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ARTICLE

Teachers' Perceptions of Artificial Intelligence-Supported Agricultural Learning and Agricultural Literacy Development among Primary School Pupils in Nigeria

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Abstract

Agricultural literacy is essential for preparing young learners to understand food systems, environmental sustainability, climate change, and modern agricultural practices. Artificial intelligence (AI) offers opportunities to enhance agricultural science instruction through adaptive learning, personalised instruction, and interactive educational technologies. However, evidence regarding teachers' perceptions of how AI supported agricultural learning contributes to agricultural literacy development among primary school pupils in Nigeria remains limited. This study investigated primary school teachers' perceptions of the influence of AI supported agricultural learning on agricultural literacy development among pupils. Specifically, the study examined AI supported instructional practices, barriers to AI integration, the perceived effectiveness of AI supported instructional approaches, and strategies for strengthening AI supported agricultural learning. A descriptive survey design was adopted. Data were collected from 165 primary school teachers using a structured questionnaire. Mean and standard deviation answered the research questions, while multiple regression analysis tested the hypotheses at the 0.05 level of significance. The findings revealed moderate implementation of AI supported agricultural learning practices, substantial barriers to AI integration, moderate perceived instructional effectiveness, and significant relationships between the predictor variables and teachers' perceptions of agricultural literacy development. The study concludes that teachers perceive AI supported agricultural learning as having considerable potential to enhance agricultural literacy among primary school pupils when supported by adequate infrastructure, teacher capacity development, and effective implementation strategies.

Keywords: artificial intelligence, agricultural learning, teacher perceptions, agricultural literacy, primary school pupils, educational technology, Nigeria.

1. INTRODUCTION

The increasing complexity of global food systems, climate change, environmental sustainability, and technological innovation has transformed the knowledge and competencies expected of future generations. Agriculture is no longer viewed solely as food production but as a multidisciplinary field encompassing 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 [1]. 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 [2]. Early exposure to agricultural concepts also strengthens pupils' appreciation of environmental conservation and responsible resource utilisation [3].

Recent advances in artificial intelligence have introduced 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 [4]. Within educational settings, AI powered technologies provide 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 [5]. These innovations have demonstrated considerable potential for improving learner engagement, academic achievement, and knowledge retention across different educational contexts [6].

Artificial intelligence supported agricultural learning involves the integration of intelligent digital technologies into agricultural instruction to improve pupils' understanding of agricultural concepts through interactive, adaptive, and learner centred instructional experiences. AI applications may include virtual farms, intelligent simulations, 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 [1]. These technologies create authentic learning environments that enable pupils to visualise agricultural processes that may otherwise be difficult to observe within conventional classroom instruction [7]. Consequently, AI supported agricultural learning has emerged as an innovative strategy for improving agricultural science at the foundational level.

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 [8]. Agricultural literacy enables learners to appreciate the importance of agriculture within 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 in later life [9].

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 [10]. Integrating artificial intelligence into these learning experiences may further strengthen pupils' conceptual understanding by providing personalised instruction, immediate feedback, interactive visualisations, and engaging learning environments that accommodate individual learning differences [11].

The Nigerian educational system has increasingly recognised the importance of digital transformation and technology enhanced learning. National policies promoting digital education encourage schools to integrate emerging technologies capable of improving instructional quality and learner outcomes. Nevertheless, many primary schools continue to experience limited access to educational technologies, inadequate teacher preparedness, insufficient digital infrastructure, and inadequate instructional resources for effective implementation of artificial intelligence supported learning [12]. These limitations are particularly evident within agricultural science, where instructional delivery remains predominantly teacher centred despite the practical and experiential nature of the subject [13]. Consequently, pupils often demonstrate limited understanding of contemporary agricultural practices and insufficient agricultural literacy required for sustainable development.

Globally, several empirical studies have reported positive relationships between artificial intelligence supported instruction and learner achievement across science education, mathematics, language learning, and environmental education. Intelligent tutoring systems have been associated with improved academic performance, personalised learning experiences, learner motivation, and higher cognitive engagement [5]. Similarly, adaptive educational technologies enhance learners' critical thinking and problem solving by providing individualised instructional support based on learning progress [6]. Although these studies provide valuable evidence regarding AI supported learning generally, relatively few have specifically investigated its application within agricultural science for primary school pupils, particularly in developing countries where digital infrastructure and educational contexts differ considerably.

Within Nigeria, existing studies have primarily examined digital learning, educational technology adoption, teacher readiness, and ICT integration in schools [13,14]. Comparatively little empirical attention has been devoted to artificial intelligence supported agricultural learning and its contribution to agricultural literacy among primary school pupils. Consequently, educational policymakers, curriculum developers, and teachers possess limited evidence regarding effective strategies for integrating artificial intelligence into agricultural instruction at the foundational education level. This knowledge gap constrains curriculum innovation and evidence-based policy decisions capable of improving agricultural science and sustainable development outcomes.

Given the growing importance of artificial intelligence within contemporary education and the increasing need to develop agricultural literacy among young learners, there is an urgent need to generate empirical evidence regarding the effectiveness of AI supported agricultural learning within Nigerian primary schools. Understanding how artificial intelligence influences pupils' agricultural literacy will assist educational institutions, governments, curriculum planners, teachers, and technology developers in designing innovative instructional approaches capable of preparing future generations for sustainable agriculture and food security. Therefore, this study investigates artificial intelligence supported agricultural learning and the development of agricultural literacy among primary school pupils.

2. OBJECTIVES OF THE STUDY

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

1. Examine primary school teachers' perceptions of existing artificial intelligence supported agricultural learning practices implemented to promote agricultural literacy among pupils.
2. Identify, from the perspectives of primary school teachers, the barriers affecting the integration of artificial intelligence technologies into agricultural learning.
3. Assess primary school teachers' perceptions of the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy among primary school pupils.
4. Determine, from the perspectives of primary school teachers, strategies for strengthening artificial intelligence supported agricultural learning to enhance agricultural literacy among primary school pupils.

2.1. Research Questions

The following research questions guided the study:

1. What are primary school teachers' perceptions of the existing artificial intelligence supported agricultural learning practices implemented to promote agricultural literacy among pupils?

2. What barriers do primary school teachers perceive as affecting the integration of artificial intelligence technologies into agricultural learning?
3. What are primary school teachers' perceptions of the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy among primary school pupils?
4. What strategies do primary school teachers perceive as effective for strengthening artificial intelligence supported agricultural learning to enhance agricultural literacy among primary school pupils?

2.2. 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 primary school teachers' perceptions of agricultural literacy development among primary school pupils.

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

H03: Artificial intelligence supported instructional approaches have no significant influence on primary school teachers' perceptions of agricultural literacy development among primary school pupils.

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

3. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

3.1. 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 [15]. 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 [4]. 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 [5]. 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 [7]. 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 [6]. 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 [8]. 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 [9].

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 [1]. These personalised learning experiences enhance conceptual understanding and encourage active participation in agricultural science, thereby strengthening agricultural literacy among young learners [11].

Recent empirical evidence supports the growing contribution of artificial intelligence to educational improvement. Chen et al. reported that AI supported adaptive learning significantly improved learners' academic achievement and conceptual understanding across science related disciplines [16]. Similarly, Crompton and Burke concluded that intelligent educational technologies enhance learner motivation, collaboration, and higher order thinking through personalised instructional support [17]. In agricultural science specifically, emerging evidence indicates that digital technologies strengthen learners' practical understanding of agricultural systems and improve environmental awareness when integrated into classroom instruction [1]. These findings suggest that artificial intelligence supported agricultural learning may substantially contribute to the development of agricultural literacy among primary school pupils.

Within Nigeria, however, the adoption of artificial intelligence in primary education remains relatively limited. Although digital learning initiatives have expanded in recent years, many schools continue to depend largely on conventional instructional approaches because of inadequate technological infrastructure, limited teacher preparedness, and insufficient digital learning resources [12]. Consequently, opportunities for utilising artificial intelligence to improve agricultural literacy remain largely underexplored. This study therefore proposes the following hypothesis:

H01: Artificial intelligence supported agricultural learning practices have no significant influence on primary school teachers' perceptions of agricultural literacy development among primary school pupils.

3.2. 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 [4]. 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 [6].

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 [10]. These infrastructural deficiencies significantly reduce opportunities for pupils to interact with intelligent educational technologies, particularly within rural communities where digital resources remain scarce [18]. 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 [19]. Inadequate teacher competence often results in underutilisation of available technologies, thereby reducing their educational effectiveness [20].

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 [18]. These financial limitations are particularly pronounced within developing countries where educational funding remains inadequate relative to increasing technological demands [21]. Consequently, schools frequently prioritise basic instructional needs over advanced technological innovations such as artificial intelligence.

Empirical studies consistently demonstrate that reducing technological, institutional, and human resource barriers significantly enhances successful educational technology implementation. Bond et al. observed that schools possessing stronger technological infrastructure and continuous teacher professional development achieved more effective educational technology integration than schools with limited institutional support [22]. Likewise, Chen et al. found that administrative commitment, teacher competence, and infrastructure availability significantly predicted successful artificial intelligence implementation within classroom instruction [16]. These findings indicate that addressing implementation barriers remains essential for improving agricultural literacy through artificial intelligence supported agricultural learning.

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

3.3. 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 [5]. Consequently, artificial intelligence has become an important instructional innovation for improving the quality of teaching and learning in both developed and developing educational systems [6].

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 [1]. These technologies therefore strengthen pupils' understanding of agricultural systems while making learning more engaging and meaningful [7].

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 [11]. 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 [4].

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 [1]. Consequently, pupils become active participants in knowledge construction rather than passive recipients of information.

The effectiveness of artificial intelligence supported instructional approaches has been confirmed by numerous empirical investigations across science and technology education. Chen et al. found that adaptive intelligent learning environments significantly improved conceptual understanding, learner engagement, and academic performance among primary school learners [16]. Likewise, Crompton and Burke reported that AI supported instructional systems increased learner motivation, collaboration, and higher order thinking while reducing learning anxiety through personalised instructional support [17]. A recent systematic review by Zawacki-Richter et al. further concluded that artificial intelligence positively influences learning achievement when integrated within learner centred pedagogical frameworks supported by adequately trained teachers [11]. These findings collectively suggest that artificial intelligence supported instructional approaches possess considerable potential for strengthening agricultural literacy among primary school pupils.

Within Nigeria, however, the implementation of artificial intelligence supported instructional approaches in primary education remains at an early stage. Although national educational reforms increasingly encourage digital transformation, many schools continue to experience inadequate technological infrastructure, limited teacher competence, unreliable electricity supply, and insufficient instructional resources necessary for effective artificial intelligence implementation [12]. Consequently, agricultural instruction continues to rely predominantly on conventional teaching methods that provide limited opportunities for personalised learning and practical exploration of agricultural concepts [13]. Empirical evidence examining how artificial intelligence supported instructional approaches influence agricultural literacy among Nigerian primary school pupils therefore remains limited. Based on this literature, the following hypothesis was formulated.

H03: Artificial intelligence supported instructional approaches have no significant influence on primary school teachers' perceptions of agricultural literacy development among primary school pupils.

3.4. 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 [21]. Consequently, strengthening artificial intelligence supported agricultural learning requires comprehensive strategies that address both technological and human dimensions of educational transformation [6].

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 [1]. Curriculum reforms further ensure that artificial intelligence becomes an integral component of instructional practice rather than an isolated technological initiative [4].

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 [5]. Evidence indicates that educational technology initiatives are considerably more successful when teachers receive continuous institutional support and professional learning opportunities [20].

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 [18]. 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 [10].

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 [1]. Collaborative innovation ecosystems further encourage development of culturally appropriate artificial intelligence applications that address local agricultural challenges while supporting national educational priorities [18].

Recent empirical investigations demonstrate that comprehensive implementation strategies significantly improve educational technology adoption and learner outcomes. Bond et al. reported that institutional leadership, teacher capacity building, technological infrastructure, and stakeholder collaboration collectively predicted successful digital transformation across schools [22]. Similarly, OECD emphasised that effective artificial intelligence implementation depends upon coordinated educational policies, continuous teacher development, curriculum innovation, and sustainable technological investment [6]. These findings suggest that strengthening artificial intelligence supported agricultural learning requires integrated interventions involving multiple educational stakeholders rather than isolated technological initiatives. Accordingly, the following hypothesis was formulated.

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

3.5. Theoretical Framework

This study is anchored on the Constructivist Learning Theory proposed by Jean Piaget and further advanced through the social constructivist perspectives of Lev Vygotsky [23,24]. 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 [23]. The theory emphasises learner centred instruction, active participation, collaboration, and authentic learning experiences that promote cognitive development.

The theory is particularly relevant to artificial intelligence supported agricultural learning because artificial intelligence technologies create interactive learning environments that enable pupils to construct agricultural knowledge through exploration, experimentation, and immediate feedback. Intelligent tutoring systems, virtual agricultural simulations, adaptive learning platforms, educational chatbots, and immersive digital environments encourage pupils to participate actively in learning activities rather than relying solely on teacher explanations [19]. These technologies provide personalised instructional experiences that accommodate learners' prior knowledge, cognitive development, and learning pace, thereby supporting the constructivist principle that knowledge is actively constructed through meaningful interaction with learning experiences [7].

Constructivist Learning Theory further 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 [1]. These experiences promote conceptual understanding, critical thinking, creativity, and agricultural literacy because learners actively apply knowledge rather than memorising isolated facts.

The theory also recognises the importance of instructional support in facilitating learning. Vygotsky's concept of the Zone of Proximal Development suggests that learners achieve higher levels of understanding when provided with appropriate guidance and scaffolding during the learning process [24]. Artificial intelligence technologies perform similar instructional functions by providing adaptive feedback, personalised guidance, intelligent assessment, and differentiated learning pathways according to individual pupils' progress [4]. Consequently, Constructivist Learning Theory provides an appropriate theoretical foundation for explaining how artificial intelligence supported agricultural learning may improve agricultural literacy among primary school pupils.

3.6. 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.

4. METHODOLOGY

4.1. 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 [25]. 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 [26]. 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 [27].

4.2. 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 [12]. 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 [21]. These variations provided an appropriate context for examining artificial intelligence supported agricultural learning and agricultural literacy among primary school pupils.

4.3. 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 [12]. Their professional responsibilities further place them in a strategic position to evaluate pupils' agricultural literacy development and the instructional effectiveness of emerging educational technologies [4].

4.4. 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. In the second stage, five public primary schools were randomly selected from each participating state. Finally, teachers responsible for Agricultural Science or Basic Science and Technology 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 [25].

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 [26]. The relatively high response rate also reduced the likelihood of non-response bias and enhanced the credibility of the study findings.

4.5. 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 measuring teachers' perceptions of the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy development among primary school pupils. Cluster IV contained items identifying strategies capable of strengthening artificial intelligence supported agricultural learning in primary schools. The instrument therefore measured teachers' perceptions regarding agricultural literacy development among pupils rather than pupils' agricultural literacy through direct assessment. 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), while Cluster III was structured on a four-point scale of High Extent (4), Moderate Extent (3), Low Extent (2) and Very Low Extent (1).

4.6. 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 science, University of Nigeria, Nsukka, while two experts specialised in Educational Technology and Measurement and Evaluation. The validators examined the instrument with respect to clarity of language, appropriateness of the items, adequacy of content coverage, logical organisation, and alignment with the objectives of the study. Their observations, corrections, and recommendations were incorporated before producing the final version of the questionnaire for administration [26].

4.7. 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 [28].

4.8. 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.

4.9. 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 [29].

4.10. 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 teachers' perceptions of agricultural literacy development among primary school pupils. Multiple regression analysis was further used to determine the extent to which artificial intelligence supported agricultural learning practices, barriers to AI integration, instructional effectiveness, and AI implementation strategies predicted teachers' perceptions of agricultural literacy development among primary school pupils. The hypotheses were tested at the 0.05 level of significance.

The regression model for the study was specified as:

$$AL = \beta_0 + \beta_1(\text{AISAL}) + \beta_2(\text{BAI}) + \beta_3(\text{AIE}) + \beta_4(\text{AIS}) + \varepsilon$$

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
- $\boldsymbol{\beta_0}$ = Constant
- $\boldsymbol{\beta_1}$**–**$\boldsymbol{\beta_4}$ = Regression Coefficients
- $\boldsymbol{\varepsilon}$ = 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.

5. 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 are primary school teachers' perceptions of the existing artificial intelligence supported agricultural learning practices implemented 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 primary schools. Respondents agreed that AI powered educational applications, intelligent instructional videos, and AI based assessment activities were implemented to some extent. However, more advanced AI technologies such as virtual agricultural simulations, adaptive learning platforms, educational chatbots, personalised learning systems, and learning analytics were generally not implemented. The overall grand mean of 2.58 suggests that AI supported agricultural learning remains at a moderate stage of implementation.

Research Question 2: What barriers do primary school teachers perceive as affecting the integration of artificial intelligence technologies into agricultural learning**?**

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: What are primary school teachers' perceptions of the effectiveness of artificial intelligence supported instructional approaches in promoting agricultural literacy among primary school pupils?

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 respondents perceived artificial intelligence supported instructional approaches to promote agricultural literacy development among primary school pupils to a moderate extent. Teachers particularly perceived that AI supported instruction enhances pupils' conceptual understanding of agricultural concepts, classroom participation, environmental awareness, and interest in agriculture. However, personalised learning and practical problem solving were perceived to be less effective because of the limited availability of advanced AI technologies in many schools.

Research Question 4: What strategies do primary school teachers perceive as effective for strengthening artificial intelligence supported agricultural learning to enhance 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

S/N	Items	Mean	SD	Remark
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.

5.1. 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 relationships between AI supported agricultural learning practices, instructional effectiveness, implementation strategies, and teachers' perceptions of agricultural literacy development among primary school pupils. Conversely, barriers to AI integration demonstrated a significant negative relationship with teachers' perceptions of agricultural literacy development, suggesting that respondents perceived implementation challenges as being associated with lower agricultural literacy development among pupils.

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

Predictor	B	Beta (β)	t	P
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 teachers' perceptions of agricultural literacy development among primary school pupils. The model explained 69.9% of the variance in teachers' perceived agricultural literacy development ($R^2 = .699$). 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 these variables significantly predicted teachers' perceptions of agricultural literacy development among primary school pupils.

5.2. Hypotheses Decision

H01: Artificial intelligence supported agricultural learning practices significantly predicted teachers' perceptions of agricultural literacy development among primary school pupils ($\beta = 0.296$, $p < .05$). Therefore, H01 was rejected.

H02: Barriers to artificial intelligence integration significantly influenced teachers' perceptions of agricultural literacy development among primary school pupils ($\beta = -0.219$, $p < .05$). Therefore, H02 was rejected.

H03: Artificial intelligence supported instructional approaches significantly predicted teachers' perceptions of agricultural literacy development among primary school pupils ($\beta = 0.227$, $p < .05$). Therefore, H03 was rejected.

H04: Artificial intelligence integration strategies significantly predicted teachers' perceptions of agricultural literacy development among primary school pupils ($\beta = 0.408$, $p < .05$). Therefore, H04 was rejected.

The regression model accounted for 69.9% of the variation in teacher's perception on 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.

6. 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. These findings suggest that although schools have begun embracing digital innovations, the implementation of sophisticated artificial intelligence technologies for agricultural instruction remains limited. The finding agrees with UNESCO, 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 [4]. It also supports the findings of Holmes and Tuomi, who observed that many educational institutions continue to utilise basic digital technologies while more advanced artificial intelligence applications remain at the developmental stage due to implementation challenges [5]. Similarly, the OECD 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 [6].

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. This finding indicates that successful integration of artificial intelligence depends not only on technological availability but also on institutional capacity, teacher preparedness, and sustainable financial investment. The finding corroborates the World Bank, which identified inadequate digital infrastructure and unequal technological access as major impediments to educational transformation in developing countries [18]. Likewise, UNESCO emphasised that artificial intelligence implementation requires coordinated investments in infrastructure, teacher capacity development, and policy support before meaningful educational benefits can be realised [21]. The finding is also consistent with Bond et al., who concluded that insufficient institutional support and inadequate professional development significantly reduce teachers' willingness and ability to integrate artificial intelligence technologies into classroom instruction [22].

The findings further indicated that respondents perceived artificial intelligence supported instructional approaches to be associated with agricultural literacy development 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. This finding suggests that teachers perceive artificial intelligence as having considerable educational potential when appropriate technological resources are available. However, because the study employed a descriptive survey design, these findings should be interpreted as perceptions rather than evidence of direct effects. The result supports Chen et al., who reported that adaptive artificial intelligence systems significantly improve learners' conceptual understanding, motivation, and academic achievement across science related disciplines [16]. Similarly, Crompton and Burke found that intelligent educational technologies promote learner engagement, collaborative learning, and higher order cognitive skills through personalised instructional support [17]. The finding also agrees with FAO, which emphasised that digital technologies strengthen agricultural science by enabling learners to visualise agricultural processes and participate actively in experiential learning activities [1].

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 the importance of comprehensive institutional approaches that integrate policy development, technological investment, curriculum reform, and capacity building. The result agrees with UNESCO, which identified teacher competence, institutional leadership, infrastructure development, and curriculum innovation as essential requirements for sustainable artificial intelligence implementation within educational systems [21]. Similarly, the OECD emphasised that coordinated educational policies and continuous investment in digital infrastructure significantly improve successful technology integration and learner outcomes [6]. The finding is equally consistent with Holmes and Tuomi, who concluded that the effectiveness of artificial intelligence in education depends largely on teacher preparedness, institutional support, and learner centred instructional design [5].

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 teachers perceived greater availability and quality of artificial intelligence supported instruction to be positively associated with agricultural literacy development, whereas implementation barriers were perceived to be negatively associated with agricultural literacy development. Because these relationships were derived from correlational analyses, they should not be interpreted as evidence of causality. 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 [23,24]. The findings further support Holmes et al., who argued that artificial intelligence creates adaptive learning environments capable of enhancing learner engagement and conceptual understanding through personalised educational experiences [19]. Likewise, UNESCO reported that well designed artificial intelligence learning environments promote learner autonomy, collaboration, and critical thinking [4].

The regression analysis demonstrated that artificial intelligence supported agricultural learning practices, barriers to artificial intelligence integration, instructional effectiveness, and implementation strategies significantly predicted teachers' perceptions of agricultural literacy development among primary school pupils. Together, these variables accounted for 69.9% of the variance in teachers' perceived agricultural literacy development. Artificial intelligence implementation strategies emerged as the strongest statistical predictor, followed by instructional practices, instructional effectiveness, and implementation barriers. Although these findings indicate significant statistical associations, the descriptive survey design and cross-sectional data do not permit causal inferences. Consequently, the observed relationships should be interpreted as predictive associations based on teachers' perceptions rather than evidence that these factors directly improve agricultural literacy among pupils. The finding supports OECD, which emphasised that successful educational transformation requires integrated institutional ecosystems rather than technology acquisition alone [6]. The finding also agrees with UNESCO, 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 [21]. Furthermore, Holmes et al. maintained that the educational benefits of artificial intelligence are maximised when technological innovation is accompanied by appropriate pedagogical and institutional reforms [19].

Hence, the findings suggest that teachers perceive artificial intelligence as having substantial potential to support agricultural science instruction and agricultural literacy development among primary school pupils in Nigeria. However, these findings reflect teachers' perceptions and statistically significant associations rather than direct evidence of improvements in pupils' agricultural literacy. Experimental and longitudinal studies are needed to establish causal relationships.

6.1. 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.

6.2. 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.

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.

6.3. Limitations of the Study and Suggestions for Further Studies

This study relied exclusively on data obtained from primary school teachers responsible for agricultural instruction. Consequently, the findings represent teachers' perceptions of how artificial intelligence supported agricultural learning relates to agricultural literacy development among primary school pupils rather than direct assessments of pupils' agricultural knowledge, practical skills, attitudes, or competencies. Therefore, the findings should not be interpreted as direct evidence of pupils' agricultural literacy outcomes but rather as teachers' professional perceptions of these outcomes.

In addition, all study variables were measured using a single self-report questionnaire completed by the same respondents. The use of a single data source and a single measurement instrument may have introduced common method variance, which could have inflated the observed relationships among the study variables. Although the findings provide useful insights into teachers' perceptions of artificial intelligence supported agricultural learning, they should be interpreted with this methodological limitation in mind.

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. Future research should also incorporate direct assessments of pupils' agricultural knowledge, practical skills, attitudes, and competencies alongside teacher report measures to provide a more comprehensive evaluation of agricultural literacy development. In addition, experimental and longitudinal research designs are recommended to establish causal relationships between artificial intelligence supported agricultural learning and pupils' educational outcomes.

7. CONCLUSION

This study examined **primary school teachers' perceptions** of the relationship between artificial intelligence supported agricultural learning and agricultural literacy development among primary school pupils in Nigeria. The findings indicate that, from the perspectives of the participating teachers, artificial intelligence supported agricultural learning practices are moderately implemented in primary schools, while substantial barriers, including inadequate technological infrastructure, poor internet connectivity, limited teacher competence, high implementation costs, unreliable electricity supply, and inadequate government funding, continue to constrain effective implementation.

The study further found that teachers perceived artificial intelligence supported instructional approaches to have considerable potential for supporting pupils' understanding of agricultural concepts, classroom participation, environmental awareness, and interest in agriculture. In addition, the regression analysis showed that artificial intelligence supported agricultural learning practices, instructional effectiveness, implementation strategies, and barriers to implementation were significant predictors of **teachers' perceptions of agricultural literacy development** among primary school pupils, with implementation strategies emerging as the strongest statistical predictor. These findings should, however, be interpreted as reflecting statistically significant associations based on teachers' perceptions rather than direct evidence of improvements in pupils' agricultural literacy or causal relationships among the study variables.

Hence, the study suggests that teachers perceive artificial intelligence supported agricultural learning as a promising approach for strengthening agricultural science instruction in Nigerian primary schools. However, realising this potential depends on sustained investment in digital infrastructure, teacher professional development, curriculum development, supportive educational policies, and equitable access to educational technologies. Future studies employing direct assessments of pupils' agricultural literacy together with experimental or longitudinal research designs are required to establish whether these perceived relationships translate into measurable improvements in pupils' agricultural knowledge, skills, attitudes, and competencies.

8. 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 artificial intelligence supported educational technologies, to facilitate the effective implementation of AI supported agricultural learning in primary schools.
2. Teacher education institutions and educational authorities should organise continuous professional development programmes to strengthen teachers' competence in the pedagogical integration and effective utilisation of artificial intelligence technologies in agricultural science instruction.
3. Curriculum developers should integrate artificial intelligence supported instructional activities, digital agriculture, and emerging agricultural technologies into the primary school agricultural science curriculum to support learner centred and experiential learning approaches.
4. Government and relevant educational stakeholders should establish sustainable funding mechanisms and strengthen public private partnerships to support the procurement, maintenance, and continuous upgrading of artificial intelligence technologies and digital learning resources in primary schools.

5. Educational policymakers should develop comprehensive national guidelines and implementation frameworks for the ethical, equitable, and effective integration of artificial intelligence into primary education while ensuring the protection of learners' privacy and data security.
6. Educational technology developers should collaborate with agricultural educators, curriculum specialists, and primary school teachers to design culturally relevant and curriculum aligned artificial intelligence applications that address local agricultural practices and learning needs.
7. School administrators should provide teachers with continuous institutional support, technical assistance, and opportunities to adopt and experiment with artificial intelligence supported instructional strategies within agricultural science classrooms.

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Toochukwu C. Nwakile: Developed the methodology, performed the statistical analyses, interpreted the findings, prepared the original manuscript draft, coordinated manuscript revision, and served as the corresponding author.
Eunice O. Innocent-Ene: Contributed to data collection, assisted with data validation and interpretation, and critically revised the manuscript for important intellectual content.
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All 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.

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