Published by

British Journal of Contemporary Research

BEXFORD PUBLISHING

Integrating Digital Tools into Agricultural Science Instruction in Secondary Schools: Opportunities and Challenges for Curriculum Developers in Delta State

Original Research Article | Volume 1 | Issue 6 | 2026 | Article Number: 092

Accepted: 01 November 2026 | Published: 10 November 2026 | ISSN: 2979-8582 (Online)

Crossref : **https://doi.org/10.67693/BJCR-KYDF3D7M**

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Abstract

This study explored the opportunities and challenges for curriculum developers and educators in integrating digital resources into agricultural science instruction in public secondary schools in Delta State, Nigeria. The present study adopted a convergent parallel mixed-methods design (QUAN + QUAL). The quantitative strand sampled 280 agricultural science instructors using a stratified proportionate sample across nine Local Government Areas in the Delta North, Delta Central and Delta South senatorial districts, with 268 verified questionnaire returns (95.71% response rate). The qualitative arm included 12 purposively selected key informants: curriculum planners from the Ministry of Basic and Secondary Education, inspectors of the Post Primary Education Board (PPEB), and heads of departments. Data were collected using the validated Electronic Tools Integration in Agricultural Science Questionnaire (DTI-ASQ; \alpha = 0.88) and semi-structured interview techniques. Descriptive analysis showed that classroom technology use was primarily limited to consumer messaging platforms ($\bar{x}$ = 2.89) and online video clips ($\bar{x}$ = 2.58). Conversely, agronomic technologies such as digital soil sensor kits, virtual farm simulation software and GIS mapping tools are largely underutilised ($\bar{x}$ = 1.48 to 1.76). Educators unanimously confirmed the instructional value of digital resources in rebranding agriculture from harsh physical labour into a modern agribusiness discipline $\bar{x}$ = 3.56) and visualising complicated biological cycles $\bar{x}$ = 3.48). One-Way ANOVA tests of inference showed substantial differences in barriers to integration between senatorial districts ($F(2, 265) = 35.835$, $p < .001$) and across school ecologies ($F(2, 265) = 87.523$, $p < .001$) by area and location. Post-hoc Tukey HSD tests indicated that Delta South riverine and rural schools are severely disadvantaged in infrastructure and experience chronic power outages, expensive data tariffs and acute hardware shortfalls. Thematic qualitative analysis showed curricular stasis due to terminal assessment regimes (WAEC/NECO) which privilege static pen-and-paper testing over applied digital proficiencies. The study finds that policy for educational technology has to shift from a general deployment of hardware to an instructional redesign that is responsive to context. Major proposals include furnishing riverine and rural schools with transportable solar-powered kits including offline-first Open Educational Resources (OER) and offering agricultural TPACK-specific teacher professional development.

Keywords: Agricultural Education, Curriculum Development, Digital Learning Tools, Educational Technology, Secondary Schools, TPACK, Delta State, Nigeria

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Introduction

Agriculture in Nigeria is predominantly small-scale and rain-fed, with staple commodities such as millet, sorghum, maize and rice grown in Northern Nigeria (Bello et al., 2020). However, agricultural output in the region has been on the decline because of poor infrastructure, restricted access to quality farm inputs, weak extension services and climate issues such as irregular rainfall, despite its importance (Garba & Shehu, 2022). These limitations have limited Nigeria's ability to maintain food security and reduce rural poverty notably in the northern states where farming is the mainstay of living. Agricultural productivity increase in Northern Nigeria averaged only 2.5% per annum between 2015 and 2022, below the 5% needed to meet national food demand (National Bureau of Statistics, 2023). Consequently, the region is increasingly looking toward modernising farming practices to boost production and sustainability.

The Information and Communication Technology (ICT) has been demonstrated to be a vital instrument for tackling agricultural issues in Nigeria notably in the northern states. Farmers' access to weather forecast, market prices, pest management and modern farming techniques in good time is made possible through the use of ICT technologies such as mobile phones, geographic information systems (GIS), remote sensing and digital advisory systems (Sani & Ibrahim, 2023). According to studies, the use of ICT in agriculture enhances decision making and resource management resulting to increased agricultural production and income (Abdullahi et al., 2020). However, the use of ICTs is not uniform due to low internet penetration and usage, low online literacy, and infrastructural deficit in rural economies (Umar & Hassan, 2021). There was intensive ICT integration through focused attempts to distribute inputs and track subsidies through national programs such as the e-Wallet program and Growth Enhancement Support Scheme (GESS) (Nwafor & Danjuma, 2024). Therefore, it is vital to expand ICT infrastructure and teach farmers in Northern Nigeria for Smart Agriculture and maximum yields. With ICT, precision farming, real-time monitoring and improved access to agricultural extension services can be made possible thereby solving the old constraints and increasing food production. Traditionally, agricultural science training in Nigerian secondary institutions has been based on chalk-and-talk teaching methods and manual labour on conventional school farm plots. This approach to pedagogy often results in the perception of agricultural education as a boring manual labour, which in turn reinforces the outdated belief held by many secondary students that agriculture is a low-income, traditional subsistence activity, not a high-yield, technology-oriented enterprise. The global agricultural landscape has experienced a structural upheaval, spurred by the Fourth Industrial Revolution (4IR). Modern agriculture is increasingly depending on precision agriculture, Internet of Things (IoT) sensors, geographic information systems (GIS), agronomic mobile applications and data-driven farm enterprise management.

Educational modernisation frameworks emphasise systematic integration of Information and Communication Technologies (ICT) and specialised digital instructional tools to bridge the gap between classroom delivery and demands of the modern workplace. The Federal Government of Nigeria recognised this need through the National Policy on Education (NPE) and the ICT in Education policy frameworks issued by the Nigerian Educational Research and Development Council (NERDC), both of which require the introduction of educational technology in the basic and senior secondary school curricula.

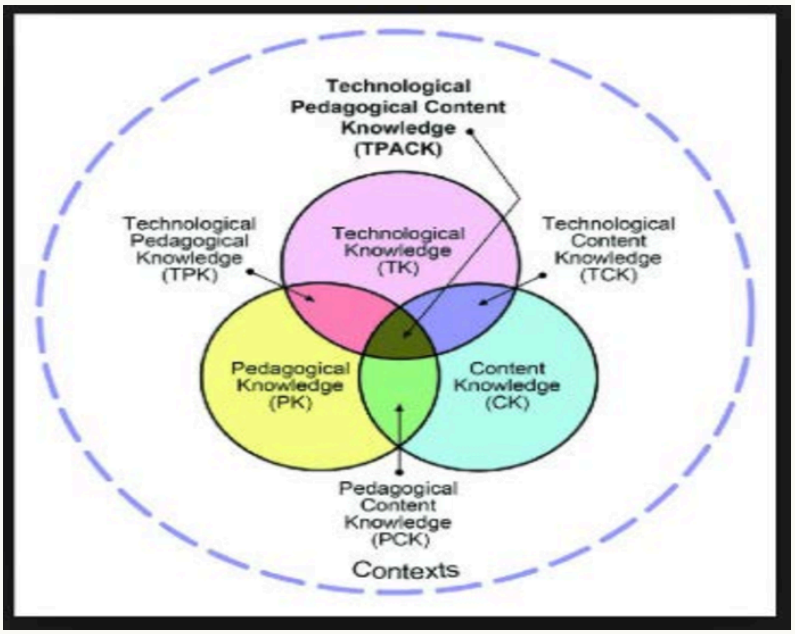
Digital instructional tools such as interactive computer-assisted instruction (CAI), offline simulation software, digital soil test kits, simulated field visits, and mobile crop diagnostic applications provide promising pathways to demystify abstract biological processes, model complex farm ecosystems, and simulate multi-season agronomic cycles within tight school term timeframes. The delta state has a unique socio-ecological and structural context to test these pedagogical innovations. The state is characterised by different agrarian belts, from upland farming villages in Delta North to freshwater riverine environments in Delta Central and mangrove/coastal zones in Delta South, and has a strong dependence on agro-allied

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trade, aquaculture and cassava/oil palm cultivation. Although the Delta State Ministry of Basic and Secondary Education and the Post Primary Education Board (PPEB) have made progressive infrastructural promises, teaching practices in secondary agriculture classrooms are still mostly analogue. There is an inherent conflict between the technology promise and the classroom realisation. Digital integration offers unprecedented chances for revolution in vocational learning, while curriculum architects face chronic systemic friction.

Relevance of Technological Pedagogical Content Knowledge (TPACK) framework

This study is conceptually grounded in the Technological Pedagogical Content Knowledge (TPACK) framework formulated by Mishra and Koehler (2006). The TPACK model posits that effective technology integration is not merely an additive process of introducing digital hardware into classrooms; rather, it requires an emergent, specialized understanding of how technology (TK), pedagogical approaches (PK), and agricultural subject matter (CK) interact dynamically.



According to Barišić, Divjak and Kirinić (2019), teacher education and professional development must include digital capabilities. Today, information and communication technology (I.C.T.) are playing an important role in Nigerian schools. Furthermore, the widespread use of I.C.T. still poses challenges in its integration into teaching and learning. Hence, the importance of integrating I.C.T. in classrooms is a critical key concern in educational institutions all over the world (Nordin et al., 2013) and not just in Nigeria.

Teachers are important in every education system as they deliver subject matter through pedagogical knowledge (Shulman, 1986). Therefore, teachers are employing ICT efficiently in this digital age. Hence the idea of technological pedagogical content knowledge (TPACK) was developed. The Technological Pedagogical Content Knowledge (TPACK) framework is a representation of teacher knowledge on technology integration in teaching and has seven areas (Barišić et al., 2019), as presented in Figure 1. TPACK presents a methodology for the effective integration of I.C.T. in teaching (Nordin et al. 2013). TPACK comprises three essential knowledge domains: technology, pedagogy, and content (Mishra & Koehler, 2006).

The TPACK duties of teachers are huge and vital for students' learning. The most significant of these functions is to enhance real learning in classrooms. Authentic learning is learning via doing. It's an active learning where the students are actively participating in the teaching and learning. The TPACK model was

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developed in 2006 based on a study of instructors of different grade levels and their classroom methods. The authors' TPACK framework was based on Shulman's work (1986). Shulman examined topic knowledge, what teachers know about the subject, and pedagogical knowledge, certain ways of teaching the subject. According to Shulman a good teacher would combine these two categories of expertise, knowledge on how to teach their subject matter well. This is called pedagogical content knowledge (P.C.K.). Many years after Shulman, the emphasis turned to the use of technology in the classroom.

The problem for curriculum developers in Delta State is not the acquisition of hardware but the development of curricula that promote TPACK: enabling agricultural science teachers to blend pedagogical approaches with digital resources to teach tough concepts such as Mendelian inheritance in animals, soil nutrient cycles and pest pathology. While literature on educational technology in Nigeria is increasing, empirical investigations that particularly isolate agricultural science instruction at the secondary school level are still scattered. Most of the literature reviewed either assessed general ICT literacy or restricted itself to computer studies. The practical, laboratory and field needs of secondary agricultural education have received scant attention. Curriculum designers thus lack context-specific empirical evidence on how to comprehensively embed digital resources into the state's unified schemes of labour without deepening inequities between urban centers (e.g. Asaba and Warri) and distant agricultural or riverine communities.

To address this empirical gap, this paper examines the opportunities and challenges confronting curriculum developers in integrating digital tools into agricultural science instruction across secondary schools in Delta State. Specifically, the study seeks to:

1. Identify viable digital instructional tools adaptable to secondary agricultural science education within the state;
2. Analyze the curriculum and instructional opportunities afforded by digital tool adoption;
3. Critically evaluate the structural, institutional, and pedagogical constraints faced by curriculum developers and classroom practitioners; and
4. Propose actionable, context-sensitive frameworks for curriculum adaptation and continuous teacher professional development.

Methodology

Research Design

The study was designed as a convergent parallel mixed-methods design (QUAN + QUAL) that integrated the cross-sectional descriptive survey approach with phenomenological qualitative inquiry. Within the framework of educational technology research, a mixed-methods paradigm moderates the inherent bias of single-method studies: quantitative measurements reveal the widespread incidence of infrastructural readiness and perceived curriculum integration obstacles. Qualitative comments, in contrast, demonstrate the institutional difficulties that educational policy designers must confront. The two strands are applied simultaneously, analysed separately and combined during interpretation to assess the interaction of systemic policies and instructional practices at the classroom level in Delta State.

Population and Sampling Framework

Population

The target population consists of:

1. All public senior secondary school agricultural science teachers (N = 720) managed by the Delta State Post Primary Education Board (PPEB);

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2. All instructional officers, inspectors and curriculum developers (N = 45) serving within the Delta State Ministry of Basic and Secondary Education and the PPEB Headquarters in Asaba.

Sample and Sampling

The study purposively selected a total of Aniocha and Ika local government areas from Delta North which are predominantly upland agrarian communities; Ughelli, Uvwie and Ethiope local government areas in Delta Central due to localised farming; and Warri South, Burutu and Bomadi from Delta South based on coastal agrarian ecosystems which are characterised by artisanal fishing and smallholder crop farming. Asaba is the seat of the Delta State Ministry of Basic and Secondary Education. Secondly, 280 agricultural science instructors were randomly selected from 720 secondary school teachers in the targeted locations.

For the qualitative section, 12 Key Informants, six curriculum planners/inspectors from the Ministry/PPEB and six main heads of agricultural science departments across chosen urban and riverine universities were recruited using purposive sampling technique.

Instrumentation

- **Section A:** Demographic and Institutional Profile (gender, years of teaching, school location [urban vs. rural/riverine], availability of standard ICT laboratories).
- **Section B (Viability & Usage Index):** Evaluates access to and classroom deployment of 10 categories of digital tools (agronomic mobile apps, simulated virtual laboratories, GIS/mapping tools, offline CAI courseware, computer-interfaced sensors). Scored on a 4-point Likert scale: Frequently Utilized (4), Occasionally Utilized (3), Rarely Utilized (2), Never Utilized (1).
- **Section C (Perceived Curriculum Opportunities):** Measures pedagogical affordances (abstract concept visualization, off-season crop cycle modeling, youth agribusiness orientation) using a 4-point Likert scale: Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1).
- **Section D (Structural & Institutional Constraints):** Evaluates infrastructural, financial, institutional, and human capital barriers using the same 4-point agreement scale.

Qualitative Instrument

The Curriculum Digitalisation Key Informant Interview Guide (CD-KIIG) contains open-ended semi-structured questions to facilitate in-depth qualitative context on gaps in policy implementation, budgetary allocations, teacher professional development models and approaches to adapting curriculum delivery to low-connectivity, riverine environments.

Validity and Reliability of the Instruments

Instrument Validation

Face and Content Validity: The DTI-ASQ and CD-KIIG were submitted to a validation panel consisting of three independent experts: two professors of Agricultural Education and Measurement & Evaluation from Delta State University (DELSU), Abraka, and one senior curriculum specialist from the Nigerian Educational Research and Development Council (NERDC). Items with a Content Validity Ratio (CVR) < 0.75 were revised or eliminated.

Construct Validity: Exploratory Factor Analysis (EFA) using Principal Axis Factoring with Varimax rotation will be conducted on pilot data to confirm that Section C (Opportunities) and Section D (Challenges) extract their hypothesized theoretical dimensions (e.g., infrastructural deficits, human capital, pedagogical enhancement) with factor loadings of 0.50 or higher.

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Reliability Testing

Quantitative Reliability

A pilot test was conducted with 30 agricultural science teachers in public secondary schools in Edo State (a neighboring state sharing similar socio-cultural, ecological, and educational administrative structures, excluded from the primary sample). The internal consistency was computed using Cronbach's alpha coefficient (α).

The pilot yield yielded the following coefficients:

- Section B (Usage Index): $\alpha = 0.84$
- Section C (Opportunities): $\alpha = 0.89$
- Section D (Challenges): $\alpha = 0.87$

The composite scale reliability reached $\alpha = 0.88$, establishing high internal consistency.

Qualitative Trustworthiness: Qualitative rigor adheres to Lincoln and Guba's criteria for naturalistic inquiry: credibility (member-checking of transcribed interview protocols), transferability (dense description of the socio-ecological contexts across Delta's three senatorial zones), dependability (comprehensive audit trails of interview recordings and coding rules), and confirmability (reflexive bracketing of researcher assumptions during analysis).

Data Collection

Procedure

The primary researchers administered the DTI-ASQ in the field over an eight-week window, supported by three trained research assistants (one stationed per senatorial district). Research assistants coordinated directly with local PPEB Zonal Directors and school principals to administer questionnaires in person during scheduled departmental meetings, ensuring response rates > 90%. Key Informant Interviews were held either in person at the Ministry/PPEB headquarters in Asaba or via secured, recorded audio teleconferences for riverine-based administrators. Each interview lasted 35 to 50 minutes and was transcribed verbatim within 48 hours.

Ethical Considerations

The study protocol was submitted to the Ethics and Research Review Committee of the Delta State Ministry of Basic and Secondary Education for formal review. The study obtained written informed consent from all teacher respondents and interview participants. Participation was voluntary, anonymous, and uncompensated. The researchers coded the data, removed personal identifiers, stored them on encrypted drives, and reported results only in aggregate form.

Data Analysis

Research Questions 1 and 2 were analysed by means and standard deviations (SD). For the Likert items, a theoretical cut-off criterion mean of 2.50 was used for assessment. The inferential statistics measured the variation in access to perceived challenges and integration in the three senatorial districts (Delta North vs. Delta Central vs. Delta South) and school location types (Urban vs. Rural vs. Riverine) using One-Way Analysis of Variance (ANOVA) at 0.05 level of significance. To identify significant omnibus differences and to determine significant pairwise differences, Tukey's Honestly Significant Difference (HSD) post-hoc test was employed.

Results

Response Rate and Demographic Characteristics of Respondents

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A total of 280 copies of the ICT in Agricultural Science Questionnaire (ICT-ASQ) were distributed and recovered across the public secondary schools in Delta North, Delta Central and Delta South. Out of this number, 268 copies of the questionnaire were verified for analysis giving an effective return rate of 95.71%. The qualitative arm was made up of 12 key informants, six curriculum officers from Delta State Ministry of Basic and Secondary Education and Post Primary Education Board (PPEB) and six heads of agricultural science departments in secondary schools.

Demographic Variable	Category	Frequency (f)	Percentage (%)
Senatorial District	Delta North	91	33.96
	Delta Central	96	35.82
	Delta South	81	30.22
School Ecological Locality	Urban	98	36.57
	Rural Agrarian	108	40.30
	Riverine / Mangrove	62	23.13
Teaching Experience	1–5 Years	48	17.91
	6–15 Years	134	50.00
	16 Years and above	86	32.09
Highest Qualification	N.C.E. (Agric. Double Major)	38	14.18
	B.Sc.(Ed.) / B.Agric. + PGDE	182	67.91
	M.Sc. / M.Ed. / Ph.D.	48	17.91
Total		**268**	**100.00**

Research Question 1: Viability and Utilization of Digital Tools

To what extent are digital tools utilized in secondary agricultural science instruction across public schools in Delta State?

The benchmark mean for decision-making is 2.50. Mean scores of 2.50 indicate "High Utilization," whereas mean scores < 2.50 indicate "Low Utilization."

S/N	Category of Digital Tool	Mean ($\bar{x}$)	SD	Remark
1	Mobile Agro-extension Apps (e.g., Plantix for pest/disease ID)	2.61	0.88	High Utilization
2	YouTube / Video demonstrations (livestock, artificial insemination)	2.58	0.84	High Utilization
3	WhatsApp / Telegram study groups for sharing farm assignments	2.89	0.76	High Utilization
4	Offline Computer-Assisted Instruction (CAI) courseware	2.24	0.79	Low Utilization

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5	Interactive virtual labs / farm simulator software	1.62	0.61	Low Utilization
6	Digital soil test kits with mobile sensor interfaces	1.48	0.54	Low Utilization
7	GIS and GPS mobile mapping tools for Farm parcel survey	1.76	0.69	Low Utilization
8	Spreadsheets (Excel) for automated farm ledger accounting	2.41	0.82	Low Utilization
9	Slide projection (PowerPoint) for anatomical/physiological slides	2.11	0.86	Low Utilization
10	Smart weather monitoring mobile applications	2.03	0.77	Low Utilization
	Cluster Aggregate	**2.17**	**0.76**	**Low Overall Utilization**

The data reveal that classroom instructional technology is largely confined to basic, consumer-grade communication tools (WhatsApp/Telegram groups $\bar{x}$ = 2.89, SD = 0.76), mobile agro-extension identification apps ($\bar{x}$ = 2.61, SD = 0.88), and video demonstrations ($\bar{x}$ = 2.58, SD = 0.84).

Conversely, purpose-built agronomic educational technology remains severely underutilized: digital soil sensors ($\bar{x}$ = 1.48), interactive virtual farm simulators ($\bar{x}$ = 1.62), and GIS farm mapping tools ($\bar{x}$ = 1.76). The cluster aggregate mean of 2.17 demonstrates that systemic digital integration across the curriculum remains low and largely ad hoc.

Qualitative interview data mirrors this dichotomy. A curriculum officer at the PPEB in Asaba noted:

"Teachers are quick to use WhatsApp on their personal phones to send diagrams of an unfertilized egg or cassava mosaic leaf. However, when we speak of formal digital integration—such as micro-controller soil testing kits or simulation software for cross-pollination—our school labs do not have the equipment or software licenses." (KII-02, Delta North)

Research Question 2: Perceived Curriculum and Pedagogical Opportunities

What opportunities are unlocked by integrating digital tools into agricultural science instruction as perceived by teachers and curriculum planners?

Agreement on perceived opportunities is established at a cutoff mean of \bar{x} \ge 2.50.

S/N	Opportunity Dimension	Mean ($\bar{x}$)	SD	Remark
1	Visualizing abstract biological processes (e.g., nitrogen cycle, oogenesis)	3.48	0.59	Agreed
2	Simulating off-season agronomic cycles independent of term limits	3.31	0.67	Agreed
3	Rebranding agriculture from manual labor to modern agribusiness	3.56	0.52	Agreed
4	Enhancing student engagement and retention through interactive media	3.42	0.61	Agreed

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5	Exposure to precision agriculture and digital farm accounting competencies	3.19	0.73	Agreed
6	Mitigating school farm boundary constraints through virtual demonstrations	3.08	0.78	Agreed
	Cluster Aggregate	**3.34**	**0.65**	**Strong Agreement**

Respondents strongly affirmed that digital tool integration creates major curriculum opportunities $\bar{x} = 3.34$, SD = 0.65). The highest-ranked benefit was rebranding agriculture from repetitive manual labor to modern enterprise ($\bar{x} = 3.56$, SD = 0.52), closely followed by visualizing abstract biological and biochemical phenomena ($\bar{x} = 3.48$, SD = 0.59).

In line with this, a senior agricultural science educator in an urban school in Warri observed:

"The moment you switch from having students weed ridges for two hours to showing them an animated drone flight assessing field canopy health, their entire perception of the vocation shifts. They stop seeing agriculture as a punitive secondary chore." (KII-08, Delta South)

Hypotheses Testing: Regional and Locational Variance In Integration Challenges

Hypothesis 1 (H01)

No significant difference exists in the mean perception of digital integration challenges among secondary school agricultural science teachers across Delta North, Delta Central, and Delta South Senatorial Districts.

To test H_{01}, respondents' cumulative scores on Section D of the DTI-ASQ (measuring infrastructural deficits, electricity constraints, hardware shortages, and technical support deficits) were analyzed using a One-Way Analysis of Variance (ANOVA).

Senatorial District	**N**	**Mean ($\bar{x}$)**	**Standard Deviation (SD)**	**Standard Error**
Delta North	91	2.88	0.44	0.046
Delta Central	96	3.04	0.41	0.042
Delta South	81	3.39	0.38	0.042
Total	**268**	**3.09**	**0.46**	**0.028**

Source of Variation	**Sum of Squares (SS)**	**df**	**Mean Square (MS)**	**F-ratio**	**p-value**	**Decision**
Between Groups	12.184	2	6.092	35.835	< .001	Significant
Within Groups	45.050	265	0.170			(p < .05)
Total	57.234	267				

Because the calculated F(2, 265) = 35.835 yields a p-value < .001, we reject the null hypothesis (H_{01}) at the \alpha = 0.05 level of significance. Perceived digital integration challenges differ significantly across the three senatorial zones.

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To identify which pairs of senatorial districts drove these differences, we computed a post-hoc Tukey HSD test.

(I) District	(J) District	Mean Difference (I−J)	Std. Error	p-value	95% Confidence Interval
Delta North	Delta Central	-0.160	0.060	.022	[-0.301, -0.019]
	Delta South	-0.510	0.063	< .001	[-0.658, -0.362]
Delta Central	Delta South	-0.350	0.062	< .001	[-0.496, -0.204]

The mean difference is significant at the .05 level.

The post-hoc test confirms that all pairwise comparisons are statistically significant ($p < .05$). Delta South reported the highest severity of integration barriers ($\bar{x} = 3.39$), significantly outscoring both Delta Central ($\bar{x} = 3.04$) and Delta North ($\bar{x} = 2.88$).

Hypothesis 2 (H02)

No significant difference exists in perceived digital integration challenges among agricultural science teachers categorized by school ecological locality (Urban vs. Rural Agrarian vs. Riverine/Mangrove).

Locality Group	N	Mean (x^-)	Standard Deviation (SD)	Standard Error
Urban	98	2.76	0.41	0.041
Rural Agrarian	108	3.19	0.38	0.037
Riverine / Mangrove	62	3.44	0.35	0.044
Total	**268**	**3.09**	**0.46**	**0.028**

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-ratio	p-value	Decision
Between Groups	22.756	2	11.378	87.523	< .001	Significant
Within Groups	34.478	265	0.130			($p < .05$)
Total	57.234	267				

Because $F(2, 265) = 87.523$ with $p < .001$, the null hypothesis (H_{02}) is rejected. Locational ecology substantially affects the severity of implementation barriers.

Tukey HSD comparisons confirmed that teachers in Riverine/Mangrove institutions ($\bar{x} = 3.44$) and Rural Agrarian schools ($\bar{x} = 3.19$) experience significantly higher integration hurdles than in Urban centers ($\bar{x} = 2.76$), $p < .001$.

Qualitative report

Below are the empirical barriers with qualitative evidence gathered from key stakeholders across Delta State.

Unreliable Grid Electricity & Generator Costs

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"In Bomadi, we do not have public electricity for months. Expecting a teacher to run desktop simulations without an inverter or dedicated fuel budget is unrealistic." Head of Dept, Bomadi (Delta South)

High Internet Data Tariff & Connectivity Gaps

"We cannot stream educational farming clips in real-time. If the materials are not stored locally on a hard drive, the lesson reverts to the blackboard." — Teacher, Aniocha North (Delta North)

Deficit in AgTech-Specific Pedagogical Knowledge (TPACK)

"Our teachers know how to operate Android phones, but they do not know how to teach animal nutrition or pasture management using digital software." — Curriculum Director, Asaba.

Time Constraints in Unified Examination Schemes

"The current termly scheme of work is packed. Teachers rush to cover WAEC/NECO theory syllabi, leaving zero margin for digital experimentation or interactive data logging." — Senior Education Officer, Ughelli (Delta Central).

Discussion of Findings

The empirical findings shed light on the intricate relationship between technological ambition and pedagogical reality in secondary agricultural science education in Delta State. Although there is broad consensus among educators about the transformative potential of educational technologies, classroom use remains piecemeal, rudimentary and sorely hampered by systemic disparities.

The Dissonance of General Technology Adoption vs. Domain-Specific AgTech

The data pertaining to Research Question 1 show an educational paradox. Although consumer-grade communication tools such as WhatsApp and telegram study groups ($\bar{x} = 2.89$) and mobile diagnostic apps ($\bar{x} = 2.61$) were highly utilised, despite being rudimentary, secondary classrooms lack key agricultural technologies, particularly digital soil test sensors ($\bar{x} = 1.48$), interactive virtual farm simulations ($\bar{x} = 1.62$), and GIS farm-mapping utilities ($\bar{x} = 1.76$). When viewed through the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006), this discrepancy suggests a serious imbalance across knowledge areas.

Teachers have rudimentary Technological Knowledge (TK) pertaining to personal smartphones and social media communications that they graft upon traditional Content Knowledge (CK). However, true Technological Content Knowledge (TCK) – the understanding of how specialised digital resources affect the representation and investigation of agricultural phenomena – and Technological Pedagogical Knowledge (TPK) are mostly uncultivated.

This finding supports the work of Osinem (2008) and Munienge et al. (2013) who found that ICT interventions in the development of agricultural curricula often remain at the level of passive media consumption (e.g., recording a video or projecting lecture notes) and do not progress to active computational manipulation, empirical data logging, or spatial modelling.

When teachers use WhatsApp to send static images of crop diseases, technology functions as an alternative distribution route. Not technology as a change agent of the underlying didactic instructional paradigm.

Perceived Curriculum Affordances: Cognitive Anchoring and Re-Branding of Agriculture

The technological tools were not heavily deployed, but the results for Research Question 2 show high pedagogical optimism $\bar{x} = 3.34$) . Respondents agreed that digital resources provide a powerful cognitive

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anchor to visualise complicated biological cycles ($\bar{x}$ = 3.48) and dynamic ecological interactions that are not easily investigated on a school farm plot.

Importantly, the top ranked opportunity was the ability of digital integration to reposition agricultural science from punitive physical labour to an up-to-date agribusiness discipline $\bar{x}$ = 3.56).

Punitive manual work on school farm plots is widely used as a disciplinary tactic in Nigerian secondary institutions, which has historically stigmatised agricultural education as backward, hard and socio-economically unrewarding.

Digital enterprise tools like sensor-based irrigation management, automated crop yield predictors and spreadsheet-based ledger accounting offer a better appreciation of modern agricultural value chains and precision agriculture to students when curriculum planners adopt them.

This alignment is in accordance with constructivist paradigms of vocational education: digital resources contextualise abstract scientific theory within authentic, contemporary workplace simulations, thus increasing vocational motivation and cognitive retention (Jegede & Owolabi, 2008).

The ecological digital divide and spatial injustice

Rejecting both null hypotheses exposes the structural stratification driving educational technology uptake across Delta State: Delta South - $\bar{x}$ = 3.39; Delta Central - $\bar{x}$ = 3.04; Delta North - $\bar{x}$ = 2.88. The significant omnibus ANOVA results ($F = 35.835$, $p < .001$) and subsequent post-hoc Tukey HSD decisions reflect the state's uneven socioeconomic and physical topography. Delta North benefits from Asaba's administrative centralisation, with relatively steady corridors of electrification, a higher concentration of internet service providers (ISPs), and direct access to Ministry funded workshops. Delta Central is an urban and peri-urban commercial axis with moderate infrastructural resilience, however instructional access declines sharply outside the major city pockets.

"There is systemic disadvantage in Delta South. The riverine, estuary, and mangrove ecologies characterizing LGAs such as Bomadi and Burutu face significant infrastructure exclusion: long-standing disturbances to the public electricity grid, high logistical expenses for moving technology, and intermittent cellular bandwidth coverage. The same discrepancies are clearly apparent in the school ecologies ($F = 87.523$, $p < .001$), where riverine ($\bar{x}$ = 3.44) and rural agricultural schools ($\bar{x}$ = 3.19) reported implementation obstacles that are much higher than those of urban schools ($\bar{x}$ = 2.76).

These data confirm the spatial digital gap described by Enakrire and Onyenania (2007) and Ikemenjima (2005). When curriculum developers mandate uniform educational technology standards across Delta State without accounting for local geography, they inadvertently create a two-tiered system: an urban elite tier that can leverage computer-assisted instruction and multimedia laboratories, and a marginalized rural-riverine tier where power deficits and data costs restrict teaching to analog methods.

Institutional and Curricular Inertia: The Hidden Structural Barriers

The mixed-methods joint display deepens the quantitative metrics by showing institutional constraints buried within examination frameworks and continuous evaluation models.

Respondents highlighted volatile electrical power $\bar{x}$ = 3.74) and exorbitant telecommunications tariffs $\bar{x}$ = 3.61) as the major physical constraints. However, qualitative interviews indicated similarly detrimental institutional frictions within curriculum administration. The unified termly plans of work produced by the Delta State Post Primary Education Board (PPEB) remain largely oriented around the standardized, high-stakes external examinations administered by the West African Examinations Council (WAEC) and the National Examinations Council (NECO).

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Because these terminal assessments evaluate practical agricultural science through static, paper-based identification sheets (e.g., matching physical specimens of weeds, parasites, and farm implements on lab benches), teachers face strong disincentives to devote class time to digital simulations, electronic spreadsheets, or mobile sensor data logging.

As recorded in qualitative interviews, teachers regard deploying digital technologies without structural alterations to examination formats as an unnecessary instructional risk that drains time from syllabus completion.

Therefore, digital integration in agriculture education cannot be achieved by merely donating technology; it requires systemic alignment among curriculum design, continuous assessment credit weighting and standardised evaluation instruments.

Conclusion

The study explored the factual realities, pedagogical opportunities and institutional constraints of integration of digital instructional resources in secondary agricultural science teaching in Delta State. Findings reveal a stark structural dichotomy: while educators and curriculum planners broadly agree that digital technologies can demystify abstract agronomic phenomena and rebrand secondary agriculture from manual labour into a technology-enabled enterprise ($\bar{x}$ = 3.56), practical classroom integration remains fragmented, superficial, and limited to consumer-grade mobile applications. Specialised agricultural technology such as sensor based soil testing kits, GIS based parcel mapping tools and interactive farm simulation software have hardly been explored by public secondary institutions.

Importantly, the empirical evidence shows a sharp ecological and spatial digital divide ($F=87.523$, $p < .001$). There is systematic denial of infrastructural access to secondary schools in the rural farming belts of Delta Central and the riverine, estuarine terrains of Delta South compared to their urban counterparts in administrative cities like Asaba. Common obstructions to instructional delivery include widespread disturbances to the electrical system, the high tariffs on internet bandwidth, a paucity of ruggedised technology, and a lack of subject-specific TPACK. The infrastructure impediments are further worsened by curricular rigidity. Terminal assessment regimes (such as WAEC and NECO) assess agricultural practicals using static, pen-and-paper specimen identification, so there is little institutional motivation for teachers to introduce electronic resources into an already congested scheme of work.

Policy Recommendations for ICT Integration in Agriculture

Given Infrastructure and capacity gaps have to be tackled proactively by policymakers if digital transformation is to be accelerated, particularly in the context of a low level of agricultural productivity and slow ICT adoption. Based on the challenges identified the following policy directions are recommended:

To implement these findings, this paper suggests that there should be multi-faceted interventions that can be implemented by the Delta State Ministry of Basic and Secondary Education, the Post Primary Education Board (PPEB), the Nigerian Educational Research and Development Council (NERDC), and the regional examination bodies.

The Ministry to buy and distribute low-power, ruggedized mobile tablets and micro-projectors that are packaged with solar charging banks (modular). This will prevent dependence on the municipal power grid and costly generators.

Formulate public-private partnerships (PPPs) or corporate social responsibility (CSR) deals with telecommunication providers to set up local servers in the educational environment at no cost. Store

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instructional agricultural information, such as HD agronomy demonstrations, crop pathology information bases, farm business spreadsheets, etc., locally on micro-servers or flash memory cards with complete offline access in low bandwidth areas.

Use an equity-weighted formula for allocation of dedicated educational technology capital expenditure, to offset geographic disadvantage identified through the ANOVA post-hoc analysis, favouring riverine (Delta South) and rural (Delta Central/North) schools.

The PPEB should partner with agricultural institutions like Delta State University Faculty of Agriculture, Songhai Delta Amukpe and IITA to provide hands-on, practical TPACK clinics. These clinics need to train teachers in the use of specific tools like the Mobile diagnostic apps (e.g., Plantix), Open-source mobile GIS tools (e.g., QGIS, Google Earth Engine) for farm cadastral mapping, mobile spreadsheets for enterprise budgeting and poultry/fishery feed formulation.

There is a need for national and state governments to put significant resources into developing mobile apps, agricultural data platforms and digital extension tools to support rural internet infrastructure. Supporting digital access through subsidised data services in the context of ICT hubs powered by solar energy in agricultural communities is a great way to enhance digital access.

Integrating inclusive digital literacy initiatives within agricultural extension service programs should be part of the job. To promote high adoption rates, especially by women and by older farmers. Training should be done in local and native languages. In addition, increased cooperation between government agencies, telecommunication providers and agritech companies is essential to ensure the inclusion and sustainability of the ICT rollout.

Policymakers need to establish strong policies for the distribution and maintenance and feedback systems of ICTs. Smart farming programs should include features like real-time monitoring, interactive dashboards, and offline functionalities to enable farmers in remote areas with limited connectivity. States have to also support innovation locally, but have a central hub for digital agriculture.

Input vouchers directly tied to online platforms and grants can have a significant impact on initial uptake. Technology availability, however, cannot ensure long-term success; it must be integrated into the entire agriculture value chain, from input supply, production, marketing and storage.

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