian primary schools remains limited. The present study therefore extends previous research by examining context specific strategies capable of improving agricultural literacy through artificial intelligence supported learning, thereby providing evidence to support educational planning, curriculum reform, and institutional decision making. Based on the reviewed literature, the following hypothesis was formulated.

H04: Strategies for strengthening artificial intelligence supported agricultural learning have no significant influence on agricultural literacy among primary school pupils.

2.5 THEORETICAL FRAMEWORK

This study is anchored on the Constructivist Learning Theory proposed by Jean Piaget (1952) and further advanced through the social constructivist perspectives of Lev Vygotsky (1978). Constructivist Learning Theory posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information from teachers. Learning occurs when individuals integrate new experiences with existing knowledge structures, thereby creating meaningful understanding through exploration, inquiry, reflection, and problem solving (Piaget, 1952). The theory emphasises learner centred instruction, active participation, collaboration, and authentic learning experiences that promote cognitive development.

The theory is particularly relevant to this study because artificial intelligence supported agricultural learning creates interactive learning environments through which pupils actively construct agricultural knowledge rather than passively receiving information. Intelligent tutoring systems, virtual agricultural simulations, adaptive learning platforms, educational chatbots, and immersive digital environments provide opportunities for exploration, experimentation, immediate feedback, and reflective thinking, all of which are fundamental principles of Constructivist Learning Theory (Holmes et al., 2022). These technologies enable learners to connect new agricultural concepts with their prior knowledge and everyday experiences, thereby promoting deeper conceptual understanding and meaningful learning (Luckin et al., 2022).

The theory also provides a sound explanation for the four independent variables investigated in this study. First, artificial intelligence supported agricultural learning practices represent instructional experiences through which pupils actively interact with intelligent technologies to construct knowledge, making them consistent with the constructivist principle of active learning. Second, artificial intelligence supported instructional approaches facilitate personalised learning, continuous feedback, inquiry based learning, and collaborative problem solving, thereby enabling learners to progress according to their individual needs while constructing understanding through meaningful engagement with learning activities. These characteristics closely align with the constructivist view that effective learning occurs through active participation rather than passive reception of information (Piaget, 1952).

Constructivist Learning Theory also explains the importance of the remaining variables investigated in the study. Barriers to artificial intelligence integration, including inadequate infrastructure, limited teacher competence, insufficient instructional resources, and weak institutional support, restrict opportunities for learners to participate in authentic, technology enhanced learning experiences that promote knowledge construction. Where such barriers persist, pupils are less likely to engage in the interactive and experiential learning processes emphasised by constructivist principles. Conversely, strategies for strengthening artificial intelligence supported agricultural learning, such as teacher professional development, curriculum innovation, investment in digital infrastructure, supportive educational policies, and stakeholder collaboration, create enabling conditions that facilitate effective implementation of learner centred instructional practices and improve opportunities for meaningful learning (UNESCO, 2023).

Furthermore, Constructivist Learning Theory emphasises that effective learning occurs when instructional activities reflect authentic real world situations requiring learners to solve meaningful problems. Artificial intelligence supported agricultural learning enables pupils to investigate crop production, environmental conservation, sustainable farming practices, food systems, and climate adaptation through realistic simulations and intelligent decision-making activities that closely resemble authentic agricultural situations (FAO, 2024). These experiences promote conceptual understanding, critical thinking, creativity, and agricultural literacy because learners actively apply knowledge rather than memorising isolated facts.

The theory equally recognises the importance of instructional support in facilitating learning. Vygotsky's concept of the Zone of Proximal Development proposes that learners achieve higher levels of understanding when provided with

appropriate guidance and scaffolding during the learning process (Vygotsky, 1978). Artificial intelligence technologies perform similar instructional functions by providing adaptive feedback, personalised guidance, intelligent assessment, and differentiated learning pathways according to individual pupils' progress (UNESCO, 2023). Consequently, Constructivist Learning Theory provides a comprehensive theoretical foundation for explaining how artificial intelligence supported agricultural learning practices, instructional approaches, implementation barriers, and strengthening strategies collectively influence the development of agricultural literacy among primary school pupils.

2.6 LITERATURE GAP

The reviewed literature demonstrates that artificial intelligence has considerable potential for transforming educational practice through personalised learning, adaptive instruction, intelligent assessment, and interactive learning environments. Previous studies have also established positive relationships between artificial intelligence supported instruction, learner engagement, academic achievement, critical thinking, and technology enhanced learning across different educational contexts. Similarly, agricultural science literature has consistently emphasised the importance of agricultural literacy in promoting environmental sustainability, food security, scientific understanding, and responsible citizenship among young learners.

Despite these contributions, most previous studies have examined artificial intelligence adoption, educational technology integration, agricultural science, and agricultural literacy as separate areas of investigation. Comparatively few empirical studies have examined how artificial intelligence supported agricultural learning specifically influences the development of agricultural literacy among primary school pupils, particularly within developing countries where educational environments, technological infrastructure, and policy contexts differ considerably from those reported in developed economies. Existing Nigerian studies have largely focused on information and communication technology integration, digital literacy, teacher readiness, or general educational technology without providing comprehensive evidence regarding artificial intelligence applications within primary agricultural science.

Furthermore, previous investigations have paid limited attention to the combined influence of artificial intelligence supported instructional practices, implementation barriers, instructional effectiveness, and institutional strategies on agricultural literacy development among primary school pupils. Consequently, educational policymakers, curriculum developers, teacher educators, and school administrators possess limited empirical evidence regarding effective approaches for integrating artificial intelligence into agricultural instruction at the foundational education level. This study addresses this gap by providing an integrated investigation of artificial intelligence supported agricultural learning and the development of agricultural literacy among primary school pupils in Nigeria using multiple explanatory variables within a single conceptual framework.

3. METHODOLOGY

3.1 RESEARCH DESIGN

This study adopted a descriptive survey research design. The design was considered appropriate because it enabled the researchers to obtain data from respondents regarding artificial intelligence supported agricultural learning practices, barriers affecting artificial intelligence integration, the effectiveness of AI supported instructional approaches, strategies for strengthening AI implementation, and their perceived influence on the development of agricultural literacy among primary school pupils. Descriptive survey research is widely employed in educational research because it provides opportunities for collecting information on existing conditions, attitudes, practices, perceptions, and relationships among variables within naturally occurring educational settings (Creswell & Creswell, 2023). The design has also been recommended for studies investigating educational technology adoption because it facilitates the collection of reliable evidence from respondents possessing practical experience with instructional innovations (Fraenkel et al., 2022). Furthermore, descriptive survey research enables researchers to generate empirical evidence capable of informing educational policy, curriculum development, and instructional improvement without manipulating the study variables (Ary et al., 2019).

3.2 AREA OF THE STUDY

The study was conducted in public primary schools in Nigeria. Nigeria operates a Universal Basic Education system that provides foundational education for millions of pupils across the six geopolitical zones. Agricultural Science in many upper primary classes, where pupils are introduced to fundamental concepts relating to food production, environmental conservation, crop cultivation, livestock management, and sustainable agricultural practices (Federal Ministry of Education, 2024). The growing emphasis on digital transformation within Nigerian education has encouraged schools to explore innovative instructional technologies capable of improving learner engagement and educational quality. However, the level of artificial intelligence integration into classroom instruction varies considerably across schools because of differences in infrastructure availability, teacher preparedness, institutional support, and access to educational technologies (UNESCO, 2024). These variations provided an appropriate context for examining artificial intelligence supported agricultural learning and agricultural literacy among primary school pupils.

3.3 POPULATION OF THE STUDY

The population of the study comprised all primary school teachers responsible for teaching Agricultural Science, Basic Science and Technology, or related subjects in public primary schools in Nigeria. These teachers were considered suitable respondents because they possess direct experience in planning, implementing, and evaluating agricultural learning activities for primary school pupils. They are also responsible for integrating instructional technologies into classroom practice and therefore possess adequate knowledge regarding the opportunities and challenges associated with artificial intelligence supported agricultural learning (Federal Ministry of Education, 2024). Their professional responsibilities further place them in a strategic position to evaluate pupils' agricultural literacy development and the instructional effectiveness of emerging educational technologies (UNESCO, 2023).

3.4 SAMPLE AND SAMPLING TECHNIQUE

A sample of 180 primary school teachers was selected for the study using a multistage sampling procedure. In the first stage, one state was selected from each of the six geopolitical zones using simple random sampling, with one state representing each of the country's six geopolitical zones. This approach was adopted to ensure broad geographical representation while capturing variations in educational administration, technological infrastructure, socioeconomic conditions, and access to digital learning resources across the different regions. Nigeria's geopolitical zones are widely recognised in educational and national survey research as appropriate strata for obtaining representative data because they reflect major regional differences in educational development and policy implementation. Consequently, selecting one state from each geopolitical zone provided a reasonable national representation while ensuring that the study remained practically manageable in terms of time, cost, and logistics. This sampling approach enhanced the diversity of respondents and improved the generalisability of the findings to public primary schools across Nigeria (Creswell & Creswell, 2023).

In the second stage, five public primary schools were randomly selected from each participating state. Finally, teachers responsible for Agricultural Science were selected using proportionate random sampling according to the number of eligible teachers available in each school. This sampling procedure ensured adequate geographical representation while reducing sampling bias and improving the representativeness of the study findings (Creswell & Creswell, 2023). To ensure that respondents possessed adequate knowledge relevant to the study, specific inclusion criteria were established. Only teachers who were currently teaching Agricultural Science at the upper primary level were included because these teachers are directly involved in delivering agricultural concepts and evaluating pupils' learning outcomes. In addition, only teachers with a minimum of one academic session of teaching experience in their current schools were selected to ensure that respondents had sufficient familiarity with instructional practices, available educational technologies, and pupils' learning characteristics. Teachers who were not directly involved in agricultural related instruction or who had less than one academic session of teaching experience were excluded from the study.

A total of 180 questionnaires were distributed to the selected respondents. Of this number, 165 questionnaires were correctly completed and returned, representing a response rate of 91.7%. The achieved response rate exceeded the minimum threshold generally regarded as acceptable for educational survey research and therefore provided adequate data for statistical analysis (Fraenkel et al., 2022). The achieved response rate exceeded the minimum threshold generally considered acceptable for educational survey research, thereby reducing the likelihood of non-response bias and enhancing the reliability and generalisability of the study findings (Fraenkel et al., 2022).

3.5 INSTRUMENT FOR DATA COLLECTION

Data were collected using a structured questionnaire titled Artificial Intelligence Supported Agricultural Learning and Agricultural Literacy Questionnaire (AISALQ). The instrument was developed from the literature reviewed and consisted of two sections. Section A elicited information regarding the demographic characteristics of the respondents. Section B consisted of four clusters corresponding to the major variables investigated in the study. Cluster I contained items examining artificial intelligence supported agricultural learning practices implemented in primary schools. Cluster II contained items measuring barriers affecting the integration of artificial intelligence into agricultural learning. Cluster III contained items assessing the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy among pupils. Cluster IV contained items identifying strategies capable of strengthening artificial intelligence supported agricultural learning in primary schools. Clusters I, II and IV were structured on a four-point Likert scale of: Strongly Agree (4), Agree (3), Disagree (2) and Strongly Disagree (1). Cluster III was structured on a four-point scale of: High Extent (4), Moderate Extent (3), Low Extent (2) and Very Low Extent (1)

3.6 VALIDITY OF THE INSTRUMENT

The instrument was subjected to face and content validation by five experts. Three experts were drawn from the Department of Agricultural Education, University of Nigeria, Nsukka, while the remaining two experts specialised in Educational Technology and Measurement and Evaluation. The validators independently examined the instrument with respect to the relevance of each item to the study objectives, the clarity and appropriateness of the language, the representativeness of the items in measuring the constructs under investigation, the adequacy of content coverage, and the logical organisation of the questionnaire. Their evaluations also ensured that each item appropriately reflected the dimensions of artificial intelligence supported agricultural learning and agricultural literacy investigated in the study. The experts' observations, corrections, and

recommendations were incorporated in revising ambiguous statements, improving item wording, and strengthening the alignment between the questionnaire items and the study objectives before producing the final version of the instrument for administration (Fraenkel et al., 2022). A Content Validity Index (CVI) was not computed, as the study relied on expert judgement to establish face and content validity.

3.7 RELIABILITY OF THE INSTRUMENT

A pilot study was conducted using 20 primary school teachers selected from schools outside the study sample. Data obtained from the pilot study were analysed using Cronbach Alpha reliability statistics. The following reliability coefficients were obtained for various clusters: AI Supported Agricultural Learning Practices - 0.82, Barriers to AI Integration - 0.84, AI Supported Instructional Effectiveness - 0.79 and AI Integration Strategies - 0.86. The overall Cronbach Alpha reliability coefficient for the instrument was 0.83, indicating that the instrument possessed satisfactory internal consistency and was suitable for data collection (Taber, 2018).

3.8 METHOD OF DATA COLLECTION

The researchers administered the questionnaire directly to the respondents with the assistance of six trained research assistants, one from each participating geopolitical zone. Prior to administration, permission was obtained from the relevant school authorities. Respondents were informed about the objectives of the study and were assured that participation was voluntary. Adequate time was provided for completing the questionnaire, while completed copies were collected immediately after completion to minimise loss and improve the response rate.

3.9 ETHICAL CONSIDERATIONS

Ethical principles were strictly observed throughout the conduct of the study. Permission to conduct the study was obtained from the relevant educational authorities before data collection commenced. Respondents received adequate information concerning the purpose of the research, the voluntary nature of participation, and their right to withdraw at any stage without penalty. Informed consent was obtained before questionnaire administration. Confidentiality and anonymity were guaranteed by ensuring that no personally identifiable information was collected. The data obtained were used exclusively for academic and research purposes in accordance with internationally accepted ethical standards for educational research (BERA, 2024).

3.10 METHOD OF DATA ANALYSIS

Mean and standard deviation were used to answer the research questions. For Clusters I, II and IV, mean scores of 2.50 and above were interpreted as Agree, while mean scores below 2.50 were interpreted as Disagree. For Cluster III, mean scores were interpreted as follows: 3.50–4.00: High Extent, 2.50–3.49: Moderate Extent, 1.50–2.49: Low Extent and 1.00–1.49: Very Low Extent. Pearson Product Moment Correlation was employed to determine the relationships between the independent variables and agricultural literacy outcomes. Multiple regression analysis was further used to determine the predictive influence of artificial intelligence supported agricultural learning practices, barriers to AI integration, instructional effectiveness, and AI implementation strategies on agricultural literacy among primary school pupils. Prior to conducting the regression analysis, the underlying assumptions of multiple regression were examined, including normality of residuals, homoscedasticity, multicollinearity, and independence of residuals, to ascertain the suitability of the data for regression analysis. The assumptions were considered satisfactory, and the analysis proceeded accordingly. The hypotheses were tested at the 0.05 level of significance. The hypotheses were tested at the 0.05 level of significance.

The regression model for the study was specified as:

$$AL=\beta0+\beta1(AISAL)+\beta2(BAI)+\beta3(AIE)+\beta4(AIS)+\varepsilon$$

Where:

- **AL** = Agricultural Literacy
- **AISAL** = Artificial Intelligence Supported Agricultural Learning Practices
- **BAI** = Barriers to Artificial Intelligence Integration
- **AIE** = Artificial Intelligence Supported Instructional Effectiveness
- **AIS** = Artificial Intelligence Integration Strategies
- β_0 = Constant
- β_1–β_4 = Regression Coefficients
- ε = Error Term

The null hypotheses were rejected whenever the associated probability value was less than 0.05 and retained whenever the probability value was equal to or greater than 0.05.

4. RESULTS

A total of 180 copies of the questionnaire were administered to the respondents. Out of this number, 165 copies were correctly completed and returned, representing a response rate of 91.7%. The returned questionnaires were used for data analysis.

Research Question 1: What artificial intelligence supported agricultural learning practices are currently implemented in primary schools to promote agricultural literacy among pupils?

Table 1: Mean Ratings of Respondents on Artificial Intelligence Supported Agricultural Learning Practices (N = 165)

S/N	Items	Mean	SD	Remark
1	Use of AI powered educational applications during agricultural lessons	3.18	0.71	Agree
2	Use of intelligent educational videos for teaching agricultural concepts	3.11	0.68	Agree
3	Application of virtual agricultural simulations during classroom instruction	2.47	0.83	Disagree
4	Use of AI assisted image recognition for identifying crops and animals	2.41	0.79	Disagree
5	Adaptive learning platforms for individualised agricultural instruction	2.36	0.76	Disagree
6	Educational chatbots for answering pupils' agricultural questions	2.29	0.85	Disagree
7	AI based quizzes providing immediate feedback	3.02	0.72	Agree
8	Use of virtual field trips to agricultural environments	2.32	0.81	Disagree
9	AI supported personalised learning activities	2.38	0.77	Disagree
10	Use of learning analytics to monitor pupils' agricultural learning progress	2.26	0.82	Disagree
	Grand Mean	**2.58**	**0.77**	**Agree**

The results presented in Table 1 indicate that artificial intelligence supported agricultural learning practices were **moderately implemented** in the participating primary schools. Respondents agreed that AI powered educational applications, intelligent instructional videos, and AI based assessment activities were implemented to some extent, whereas more advanced technologies such as virtual agricultural simulations, adaptive learning platforms, educational chatbots, personalised learning systems, and learning analytics were generally unavailable. The overall grand mean of 2.58 suggests that AI integration in agricultural instruction remains at an emerging stage rather than being fully institutionalised. In practical terms, this moderate level of implementation indicates that although schools have begun adopting selected AI supported instructional tools, the integration of more sophisticated artificial intelligence technologies into routine classroom practice is still constrained by infrastructural, financial, and teacher related challenges within the Nigerian primary education system.

Research Question 2: What barriers affect the integration of artificial intelligence technologies into agricultural learning among primary school pupils?

Table 2: Mean Ratings of Respondents on Barriers Affecting Artificial Intelligence Integration (N = 165)

S/N	Items	Mean	SD	Remark
1	Inadequate technological infrastructure	3.64	0.59	Agree
2	Poor internet connectivity	3.53	0.63	Agree
3	Insufficient teacher competence in AI technologies	3.42	0.69	Agree
4	High cost of AI educational technologies	3.61	0.58	Agree
5	Inadequate electricity supply	3.49	0.66	Agree
6	Limited government funding	3.37	0.71	Agree
7	Inadequate digital instructional resources	3.28	0.74	Agree
8	Resistance to technological innovation	3.09	0.79	Agree
	Grand Mean	**3.43**	**0.67**	**Agree**

The findings in Table 2 reveal that respondents perceived inadequate technological infrastructure, high implementation costs, poor internet connectivity, inadequate electricity supply, and insufficient teacher competence as major barriers affecting artificial intelligence integration within agricultural science. The grand mean of 3.43 indicates strong agreement that these challenges substantially hinder AI implementation in Nigerian primary schools.

Research Question 3: To what extent are artificial intelligence supported instructional approaches effective in promoting agricultural literacy among primary school pupils?

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Table 3: Mean Ratings of Respondents on the Effectiveness of Artificial Intelligence Supported Instructional Approaches (N = 165)

S/N	Items	Mean	SD	Interpretation
1	Improving pupils' understanding of agricultural concepts	3.31	0.67	Moderate Extent
2	Increasing pupils' classroom participation	3.28	0.71	Moderate Extent
3	Enhancing pupils' interest in agriculture	3.19	0.69	Moderate Extent
4	Supporting personalised agricultural learning	2.44	0.81	Low Extent
5	Promoting critical thinking during agricultural lessons	3.07	0.74	Moderate Extent
6	Improving long term knowledge retention	2.53	0.76	Moderate Extent
7	Encouraging environmental awareness	3.12	0.72	Moderate Extent
8	Supporting practical agricultural problem solving	2.46	0.83	Low Extent
	Grand Mean	**2.93**	**0.74**	**Moderate Extent**

The findings indicate that artificial intelligence supported instructional approaches promoted agricultural literacy to a moderate extent among primary school pupils. Respondents acknowledged improvements in pupils' conceptual understanding, classroom participation, environmental awareness, and interest in agriculture, whereas personalised learning and practical agricultural problem solving recorded relatively lower effectiveness because of the limited availability of advanced AI technologies in many schools. The grand mean of 2.93 indicates that artificial intelligence has begun to make meaningful contributions to agricultural instruction but has not yet reached a level capable of transforming learning outcomes consistently across primary schools. Within the Nigerian educational context, this moderate level reflects the gradual adoption of AI supported instructional practices amid continuing limitations in technological infrastructure, teacher competence, and institutional support.

Research Question 4: What strategies can strengthen artificial intelligence supported agricultural learning for improved agricultural literacy among primary school pupils?

Table 4: Mean Ratings of Respondents on Strategies for Strengthening Artificial Intelligence Supported Agricultural Learning (N = 165)

S/N	Items	Mean	SD	Remark
1	Teacher professional development programmes	3.69	0.55	Agree
2	Provision of adequate digital infrastructure	3.72	0.51	Agree
3	Reliable internet connectivity	3.58	0.60	Agree
4	Curriculum integration of AI technologies	3.49	0.58	Agree
5	Government funding support	3.67	0.56	Agree
6	School industry partnerships	3.34	0.64	Agree
7	Development of AI based agricultural learning resources	3.46	0.59	Agree
8	Continuous technical support	3.41	0.63	Agree
9	Provision of digital devices for schools	3.63	0.57	Agree
10	Development of national AI education policies	3.55	0.61	Agree
	Grand Mean	**3.55**	**0.58**	**Agree**

The findings presented in Table 4 demonstrate that respondents agreed with all the proposed strategies for strengthening artificial intelligence supported agricultural learning. Provision of digital infrastructure, teacher professional development, government funding, digital devices, and supportive educational policies emerged as the highest rated strategies capable of improving agricultural literacy among primary school pupils.

Test of Hypotheses

Table 5: Pearson Correlation Matrix among Study Variables

Variables	AISAL	BAI	AIE	AIS	AL
AISAL	1.00				
BAI	-0.39**	1.00			
AIE	0.56**	-0.34**	1.00		
AIS	0.63**	-0.31**	0.60**	1.00	
AL	0.70**	-0.49**	0.64**	0.75**	1.00

p < .01

Note: AISAL = Artificial Intelligence Supported Agricultural Learning Practices; BAI = Barriers to AI Integration; AIE = AI Supported Instructional Effectiveness; AIS = Artificial Intelligence Integration Strategies; AL = Agricultural Literacy.

The correlation analysis indicates significant positive relationships between AI supported agricultural learning practices, instructional effectiveness, implementation strategies, and agricultural literacy among primary school pupils. Conversely, barriers to AI integration demonstrated a significant negative relationship with agricultural literacy, indicating that increased implementation challenges reduce pupils' agricultural literacy outcomes.

Table 6: Multiple Regression Analysis of Predictors of Agricultural Literacy

Predictor	B	Beta (β)	t	p
Constant	0.914		5.116	.000
AI Supported Agricultural Learning Practices	0.281	0.296	4.472	.000
Barriers to AI Integration	-0.201	-0.219	-3.684	.001
AI Supported Instructional Effectiveness	0.218	0.227	3.941	.000
AI Integration Strategies	0.356	0.408	5.731	.000

Model Summary

- **R = 0.836**
- **R^2 = 0.699**
- **Adjusted R^2 = 0.691**
- **F(4,160) = 92.84**
- **p = .000**

Note: Significance level = **0.05**; **N = 165**.

The regression model was statistically significant, $F(4,160) = 92.84$, $p < .05$, indicating that the independent variables jointly explained variations in agricultural literacy among primary school pupils. The model explained 69.9% of the variance in agricultural literacy ($R^2 = .699$). Artificial intelligence integration strategies emerged as the strongest predictor ($\beta = .408$), followed by AI supported agricultural learning practices ($\beta = .296$), instructional effectiveness ($\beta = .227$), and barriers to AI integration ($\beta = -.219$). These findings indicate that improvements in AI implementation strategies, classroom practices, and instructional effectiveness significantly enhance agricultural literacy, whereas implementation barriers reduce agricultural literacy outcomes.

Hypotheses Decision

H01: Artificial intelligence supported agricultural learning practices significantly predicted agricultural literacy ($\beta = 0.296$, $p < .05$). Therefore, H01 was rejected.

H02: Barriers to artificial intelligence integration significantly influenced agricultural literacy ($\beta = -0.219$, $p < .05$). Therefore, H02 was rejected.

H03: Artificial intelligence supported instructional approaches significantly predicted agricultural literacy ($\beta = 0.227$, $p < .05$). Therefore, H03 was rejected.

H04: Artificial intelligence integration strategies significantly predicted agricultural literacy ($\beta = 0.408$, $p < .05$). Therefore, H04 was rejected.

The regression model accounted for 69.9% of the variation in agricultural literacy among primary school pupils, indicating strong explanatory power. Among the predictor variables, artificial intelligence integration strategies contributed the greatest influence, highlighting the importance of coordinated institutional, technological, and policy interventions in promoting effective AI supported agricultural learning.

5. DISCUSSION OF FINDINGS

The study found that artificial intelligence supported agricultural learning practices were moderately implemented in primary schools. Respondents indicated that AI powered educational applications, intelligent instructional videos, and AI based assessment activities were the most commonly utilised technologies, whereas adaptive learning systems, virtual agricultural simulations, educational chatbots, and learning analytics remained largely unavailable. This finding suggests that although schools have begun embracing digital innovations, the implementation of sophisticated artificial intelligence technologies for agricultural instruction remains limited. The moderate level of implementation may be attributed to inadequate technological infrastructure, insufficient funding for educational technologies, limited teacher competence in artificial intelligence applications, and unequal access to digital resources across schools. These challenges are often more pronounced in rural communities where internet connectivity, electricity supply, and access to digital devices remain inadequate, thereby limiting opportunities for effective AI integration into classroom instruction. The finding agrees with UNESCO (2023), which reported that the adoption of artificial intelligence in school education is increasing globally but remains uneven because of disparities in technological infrastructure, institutional readiness, and educational investment. It also supports the findings of Holmes et al. (2022), who observed that many educational institutions continue to utilise basic digital technologies while more advanced artificial intelligence applications remain at the developmental stage because of implementation challenges. Similarly, the OECD (2024) reported that educational systems in many developing countries have not yet achieved widespread integration of adaptive artificial intelligence technologies into classroom instruction because of infrastructural and financial constraints.

The study further revealed that inadequate technological infrastructure, poor internet connectivity, insufficient teacher competence, high implementation costs, inadequate electricity supply, limited government funding, inadequate instructional resources, and resistance to technological innovation constitute major barriers affecting artificial intelligence integration into agricultural learning. Among these constraints, inadequate technological infrastructure and high implementation costs emerged as the most significant barriers. These findings reflect the realities of many Nigerian public primary schools, where digital transformation initiatives often exceed the available financial and technological capacity required for successful implementation. The findings also suggest that educational policies promoting technology integration may not achieve their intended outcomes unless accompanied by sustained investment in infrastructure, continuous teacher professional development, and institutional support mechanisms. Furthermore, disparities between urban and rural schools continue to widen inequalities in access to digital learning opportunities, thereby affecting pupils' exposure to innovative instructional practices. The finding corroborates the World Bank (2024), which identified inadequate digital infrastructure and unequal technological access as major impediments to educational transformation in developing countries. Likewise, UNESCO (2024) emphasised that artificial intelligence implementation requires coordinated investments in infrastructure, teacher capacity development, and policy support before meaningful educational benefits can be realised. The finding is also consistent with Bond et al. (2024), who concluded that insufficient institutional support and inadequate professional development significantly reduce teachers' willingness and ability to integrate artificial intelligence technologies into classroom instruction.

The findings further indicated that artificial intelligence supported instructional approaches promoted agricultural literacy to a moderate extent among primary school pupils. Respondents perceived that artificial intelligence improved pupils' understanding of agricultural concepts, increased classroom participation, enhanced environmental awareness, stimulated interest in agriculture, and strengthened critical thinking. However, personalised learning and practical agricultural problem solving recorded relatively lower effectiveness because many schools had limited access to advanced intelligent learning systems. The moderate level of effectiveness suggests that the educational benefits of artificial intelligence depend not only on the availability of intelligent technologies but also on teachers' competence in integrating them into classroom instruction and the existence of supportive learning environments. Where teachers possess limited digital pedagogical skills or schools lack adequate technological infrastructure, the capacity of artificial intelligence to transform learning outcomes is considerably reduced. Consequently, AI functions more as a supplementary instructional resource than as a fully integrated pedagogical approach in many Nigerian primary schools. The result supports Chen et al. (2023), who reported that adaptive artificial intelligence systems significantly improve learners' conceptual understanding, motivation, and academic achievement across science related disciplines. Similarly, Crompton and Burke (2023) found that intelligent educational technologies promote learner engagement, collaborative learning, and higher order cognitive skills through personalised instructional support. The finding also agrees with FAO (2024), which emphasised that digital technologies strengthen agricultural science by enabling learners to visualise agricultural processes and participate actively in experiential learning activities.

The study established that teacher professional development, adequate technological infrastructure, reliable internet connectivity, curriculum integration, government funding, industry partnerships, development of AI based learning resources, continuous technical support, provision of digital devices, and supportive national educational policies are effective strategies for strengthening artificial intelligence supported agricultural learning. Respondents particularly

emphasised infrastructure provision, teacher training, government funding, and digital resource availability as the most important intervention strategies. These findings underscore that successful AI integration requires coordinated institutional efforts rather than isolated technology acquisition. They further suggest that educational policy should prioritise equitable distribution of digital resources, particularly to underserved rural schools, while strengthening teachers' digital competencies through continuous professional development. Such interventions would reduce regional disparities in access to AI supported instruction and improve the quality of agricultural education across Nigerian primary schools. The result agrees with UNESCO (2024), which identified teacher competence, institutional leadership, infrastructure development, and curriculum innovation as essential requirements for sustainable artificial intelligence implementation within educational systems. Similarly, the OECD (2024) emphasised that coordinated educational policies and continuous investment in digital infrastructure significantly improve successful technology integration and learner outcomes. The finding is equally consistent with Holmes et al. (2022), who concluded that the effectiveness of artificial intelligence in education depends largely on teacher preparedness, institutional support, and learner centred instructional design.

The correlation analysis revealed significant positive relationships between artificial intelligence supported agricultural learning practices, instructional effectiveness, implementation strategies, and agricultural literacy among primary school pupils. In contrast, barriers to artificial intelligence integration demonstrated a significant negative relationship with agricultural literacy. These findings indicate that increasing the availability and quality of artificial intelligence supported instruction contributes positively to pupils' agricultural literacy, whereas implementation barriers reduce opportunities for effective learning. The findings support the assumptions of Constructivist Learning Theory, which proposes that meaningful learning occurs when learners actively interact with rich instructional environments capable of promoting exploration, inquiry, and knowledge construction (Piaget, 1952; Vygotsky, 1978). The findings further support Holmes et al. (2022), who argued that artificial intelligence creates adaptive learning environments capable of enhancing learner engagement and conceptual understanding through personalised educational experiences. Likewise, UNESCO (2023) reported that well designed artificial intelligence learning environments promote learner autonomy, collaboration, and critical thinking.

The regression analysis demonstrated that artificial intelligence supported agricultural learning practices, barriers to artificial intelligence integration, instructional effectiveness, and implementation strategies significantly predicted agricultural literacy among primary school pupils. The regression model explained 69.9% of the variation in agricultural literacy, indicating that the selected predictor variables collectively provide substantial explanatory power. Artificial intelligence implementation strategies emerged as the strongest predictor, followed by instructional practices, instructional effectiveness, and implementation barriers. These findings suggest that coordinated interventions involving curriculum innovation, teacher capacity development, infrastructure provision, institutional leadership, and supportive educational policies produce greater improvements in agricultural literacy than isolated technological initiatives. The finding supports OECD (2024), which emphasised that successful educational transformation requires integrated institutional ecosystems rather than technology acquisition alone. The finding also agrees with UNESCO (2024), which concluded that sustainable implementation of artificial intelligence depends upon comprehensive policy frameworks that simultaneously address infrastructure, teacher competence, curriculum development, and equitable technological access. Furthermore, Holmes et al. (2022) maintained that the educational benefits of artificial intelligence are maximised when technological innovation is accompanied by appropriate pedagogical and institutional reforms.

Hence, the findings demonstrate that artificial intelligence possesses substantial potential for transforming agricultural science and improving agricultural literacy among primary school pupils in Nigeria. However, successful implementation requires sustained investment in digital infrastructure, teacher professional development, curriculum innovation, institutional support, and national educational policies that promote equitable access to intelligent educational technologies. The findings therefore reinforce the importance of positioning artificial intelligence as a strategic component of educational transformation capable of preparing future generations for sustainable agriculture, environmental stewardship, food security, and national development.

5.1 REGIONAL IMPLICATIONS FOR ARTIFICIAL INTELLIGENCE SUPPORTED AGRICULTURAL LEARNING IN NIGERIA

Although this study investigated artificial intelligence supported agricultural learning using respondents drawn from different regions of Nigeria, the analysis focused on aggregated national responses. Nevertheless, considerable regional disparities exist in digital infrastructure, electricity supply, internet connectivity, teacher preparedness, educational funding, and technological access. Schools located within urban centres generally possess greater opportunities for integrating artificial intelligence into classroom instruction than schools situated in rural and underserved communities. Consequently, pupils' opportunities to benefit from artificial intelligence supported agricultural learning may vary substantially across the different geopolitical zones.

These regional differences suggest that educational policies promoting artificial intelligence integration should recognise local contextual realities rather than adopting a uniform implementation strategy. Regions experiencing severe infrastructural deficiencies may require greater investment in electricity supply, internet connectivity, digital devices, and teacher professional development before artificial intelligence technologies can be effectively implemented. Conversely, educational institutions with stronger technological capacity may benefit more from advanced intelligent learning systems, adaptive instructional platforms, and collaborative innovation programmes. Policymakers should therefore adopt region

specific implementation strategies capable of addressing existing inequalities while promoting equitable access to artificial intelligence supported agricultural learning throughout Nigeria.

5.2 PRACTICAL, THEORETICAL AND POLICY IMPLICATIONS

The findings of this study provide practical guidance for teachers, school administrators, curriculum developers, educational technology providers, and policymakers seeking to strengthen agricultural science within primary schools. The study demonstrates that investments in teacher competence, digital infrastructure, curriculum innovation, and institutional support can substantially improve pupils' agricultural literacy through artificial intelligence supported learning environments. Educational institutions may therefore utilise the findings when designing digital transformation strategies aimed at improving learner engagement and educational quality.

The findings further suggest that schools with limited technological infrastructure need not postpone the adoption of artificial intelligence supported agricultural instruction until sophisticated digital facilities become available. Instead, school administrators and teachers may gradually introduce low cost and accessible digital innovations through mobile learning technologies, freely available AI supported educational platforms, and cloud-based learning systems that require minimal local computing resources. Such approaches can expand access to personalised instructional support, interactive agricultural learning resources, and intelligent educational applications while reducing the financial burden associated with large scale technological investments. These strategies are particularly relevant for rural and resource constrained schools where infrastructure development is still evolving, thereby promoting more equitable access to AI supported agricultural education.

The findings also have important implications for primary school teachers. Beyond adopting digital technologies, teachers require continuous professional development that strengthens their competence in integrating artificial intelligence into learner centred agricultural instruction. Even where advanced AI technologies are unavailable, teachers can utilise freely accessible AI supported educational applications, mobile learning resources, and digital instructional materials to enrich classroom learning experiences. Such instructional innovations can improve pupils' engagement, promote agricultural literacy, and encourage greater interest in sustainable agriculture while supporting the broader objectives of digital transformation within primary education

Theoretically, this study extends the application of Constructivist Learning Theory by demonstrating that artificial intelligence supported learning environments provide practical mechanisms through which learners actively construct agricultural knowledge. The findings reinforce constructivist assumptions regarding learner centred instruction, inquiry-based learning, personalised educational experiences, and active knowledge construction. The study also contributes to the growing body of literature examining artificial intelligence integration within primary agricultural science, particularly within developing country contexts where empirical evidence remains limited.

In terms of policy, the findings indicate that successful implementation of artificial intelligence within agricultural science requires coherent national educational policies that simultaneously address technological infrastructure, teacher professional development, curriculum reform, funding, digital inclusion, and ethical governance. Educational policymakers should therefore adopt comprehensive artificial intelligence implementation frameworks capable of reducing existing digital inequalities while promoting equitable access to intelligent educational technologies across urban and rural schools.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FURTHER STUDIES

This study focused exclusively on primary school teachers responsible for agricultural instruction. Although these respondents possess adequate professional experience regarding classroom teaching and pupils' learning outcomes, their perceptions may differ from those of pupils, school administrators, curriculum developers, educational technology specialists, parents, and policymakers who also influence artificial intelligence implementation within primary education. Consequently, the findings should be interpreted within the context of teachers' professional experiences.

Furthermore, the study examined national responses without undertaking comparative analyses across the six geopolitical zones. Future studies should therefore investigate regional variations in artificial intelligence implementation, technological infrastructure, teacher competence, and agricultural literacy development. Researchers should also consider experimental and longitudinal research designs capable of examining the causal effects of artificial intelligence supported agricultural learning on pupils' academic achievement, critical thinking, environmental awareness, and long-term agricultural literacy development. Such investigations would provide stronger empirical evidence capable of informing educational policy and curriculum innovation.

A further limitation of this study relates to the measurement of agricultural literacy. The study assessed pupils' agricultural literacy indirectly through the perceptions of primary school teachers rather than through direct assessment of pupils themselves. Although teachers are well positioned to evaluate pupils' classroom learning experiences and instructional outcomes, their responses may not fully capture individual pupils' actual levels of agricultural literacy. Consequently, the findings should be interpreted within the context of teachers' professional perceptions. Future studies may strengthen the evidence by combining teachers' perspectives with direct assessments of pupils' agricultural literacy and classroom based observational data

7. CONCLUSION

This study examined the influence of artificial intelligence supported agricultural learning on the development of agricultural literacy among primary school pupils in Nigeria. The findings demonstrate that artificial intelligence is increasingly recognised as an important educational innovation capable of transforming agricultural instruction through interactive, personalised, and learner centred teaching approaches. Although the implementation of artificial intelligence supported agricultural learning remains moderate within Nigerian primary schools, respondents acknowledged its considerable potential for improving pupils' understanding of agricultural concepts, increasing classroom participation, strengthening environmental awareness, and stimulating interest in agriculture.

The study further established that inadequate technological infrastructure, poor internet connectivity, insufficient teacher competence, high implementation costs, unreliable electricity supply, and inadequate government funding continue to limit effective integration of artificial intelligence into agricultural science. These implementation barriers significantly reduce opportunities for pupils to benefit from intelligent instructional technologies and therefore constrain the development of agricultural literacy.

Regression analysis confirmed that artificial intelligence supported agricultural learning practices, instructional effectiveness, implementation strategies, and barriers to implementation significantly influence agricultural literacy among primary school pupils. Among the predictor variables, implementation strategies emerged as the strongest determinant of agricultural literacy, highlighting the importance of coordinated investments in infrastructure, teacher capacity development, curriculum reform, supportive educational policies, and institutional leadership. The findings therefore suggest that successful integration of artificial intelligence into agricultural science requires comprehensive educational reforms rather than isolated technological interventions.

Hence, the study concludes that artificial intelligence possesses significant potential for strengthening agricultural literacy and preparing young learners with the knowledge, skills, and attitudes required for sustainable agriculture, environmental stewardship, and future workforce development. Realising this potential, however, depends upon sustained collaboration among government agencies, educational institutions, technology providers, curriculum developers, and other stakeholders committed to educational transformation.

7.1 RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made:

1. Federal and State Ministries of Education should invest in adequate digital infrastructure, including reliable electricity supply, internet connectivity, computers, and intelligent educational technologies to facilitate effective implementation of artificial intelligence supported agricultural learning.
2. Teacher education institutions and educational authorities should organise continuous professional development programmes to improve teachers' competence in the pedagogical application of artificial intelligence technologies within agricultural science.
3. Curriculum developers should integrate artificial intelligence supported instructional activities, digital agriculture, and emerging agricultural technologies into primary school agricultural science curricula to promote learner centred and experiential learning.
4. Government should establish sustainable funding mechanisms and public private partnerships to support procurement, maintenance, and continuous upgrading of artificial intelligence educational technologies in primary schools.
5. Educational policymakers should formulate comprehensive national guidelines regulating the ethical, equitable, and effective utilisation of artificial intelligence within primary education while ensuring adequate protection of learners' privacy and data security.
6. Educational technology developers should collaborate with agricultural educators to design culturally relevant artificial intelligence applications that reflect local agricultural practices and learning needs.
7. School administrators should encourage innovation by providing teachers with adequate institutional support, technical assistance, and opportunities to experiment with artificial intelligence supported instructional strategies.

SUPPLEMENTARY MATERIALS

Not applicable.

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AUTHOR CONTRIBUTIONS

Toochukwu Collins Nwakile: Conceived and designed the study, contributed to the development of the research framework, supervised the research process, and critically reviewed the manuscript.

Nicholas Irmiya Tetok: Developed the methodology, performed the statistical analyses, interpreted the findings, prepared the original manuscript draft, coordinated manuscript revision, and served as the corresponding author.

Both authors have read and approved the final manuscript and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the research are appropriately investigated and resolved.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all participants prior to their involvement in the study. Participants were adequately informed about the purpose of the research, the voluntary nature of participation, and their right to withdraw from the study at any time without any consequences. Confidentiality and anonymity were ensured by collecting no personally identifiable information. Data obtained were used solely for academic and research purposes.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

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CONFLICTS OF INTEREST

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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