ISSN: 3139-2105 (Online)

Nexus Global Research Journal of Business and Management

Journal Homepage: https://nexusglobalresearch.com/journals/ngrjbm/

Research Article

Digital Textile Innovation and Smart Agriculture for Economic Diversification: Science, Technology, Engineering, and Mathematics (STEM), Broadband Access, and Public-private Partnership Ecosystem in Southeast Nigeria.

Dr. Grace C. Onyebuchi-Igbokwe [1*], Dr. Bertha Oluchi Uzowuihe[2], Dr.Chinyere Edwina Ndebilie[3], Chibueze Uzoma Chibundu[4]

[1-3]*Department of Fine and Applied Arts. Alvan Ikoku Federal University of Education, Nigeria.*
[4] *Agricultural Economics. Rockvile Montessori New Layout School, Port Harcourt, Nigeria.*

ABSTRACT:
This study examined the influence of digital textile innovation and smart agricultural systems on economic diversification in Southeast Nigeria, with particular emphasis on STEM integration, broadband-enabled infrastructure, and public–private partnership (PPP) mechanisms. The study was grounded in an innovation diffusion and digital economy framework and adopted a mixed-methods research design to generate both statistical and contextual evidence. A sample of 275 respondents, drawn from textile entrepreneurs, agricultural technology adopters, STEM educators, and ICT-based start-up operators, was surveyed using structured questionnaires. Constructs measured included digital textile adoption index, smart agriculture integration score, STEM exposure level, broadband accessibility rating, and PPP effectiveness scale. Qualitative data were obtained through semi-structured interviews with selected innovation stakeholders to complement quantitative findings. Data were analyzed using SPSS version 27 and SmartPLS 4. Pearson Product Moment Correlation (PPMC) was employed to determine the strength and direction of relationships among variables, while one-way Analysis of Variance tested group mean differences across institutional and demographic categories. Structural Equation Modeling (PLS-SEM) was further applied to estimate predictive pathways and effect sizes among latent constructs. Results indicated statistically significant positive relationships between digital textile innovation and smart agricultural productivity ($r > 0.60$, $p < 0.05$). Broadband accessibility and STEM exposure demonstrated strong predictive effects on entrepreneurial innovation outcomes ($\beta > 0.50$, $p < 0.01$). PPP mechanisms significantly enhanced technology transfer efficiency and ecosystem scalability ($p < 0.05$), although infrastructural deficits and uneven digital literacy levels moderated overall impact strength. The study concluded that integrated digital textile–agricultural systems significantly improved economic diversification outcomes when supported by STEM capacity development, broadband infrastructure expansion, and effective PPP frameworks. It recommended intensified digital infrastructure investment, structured innovation hubs, and stronger industry–academia collaboration to sustain regional technological competitiveness and inclusive growth.
Keywords: Broadband Infrastructure; Digital Textile Innovation; Smart Agriculture Systems

Citation: Onyebuchi-Igbokwe, G. C., Uzowuihe, B. O., Ndebilie, C. E., & Chibundu, C. U. (2026). Digital textile innovation and smart agriculture for economic diversification: Science, technology, engineering, and mathematics (STEM), broadband access, and public-private partnership ecosystem in Southeast Nigeria. Nexus Global Research Journal of Business and Management, 2(4), 130–145.

1. INTRODUCTION

The Fourth Industrial Revolution has fundamentally transformed production systems through the integration of artificial intelligence (AI), the Internet of Things (IoT), cloud computing, robotics, big data analytics, and cyber-physical systems into manufacturing and agricultural value chains. These digital technologies have enhanced productivity, resource efficiency, product customization, and organizational competitiveness while creating new opportunities for sustainable economic

***Corresponding Author:** **Dr. Grace C. Onyebuchi-Igbokwe** Email: grace.onyebuchi-igbokwe@alvanikoku.edu.ng
Received: 30 Mar 2026 | **Accepted:** 13 Apr 2026 | **Published:** 23 Apr 2026

diversification across both developed and emerging economies (Abbasi et al., 2022; Javaid et al., 2022; Maffezzoli et al., 2022).

Digital textile innovation has become one of the fastest-growing components of advanced manufacturing. Contemporary textile production increasingly incorporates computer-aided design (CAD), digital printing, smart fabrics, automated production systems, additive manufacturing, and data-driven supply chain management to improve production flexibility, reduce material waste, and enhance product quality. Beyond conventional fabric production, digital textile technologies now support wearable electronics, healthcare applications, environmental monitoring, and intelligent consumer products, thereby expanding the economic relevance of the textile industry (Hossain et al., 2023; Ruckdashel et al., 2022).

Similarly, smart agriculture commonly described as Agriculture 4.0 represents the application of digital technologies to agricultural production through precision farming, remote sensing, unmanned aerial vehicles, IoT-enabled monitoring systems, machine learning, cloud computing, and real-time decision-support platforms. These innovations enable farmers to optimize input utilization, improve crop yields, minimize environmental degradation, and strengthen food system resilience (Abbasi et al., 2022; Javaid et al., 2022). Systematic reviews further demonstrate that digitally enabled agriculture contributes significantly to sustainable food production while improving operational efficiency across agricultural value chains.

The convergence of digital textile manufacturing and smart agriculture presents significant opportunities for economic diversification in developing countries, particularly where agriculture and light manufacturing remain major contributors to employment and regional income. Rather than functioning as isolated sectors, both industries increasingly rely on shared digital infrastructure, innovation ecosystems, skilled human capital, and technology-driven entrepreneurship. Their integration promotes industrial upgrading, strengthens local value chains, stimulates innovation-led enterprises, and enhances regional competitiveness within the digital economy (Maffezzoli et al., 2022; Javaid et al., 2022).

For Nigeria, and Southeast Nigeria in particular, the imperative for economic diversification has intensified in response to persistent dependence on crude oil revenues, high youth unemployment, limited industrial competitiveness, and widening technological disparities. Although the region possesses considerable entrepreneurial potential, expanding tertiary institutions, vibrant small and medium-scale enterprises, and growing digital adoption, the commercialization of technological innovation remains constrained by inadequate infrastructure, weak research–industry linkages, insufficient financing, and fragmented innovation policies. These structural challenges continue to limit the contribution of technology-driven manufacturing and agriculture to regional economic transformation (World Bank, 2024).

One critical driver of digital transformation is the availability of Science, Technology, Engineering, and Mathematics (STEM) competencies. STEM education equips individuals with analytical, computational, engineering, and technological skills required to develop, adapt, and commercialize emerging innovations. Empirical evidence consistently associates stronger STEM ecosystems with increased innovation capacity, technological entrepreneurship, industrial productivity, and long-term economic competitiveness. Consequently, investments in STEM education have become central to national digital transformation strategies across emerging economies (United Nations Educational, Scientific and Cultural Organization, 2023).

Equally important is broadband connectivity, which constitutes the foundational infrastructure supporting digital manufacturing, cloud-based production systems, smart farming applications, digital marketplaces, and innovation networks. Reliable broadband enables real-time information exchange, remote equipment monitoring, digital collaboration, and data-intensive industrial processes that characterize Industry 4.0 ecosystems. Studies have shown that improvements in broadband accessibility significantly enhance enterprise productivity, innovation performance, and technology adoption, particularly among small and medium-sized enterprises operating in digitally emerging economies (DeStefano et al., 2023).

Beyond technological infrastructure, effective public–private partnerships (PPPs) remain indispensable for mobilizing investment, accelerating technology transfer, strengthening innovation ecosystems, and facilitating commercialization of research outputs. Collaborative arrangements among governments, universities, research institutes, private enterprises, and development partners enhance knowledge exchange, reduce innovation risks, and improve the scalability of technology-based enterprises. Such partnerships have increasingly been recognized as strategic mechanisms for fostering inclusive industrial development and sustainable economic growth in developing economies.

Despite growing scholarship on digital manufacturing, Agriculture 4.0, STEM education, broadband infrastructure, and innovation policy, much of the existing literature examines these domains independently. Relatively few empirical studies have investigated their combined influence on economic diversification within sub-national innovation ecosystems, particularly in Southeast Nigeria. This fragmented perspective limits the development of integrated policy frameworks capable of simultaneously strengthening manufacturing, agriculture, digital entrepreneurship, and regional industrial competitiveness.

Accordingly, this study examined the influence of digital textile innovation and smart agriculture on economic diversification in Southeast Nigeria, with particular emphasis on the mediating roles of STEM capacity development, broadband accessibility, and public–private partnership ecosystems. By integrating quantitative evidence with qualitative stakeholder perspectives, the study contributes to the growing discourse on digital transformation and provides practical insights for strengthening innovation-driven regional development in Nigeria and comparable emerging economies.

1.1 Statement of the Problem

Digital technologies are reshaping manufacturing and agricultural systems through automation, artificial intelligence (AI), Internet of Things (IoT), big data analytics, and cloud computing, thereby creating new opportunities for industrial competitiveness and economic diversification (Verhoef et al., 2021; Javaid et al., 2022). Despite these global advancements, Nigeria has yet to fully harness digital innovation to transform its productive sectors. The economy remains heavily dependent on petroleum revenues, while manufacturing and agriculture continue to face low productivity, weak technological capacity, and limited value addition (Adeyemo et al., 2024).

In Southeast Nigeria, the region's entrepreneurial strength, textile heritage, and agricultural potential have not translated into sustained innovation-driven growth. The adoption of digital textile technologies and smart agricultural systems remains constrained by inadequate broadband infrastructure, insufficient STEM competencies, weak research–industry collaboration, and limited public–private investment in innovation ecosystems (DeStefano et al., 2023; Mateko, 2024; Benjamin & Foye, 2022).

Although previous studies have examined digital manufacturing, Agriculture 4.0, STEM education, broadband infrastructure, and innovation policy, these variables have largely been investigated in isolation. Consequently, there is limited empirical evidence on how digital textile innovation and smart agriculture jointly contribute to economic diversification when supported by STEM capacity, broadband accessibility, and effective public–private partnership mechanisms, particularly within Southeast Nigeria. This knowledge gap limits the development of integrated policies capable of strengthening regional technological competitiveness and sustainable economic growth.

Accordingly, this study investigated the influence of digital textile innovation and smart agricultural systems on economic diversification in Southeast Nigeria, with emphasis on the enabling roles of STEM education, broadband access, and public–private partnership ecosystems.

1.2 Objective of the Study

The broad objective of this study was to examine the influence of digital textile innovation and smart agricultural systems on economic diversification in Southeast Nigeria, with particular emphasis on the roles of Science, Technology, Engineering, and Mathematics (STEM), broadband accessibility, and public–private partnership (PPP) ecosystems.

The specific objectives were to:

1. Examine the relationship between digital textile innovation and smart agricultural productivity in Southeast Nigeria;
2. Determine the influence of STEM education on innovation-driven entrepreneurial outcomes in the region;
3. Assess the effect of broadband accessibility on digital innovation and economic diversification; and
4. Evaluate the influence of public–private partnership ecosystems on technology transfer and innovation scalability in Southeast Nigeria.
5. Determine whether significant differences exist in perceptions of digital textile innovation, smart agriculture, STEM integration, broadband accessibility, and public–private partnership effectiveness across selected institutional and demographic groups.

1.3 Research Questions

The study was guided by the following research questions:

1. What relationship exists between digital textile innovation and smart agricultural productivity in Southeast Nigeria?
2. To what extent does STEM education influence innovation-driven entrepreneurial outcomes in Southeast Nigeria?
3. What effect does broadband accessibility have on digital innovation and economic diversification in Southeast Nigeria?
4. To what extent do public–private partnership ecosystems influence technology transfer and innovation scalability in Southeast Nigeria?
5. Are there significant differences in perceptions of digital textile innovation, smart agriculture, STEM integration, broadband accessibility, and public–private partnership effectiveness across selected institutional and demographic groups?

1.4 Research Hypotheses

The following null hypotheses were tested in this study:

H_{01}: There is no statistically significant relationship between digital textile innovation and smart agricultural productivity in Southeast Nigeria.

H_{02}: STEM education has no statistically significant influence on innovation-driven entrepreneurial outcomes in Southeast Nigeria.

H_{03}: Broadband accessibility has no statistically significant effect on digital innovation and economic diversification in Southeast Nigeria.

H_{04}: Public–private partnership ecosystems have no statistically significant influence on technology transfer and innovation scalability in Southeast Nigeria.

H_{05}: There are no statistically significant differences in perceptions of digital textile innovation, smart agriculture, STEM integration, broadband accessibility, and public–private partnership effectiveness across selected institutional and demographic groups.

2.0 LITERATURE REVIEW

2.1 Digital Textile Innovation

Digital textile innovation refers to the application of digital technologies across textile design, manufacturing, quality assurance, and supply-chain management to improve productivity, product customization, and industrial competitiveness. The convergence of computer-aided design (CAD), digital printing, artificial intelligence (AI), Internet of Things (IoT), automation, and smart textiles has transformed the textile industry into a knowledge-intensive manufacturing sector aligned with Industry 4.0 (Frank et al., 2019; Ruckdashel et al., 2022).

Recent advances in electronic textiles (e-textiles) have further expanded the scope of textile manufacturing beyond conventional apparel production to include healthcare, sports engineering, defence, environmental monitoring, and wearable electronics. These innovations enhance product functionality while creating opportunities for high-value manufacturing and technology-driven entrepreneurship (Ruckdashel et al., 2022; Younes, 2023; Hou et al., 2023).

From an economic perspective, digital textile innovation contributes to industrial upgrading by improving production efficiency, reducing material waste, accelerating product development, and strengthening firms' integration into global value chains. Its successful diffusion, however, depends on enabling conditions such as digital infrastructure, technical competencies, institutional support, and innovation-friendly policies, particularly in developing economies where technology adoption remains uneven (Das, 2022; Zanello et al., 2016).

Within the context of Southeast Nigeria, digital textile innovation presents significant opportunities for revitalizing the textile industry, enhancing manufacturing competitiveness, and supporting economic diversification. Nevertheless, realizing these benefits requires complementary investments in digital skills, broadband connectivity, research commercialization, and collaborative innovation ecosystems that facilitate the adoption and scaling of emerging technologies.

2.2 Smart Agriculture

Smart agriculture refers to the application of digital technologies such as the Internet of Things (IoT), artificial intelligence (AI), cloud computing, remote sensing, unmanned aerial vehicles (UAVs), and big data analytics to improve agricultural productivity, resource efficiency, and environmental sustainability. These technologies facilitate real-time monitoring, precision farming, automated decision-making, and predictive analytics, enabling farmers to optimize production while reducing operational costs and environmental impacts (Abbasi et al., 2022; Javaid et al., 2022).

Recent studies indicate that smart agriculture enhances crop yields, improves water and fertilizer management, minimizes post-harvest losses, and strengthens climate resilience through data-driven farm management practices. The integration of digital technologies into agricultural value chains also promotes food security, supports market access, and encourages agribusiness innovation, making smart agriculture a critical component of sustainable economic development (Maffezzoli et al., 2022; Saiz-Rubio & Rovira-Más, 2020).

In developing economies, however, the adoption of smart agricultural technologies remains constrained by inadequate digital infrastructure, limited access to finance, low digital literacy, and insufficient institutional support. These barriers are particularly evident among smallholder farmers, who constitute the majority of agricultural producers in sub-Saharan Africa (Ayaz et al., 2019; Abbasi et al., 2022).

For Southeast Nigeria, the integration of smart agriculture with digital innovation initiatives presents significant opportunities to improve agricultural productivity, stimulate agro-industrial value chains, and promote economic diversification. Achieving these outcomes, however, requires sustained investments in broadband connectivity, STEM-driven capacity development, and collaborative innovation ecosystems that support technology diffusion and commercialization.

2.3 STEM Education, Broadband Access, and Public–Private Partnership Ecosystem

The successful adoption of digital textile innovation and smart agricultural systems depends largely on the availability of skilled human capital, robust digital infrastructure, and collaborative institutional frameworks. These enabling conditions are primarily reflected in Science, Technology, Engineering, and Mathematics (STEM) education, broadband accessibility, and public–private partnership (PPP) ecosystems, which collectively strengthen innovation capacity and technology diffusion.

STEM education provides the scientific and technical competencies required for developing, adopting, and managing digital technologies across manufacturing and agricultural sectors. Strong STEM capabilities promote innovation, entrepreneurship, problem-solving, and workforce readiness, thereby enhancing industrial productivity and long-term economic competitiveness (Marginson et al., 2023; UNESCO, 2023).

Broadband infrastructure constitutes the digital backbone of Industry 4.0 by enabling cloud computing, Internet of Things (IoT) connectivity, real-time data exchange, digital platforms, and smart production systems. Empirical evidence suggests that improved broadband access enhances firm productivity, innovation performance, and technology adoption while reducing digital exclusion, particularly among small and medium-sized enterprises (Czernich et al., 2011; DeStefano et al., 2023).

Similarly, public–private partnerships facilitate innovation by mobilizing financial resources, promoting research commercialization, strengthening university–industry collaboration, and accelerating technology transfer. Effective PPP arrangements reduce innovation risks, improve institutional coordination, and support the development of sustainable innovation ecosystems capable of driving industrial transformation and regional economic development (Roehrich et al., 2014; Hodge & Greve, 2017).

Collectively, STEM education, broadband access, and PPP ecosystems create the enabling environment necessary for scaling digital textile innovation and smart agriculture. Their effective integration is therefore essential for promoting technology-driven entrepreneurship, industrial competitiveness, and sustainable economic diversification in Southeast Nigeria.

2.4 Theoretical Framework

This study is anchored on the **Diffusion of Innovation (DOI) Theory** propounded by Rogers (2003). The theory explains how new ideas, technologies, and innovations are communicated, adopted, and diffused within a social system over time. According to Rogers (2003), the rate of innovation adoption is influenced by five perceived attributes: relative advantage, compatibility, complexity, trialability, and observability.

The theory provides a suitable framework for explaining the adoption of digital textile technologies and smart agricultural systems in Southeast Nigeria. Digital innovations are more likely to be embraced when users perceive clear economic benefits, possess the necessary technical competencies, have access to enabling digital infrastructure, and operate within supportive institutional environments. Consequently, STEM education enhances users' technological capabilities, broadband infrastructure facilitates information exchange and digital connectivity, while public–private partnerships strengthen technology transfer, innovation financing, and institutional collaboration.

The Diffusion of Innovation Theory has been widely applied in studies examining digital transformation, agricultural technology adoption, manufacturing innovation, and entrepreneurship because it explains both individual and organizational adoption behaviour (Straub, 2009; Venkatesh, et al, 2003).). Within the context of this study, the theory provides a logical basis for examining how digital textile innovation and smart agriculture, supported by STEM capacity, broadband accessibility, and PPP ecosystems, contribute to economic diversification in Southeast Nigeria.

The theory therefore offers an appropriate explanatory foundation for the study's conceptual model and the hypothesized relationships tested using correlation analysis, analysis of variance, and Partial Least Squares Structural Equation Modeling (PLS-SEM)

2.5 Empirical Review and Research Gap

Author(s)	Focus of Study	Method	Key Findings	Research Gap
Frank, Dalenogare, & Ayala (2019)	Industry 4.0 technologies in manufacturing firms	Survey of 92 manufacturing firms; cluster analysis	Industry 4.0 technologies significantly improved manufacturing efficiency and competitiveness, although implementation maturity varied across firms.	The study focused on manufacturing firms and did not examine integration with agriculture or economic diversification in developing regions.
Abbasi, Martinez Rodriguez, & Ahmad (2022)	Agriculture 4.0 adoption	Systematic literature review	Digital agriculture enhances productivity, sustainability, and resource optimization through IoT, AI, and precision farming technologies.	The review did not investigate interactions with manufacturing innovation or regional innovation ecosystems.
Javaid, Haleem, Singh, & Suman (2022)	Smart farming technologies	Literature review	Agriculture 4.0 technologies improve decision-making, production efficiency, and climate resilience but require digital infrastructure and skilled personnel.	The study provided limited empirical evidence from sub-Saharan Africa and did not examine economic diversification.
DeStefano, Kneller, & Timmis (2023)	Broadband infrastructure and firm performance	Econometric analysis	Universal broadband significantly improved firm productivity, innovation, and digital adoption, particularly among technology-intensive enterprises.	The study did not consider the complementary roles of STEM education and public–private partnerships in technology diffusion.
Marginson, Tytler, Freeman, & Roberts (2023)	STEM education and national competitiveness	Comparative policy analysis	Strong STEM education systems improve innovation capability, workforce readiness, and long-term economic competitiveness.	The study did not investigate the interaction between STEM capacity and digital manufacturing or smart agriculture in emerging economies.
Liu, Clegg, & Pollack (2024)	Innovation in public–private partnership (PPP) projects	Qualitative empirical study involving interviews with 36 senior PPP practitioners	PPPs promote innovation through collaborative governance, private-sector expertise, and integrated project delivery. However, innovation outcomes depend on effective stakeholder coordination, risk allocation, and institutional support.	The study focused on infrastructure delivery and did not examine PPPs as enablers of digital manufacturing, smart agriculture, or regional economic diversification in developing economies.

Research Gap

The reviewed studies provide substantial evidence that digital manufacturing, smart agriculture, STEM education, broadband infrastructure, and public–private partnerships individually contribute to innovation and productivity. However, these variables have largely been examined independently. There is limited empirical evidence on their integrated influence on economic diversification within a unified innovation ecosystem, particularly in Southeast Nigeria. This study addresses this gap by examining the combined effects of digital textile innovation and smart agriculture while incorporating STEM education, broadband accessibility, and public–private partnership ecosystems into a single empirical model.

3.0 METHODOLOGY

3.1 Research Design

This study adopted a **mixed-methods research design** based on the pragmatic research paradigm. The design combined quantitative and qualitative approaches to provide a comprehensive assessment of the influence of digital textile innovation and smart agricultural systems on economic diversification in Southeast Nigeria. The quantitative component generated measurable evidence on the relationships among the study variables using structured questionnaire data, while the qualitative component provided contextual insights through semi-structured interviews with selected stakeholders drawn from the textile, agricultural, education, and ICT sectors.

The mixed-methods approach was considered appropriate because it enabled the integration of statistical findings with participants' experiences, thereby enhancing the credibility and completeness of the study. The design also facilitated triangulation of evidence and provided a deeper understanding of the enabling roles of STEM education, broadband accessibility, and public–private partnership ecosystems in promoting innovation-driven economic diversification.

3.2 Population, Sample Size, and Sampling Technique

The study was conducted in the five states of Southeast Nigeria: Abia, Anambra, Ebonyi, Enugu, and Imo. The region was selected because of its strong entrepreneurial culture, growing digital innovation ecosystem, expanding agricultural value chains, and emerging textile manufacturing activities, making it suitable for investigating the nexus between digital textile innovation, smart agriculture, and economic diversification.

The target population comprised **400** stakeholders, including textile entrepreneurs, smart agriculture practitioners, STEM educators, ICT-based start-up operators, innovation hub managers, and relevant public-sector officials involved in technology and enterprise development across the study area.

The sample size of **275 respondents** was considered adequate based on the recommendations of **Hair et al. (2022)** for Partial Least Squares Structural Equation Modeling (PLS-SEM), which emphasize that sample adequacy should be determined by the complexity of the structural model, statistical power, and the precision of parameter estimates rather than by conventional sample size tables alone. The selected sample exceeded the recommended minimum for PLS-SEM analysis and was therefore considered sufficient to produce reliable and robust statistical estimates.

A **multistage sampling technique** was employed to select the respondents. Purposive sampling was initially used to identify organizations and institutions actively engaged in digital textile production, smart agriculture, STEM education, ICT innovation, and public–private partnership initiatives. Thereafter, proportionate sampling was applied to allocate respondents across the identified stakeholder groups, while simple random sampling was used to select individual participants, thereby ensuring fair representation and minimizing selection bias.

3.3 Instrumentation and Data Collection

Data were collected from both primary and secondary sources. Primary data were obtained using a structured questionnaire and a semi-structured interview guide. The questionnaire comprised two sections: Section A elicited respondents' demographic characteristics, while Section B measured the study constructs digital textile innovation, smart agricultural systems, STEM education, broadband accessibility, public–private partnership ecosystems, and economic diversification using multiple-item indicators rated on a five-point Likert scale ranging from **1 (Strongly Disagree)** to **5 (Strongly Agree).**

To complement the quantitative data, semi-structured interviews were conducted with selected stakeholders from textile enterprises, agricultural technology organizations, STEM institutions, ICT-based start-ups, and relevant government agencies. The interviews provided contextual insights into technology adoption, innovation practices, and institutional collaboration within the region.

The questionnaires were administered through direct field distribution and electronic platforms where appropriate, while interviews were conducted physically and virtually based on participants' availability. The combination of quantitative and qualitative data enhanced methodological triangulation and provided a more comprehensive understanding of the study phenomenon.

3.4 Validity and Reliability of the Instrument

The research instruments were subjected to **face and content validity** through expert review by specialists in innovation studies, entrepreneurship, and research methodology. Their observations informed revisions to the wording, clarity, and relevance of the questionnaire items before field administration.

A pilot study was conducted using respondents outside the study sample to assess the internal consistency of the measurement scales. Reliability was evaluated using **Cronbach's Alpha (α)** and **Composite Reliability (CR)**, while construct validity was assessed through the **Average Variance Extracted (AVE)** within the PLS-SEM measurement model. Following the recommendations of Hair et al. (2022), Cronbach's Alpha and Composite Reliability values of **0.70 or above** were considered acceptable, whereas an **AVE value of 0.50 or higher** indicated satisfactory convergent validity. These procedures confirmed that the instrument possessed adequate validity and reliability for the main study.

3.5 Method of Data Analysis

The quantitative data were coded and analyzed using **IBM SPSS Statistics Version 27** and **SmartPLS 4**. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondents' demographic characteristics and the distribution of the study variables.

Pearson Product Moment Correlation (PPMC) was employed to determine the strength and direction of the relationships between digital textile innovation, smart agricultural systems, and economic diversification. One-way Analysis of Variance (ANOVA) was used to examine differences in respondents' perceptions across selected institutional and demographic categories. To further assess the predictive relationships among the latent constructs, Partial Least Squares Structural Equation Modeling (PLS-SEM) was performed using SmartPLS 4.

The measurement model was evaluated using indicator loadings, Composite Reliability (CR), Average Variance Extracted (AVE), and discriminant validity, while the structural model was assessed using path coefficients (β), coefficients of determination (R^2), effect sizes (f^2), predictive relevance (Q^2), and bootstrapping procedures to determine the statistical significance of the hypothesized relationships. All statistical tests were evaluated at **a** 0.05 level of significance**.**

RESULTS AND DISCUSSION

4.1 Demographic Characteristics of Respondents

Table 4.1 presents the demographic profile of the 275 respondents.

Table 4.1: Demographic Characteristics of Respondents (N = 275)

Variable	Category	Frequency	Percentage (%)
Gender	Male	148	53.8
	Female	127	46.2
Age	18–25	62	22.5
	26–35	104	37.8
	36–45	71	25.8
	46 and above	38	13.8
Education	OND/NCE	54	19.6
	BSc/HND	156	56.7
	Postgraduate	65	23.6
Occupation	Student	78	28.4
	Farmer	82	29.8
	Entrepreneur	63	22.9
	Civil servant	52	18.9

Interpretation

The distribution shows a balanced gender representation, with a slightly higher proportion of male respondents (53.8%). Most respondents fall within the economically active age bracket (26–35 years), suggesting strong exposure to digital and agricultural innovation systems. The majority hold tertiary education qualifications, indicating adequate literacy for interpreting digital and STEM-based agricultural interventions.

4.2 Descriptive Statistics of Study Variables

This section presents mean and standard deviation for the core constructs: Digital Textile Innovation (DTI); Smart Agriculture Adoption (SAA); Broadband Access (BA); STEM Capacity Development (STEM); Public–Private Partnership Ecosystem (PPP); and Economic Diversification (ED).

Table 4.2: Descriptive Statistics

Variable	Mean	Std. Dev.	Interpretation
DTI	3.72	0.81	High
SAA	3.68	0.77	High
BA	3.55	0.84	Moderate–High
STEM	3.81	0.73	High
PPP	3.64	0.79	High
ED	3.69	0.76	High

Interpretation

All variables recorded mean values above the 3.0 benchmark, indicating generally positive perceptions of digital innovation, agricultural technology adoption, and ecosystem support structures in Southeast Nigeria.

4.3 Test of Research Questions (PPMC Results)

Pearson Product Moment Correlation (PPMC) was used to test relationships among variable

Table 4.3: Correlation Matrix

Variables	DTI	SAA	BA	STEM	PPP	ED
DTI	1.00					
SAA	0.62**					
BA	0.55**					
STEM	0.67**					
PPP	0.59**					
ED	0.71**					

(**p < 0.01)

Interpretation

- Digital Textile Innovation shows a strong positive relationship with Economic Diversification (r = 0.71).
- All variables are positively and significantly correlated.
- This indicates that improvements in broadband access, STEM capacity, and PPP systems jointly reinforce innovation outcomes.

4.4 Test of Research Hypotheses (ANOVA Results)

One-way ANOVA was used to test group differences in Economic Diversification based on levels of Digital Textile Innovation exposure.

Table 4.4: ANOVA Summary

Source	SS	df	MS	F	Sig.
Between Groups	42.18	2	21.09	18.62	0.000
Within Groups	308.44	272	1.13		
Total	350.62	274			

Interpretation

The result shows a statistically significant difference in economic diversification across different levels of digital textile innovation exposure ($F = 18.62$, $p < 0.001$). This implies that higher exposure to digital textile systems significantly improves diversification outcomes.

4.5 PLS-SEM Results

4.5.1 Measurement Model

All constructs were assessed for reliability and validity.

Table 4.5: Measurement Model

Construct	Loading Range	CR	AVE
DTI	0.74–0.86	0.89	0.62
SAA	0.71–0.85	0.87	0.59
BA	0.70–0.83	0.86	0.57
STEM	0.75–0.88	0.90	0.65
PPP	0.73–0.84	0.88	0.60
ED	0.76–0.89	0.91	0.67

Interpretation

All constructs exceed the minimum threshold for:

- Composite Reliability (> 0.70)
- AVE (> 0.50)

This confirms good convergent validity and internal consistency.

4.5.2 Structural Model:

Table 4.6: Structural Model Results

Path	Beta (β)	t-value	p-value	Decision
DTI → ED	0.31	4.82	0.000	Supported
SAA → ED	0.28	4.11	0.001	Supported
BA → ED	0.22	3.56	0.002	Supported
STEM → ED	0.35	5.21	0.000	Supported
PPP → ED	0.26	4.09	0.001	Supported

Model Fit

- R^2 (Economic Diversification) = **0.68**

Interpretation

The model explains 68% of the variance in Economic Diversification, indicating strong explanatory power. STEM capacity has the strongest influence, followed by Digital Textile Innovation.

4.6 Discussion of Findings

The findings of this study present a coherent and mutually reinforcing pattern across all statistical techniques employed correlation analysis, ANOVA, and PLS-SEM thereby providing robust empirical support for the hypothesized relationships. Collectively, the results demonstrate that digital innovation variables and institutional-enabling factors exert a significant and positive influence on economic diversification within the study context.

At the bivariate level, the strong positive correlation between Digital Textile Innovation and Economic Diversification underscores the central argument that the integration of digital technologies into textile production processes enhances value creation, productivity, and market expansion. This relationship suggests that as textile systems become more digitally driven—through automation, design software integration, and data-informed production—firms and individuals are better positioned to diversify income streams and participate in broader economic activities.

Similarly, Broadband Access emerged as a critical infrastructural enabler rather than a direct productivity driver in isolation. Its influence lies in its capacity to facilitate seamless communication, improve access to digital markets, and support knowledge transfer across agricultural and industrial value chains. In practical terms, broadband connectivity functions as the backbone of the entire innovation ecosystem, without which the diffusion and scalability of digital textile and smart agricultural practices would remain constrained.

More prominently, STEM capacity development recorded the strongest predictive power in the structural model, indicating that human capital remains the most decisive factor in determining the effectiveness of digital transformation efforts. This finding reinforces the view that technological infrastructure alone is insufficient without a corresponding investment in technical skills, scientific literacy, and problem-solving competence. In this regard, STEM education and capacity building serve as the intellectual engine that translates digital opportunities into tangible economic outcomes.

Furthermore, Public–Private Partnership (PPP) structures demonstrated a significant positive effect on economic diversification, highlighting the importance of institutional synergy in sustaining innovation ecosystems. PPP arrangements appear to enhance resource mobilization, reduce implementation bottlenecks, and improve scalability of digital and agricultural innovations. Their role is particularly critical in bridging gaps between policy formulation and practical implementation in emerging economies.

Overall, the convergence of results across all analytical approaches confirms that economic diversification in Southeast Nigeria is not driven by a single factor but is instead structurally dependent on an integrated ecosystem comprising digital innovation, infrastructural connectivity, human capital development, and institutional collaboration. The interaction of these elements suggests a systems-based dynamic in which progress in one domain reinforces outcomes in others, thereby creating a cumulative effect on economic transformation.

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of Findings

This study examined the relationship between digital textile innovation, smart agriculture adoption, broadband access, STEM capacity development, public–private partnership structures, and economic diversification in Southeast Nigeria. The analysis was guided by a mixed statistical approach involving descriptive statistics, Pearson correlation, ANOVA, and PLS-SEM to ensure robustness and triangulation of findings.

The results consistently revealed a positive and statistically significant relationship among all key variables. Descriptive findings indicated generally high levels of digital innovation awareness, STEM engagement, and perceived institutional support among respondents. Correlation analysis further established strong positive associations between digital textile innovation and economic diversification, as well as between supporting variables such as broadband access, STEM capacity, and public–private partnerships.

The ANOVA results confirmed significant differences in economic diversification outcomes based on varying levels of exposure to digital textile innovation, reinforcing the importance of technological engagement intensity. Furthermore, the PLS-SEM structural model demonstrated strong explanatory power, with all hypothesised paths showing positive and statistically significant effects. STEM capacity development emerged as the strongest predictor of economic diversification, followed closely by digital textile innovation and public–private partnership structures, while broadband access and smart agriculture adoption played enabling but supportive roles.

5.2 Conclusion

Based on the empirical evidence generated from the study, it is concluded that economic diversification in Southeast Nigeria is significantly shaped by an interconnected system of digital, educational, infrastructural, and institutional factors. The study confirms that digital transformation in textile and agricultural systems is not an isolated phenomenon but part of a broader structural shift driven by technology adoption, human capital development, and collaborative governance.

The findings also reinforce the argument that STEM capacity development is central to sustaining innovation-led economic transformation, as it equips individuals with the technical and analytical competencies required to effectively leverage digital tools. Similarly, broadband infrastructure functions as a foundational enabler that supports connectivity and access to information, while public–private partnerships enhance resource mobilization and implementation efficiency.

This study aligns with recent empirical evidence which demonstrates that digital textile innovation embedded within art education systems significantly contributes to sustainable economic development and institutional reform in Southeast Nigeria (Onyebuchi-Igbokwe et al., 2026).

Overall, the study establishes that economic diversification is most effectively achieved through a synergistic ecosystem in which digital innovation, institutional collaboration, and human capital development interact to produce cumulative economic benefits.

5.3 Recommendations

In line with the findings, the following recommendations were made:

First, government and relevant stakeholders should intensify investment in **STEM education and capacity-building programmes,** as this has been identified as the strongest driver of economic diversification. Curriculum reforms, technical training, and innovation hubs should be expanded across tertiary and vocational institutions.

Second, there is a need to improve **broadband infrastructure and digital connectivity**, particularly in rural and semi-urban areas. Affordable and reliable internet access will enhance participation in digital textile systems, smart agriculture, and broader innovation ecosystems.

Third, policymakers should actively promote **digital textile innovation and smart agriculture integration** through targeted incentives such as grants, innovation clusters, and technology incubation centres. These interventions will accelerate adoption and scale-up of productive technologies.

Fourth, the strengthening of **public–private partnerships (PPPs)** is essential. Government should create enabling regulatory frameworks that encourage private sector participation in agricultural and industrial innovation while ensuring accountability and sustainability.

Finally, stakeholders should encourage cross-sector collaboration among educational institutions, technology firms, and agricultural enterprises to ensure that innovation outcomes translate into measurable economic diversification.

5.4 Contribution to Knowledge

This study contributes to existing literature by empirically integrating digital textile innovation and smart agriculture within a unified framework of economic diversification in a developing economy context. It further establishes STEM capacity development as a dominant predictor within this ecosystem, thereby extending theoretical understanding of human capital-led innovation models in emerging markets.

5.5 Limitations of the Study

The study is limited by its simulated empirical design, which may not fully capture real-time behavioural and economic variations. Additionally, the cross-sectional nature of the data restricts causal interpretation over time. Geographic focus on Southeast Nigeria may also limit generalizability to other regions.

5.6 Suggestions for Further Studies

Future studies should consider longitudinal designs to capture dynamic changes in digital adoption and economic diversification over time. Comparative studies across different geopolitical zones in Nigeria or other African economies would also provide broader generalizability. Additionally, qualitative approaches may be employed to explore deeper institutional and behavioral dynamics influencing technology adoption.

REFERENCES:

- **Abbasi, R., Martinez Rodriguez, P., & Ahmad, R. (2022).** The digitization of agricultural industry: A systematic literature review on Agriculture 4.0. *Smart Agricultural Technology, 2*, 100042. https://doi.org/10.1016/j.atech.2022.100042
- Adeyemo, J. T., Ahmed, A., Abaver, D. T., Riyadh, H. A., Tabash, M. I., & Lawal, A. I. (2024). *Technological Innovation and Agricultural Productivity in Nigeria Amidst Oil Transition: ARDL Analysis*. Economies, 12(9), 253. https://doi.org/10.3390/economies12090253
- Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E. H. M. (2019). Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. *IEEE Access, 7*, 129551–129583. https://doi.org/10.1109/ACCESS.2019.2932609
- Benjamin, O. O., & Foye, V. O. (2022). *Inclusion, Organizational Resilience, and Sustainable Development in Nigeria: The Role of Digital Innovations*. *Environmental Sciences Proceedings, 15*(1), 27. https://doi.org/10.3390/environsciproc2022015027
- **Czernich, N., Falck, O., Kretschmer, T., & Woessmann, L. (2011).** Broadband infrastructure and economic growth. *The Economic Journal, 121*(552), 505–532.

https://doi.org/10.1111/j.1468-0297.2011.02420.x

- Das, B. (2022). Diffusion of innovations: Theoretical perspectives and empirical evidence. *African Journal of Science, Technology, Innovation and Development, 14*(1), 94–103. https://doi.org/10.1080/20421338.2020.1814517
- **DeStefano, T., Kneller, R., & Timmis, J. (2023).** The (fuzzy) digital divide: The effect of universal broadband on firm performance. *Journal of Economic Geography, 23*(1), 139–177. https://doi.org/10.1093/jeg/lbac006
- **Elhusseiny, H., & Crispim, J. A. (2022).** SMEs, barriers and opportunities on adopting Industry 4.0: A review. *Procedia Computer Science, 196*, 864–871. https://doi.org/10.1016/j.procs.2021.12.086
- Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). *Industry 4.0 technologies: Implementation patterns in manufacturing companies*. *International Journal of Production Economics, 210*, 15–26. https://doi.org/10.1016/j.ijpe.2019.01.004
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). Sage Publications. https://us.sagepub.com/en-us/nam/a-primer-on-partial-least-squares-structural-equation-modeling-pls-sem/book280653
- **Hodge, G. A., & Greve, C. (2017).** On public–private partnership performance: A contemporary review. *Public Works Management & Policy, 22*(1), 55–78. https://doi.org/10.1177/1087724X16657830
- **Hou, Z., Liu, X., Tian, M., Zhang, X., Qu, L., Fan, T., & Miao, J. (2023).** Smart fibers and textiles for emerging clothes-based wearable electronics: Materials, fabrications and applications. *Journal of Materials Chemistry A, 11*, 17336–17372. https://doi.org/10.1039/D3TA02617E
- **Islam, M. R., Afroj, S., Yin, J., Novoselov, K. S., Chen, J., & Karim, N. (2024).** *Advances in printed electronic textiles*. *Advanced Science, 11*(6), e2304140. https://doi.org/10.1002/advs.202304140
- **Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022).** Enhancing smart farming through the applications of Agriculture 4.0 technologies. *International Journal of Intelligent Networks, 3*, 150–164. https://doi.org/10.1016/j.ijin.2022.09.004
- **Liu, L. X., Clegg, S., & Pollack, J. (2024).** *The effect of public–private partnerships on innovation in infrastructure delivery*. *Project Management Journal, 55*(1), 31–49. https://doi.org/10.1177/87569728231189989
- **Maffezzoli, F., Ardolino, M., Bacchetti, A., Perona, M., & Renga, F. (2022).** Agriculture 4.0: A systematic literature review on the paradigm, technologies and benefits. *Futures, 142*, 102998. https://doi.org/10.1016/j.futures.2022.102998
- **Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2023).** *STEM: Country Comparisons, International Comparisons*. Routledge.
- Mateko, F. M. (2024). *Information and Communication Technology and Poverty Alleviation in Nigeria*. *African Journal of Science, Technology, Innovation and Development, 16*(3), 439–450. https://doi.org/10.1080/20421338.2024.2334172
- Onyebuchi-Igbokwe, G.C.,Ndebilie, C.E.,Uzowuihe, B.O.,& Ohanele, R.C. (2026). Digital textile innovation and sustainable art education reform in Southeast Nigeria: Gpvernance, security, and development implications. *Alvan Journal of Social Sciences (AJSS)* 3, (1), 288-306. https://www-ajsspub-org.b12sites.com
- **Roehrich, J. K., Lewis, M. A., & George, G. (2014).** Are public–private partnerships a healthy option? A systematic literature review. *Social Science & Medicine, 113,*

110–119. https://doi.org/10.1016/j.socscimed.2014.03.037

- Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). Free Press. https://www.simonandschuster.com/books/Diffusion-of-Innovations-5th-Edition/Everett-M-Rogers/9780743222099
- Ruckdashel, R. R., et al. (2022). *Electronic Textiles (E-Textiles): Emerging Applications, Challenges, and Opportunities*. *Micromachines, 13*(10), 1789. https://doi.org/10.3390/mi13101789\
- Saiz-Rubio, V., & Rovira-Más, F. (2020). From smart farming towards Agriculture 5.0: A review on crop data management. *Agronomy, 10*(2), 207. https://doi.org/10.3390/agronomy10020207
- Straub, E. T. (2009). Understanding technology adoption: Theory and future directions for informal learning. *Review of Educational Research, 79*(2), 625–649. https://doi.org/10.3102/0034654308325896
- **UNESCO. (2023).** *Global education monitoring and STEM development reports.*
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). *User acceptance of information technology: Toward a unified view*. *MIS Quarterly, 27*(3), 425–478. https://doi.org/10.2307/30036540
- Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). *Digital Transformation: A Multidisciplinary Reflection and Research Agenda*. *Journal of Business Research, 122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022
- World Bank. (2024). *Nigeria development update: Staying the course—Progress amid pressing challenges*. World Bank Group. https://doi.org/10.1596/42407
- **Younes, B. (2023).** *Smart E-textiles: A review of their aspects and applications. Journal of Industrial Textiles, 53.* https://doi.org/10.1177/15280837231215493
- Zanello, G., Fu, X., Mohnen, P., & Ventresca, M. (2016). The creation and diffusion of innovation in developing countries: A systematic literature review. *Journal of Economic Surveys, 30*(5), 884–912. https://doi.org/10.1111/joes.12126

