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Integrating AI, IoT, and Robotics into TVET Building and Woodwork Training for Skills Competitiveness

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Abstract
This study employed a descriptive survey design to examine the integration of Artificial Intelligence (AI), the Internet of Things (IoT), robotics, and automation in Nigerian TVET Building and Woodwork programs, assessing challenges and strategic interventions. Using a purposive sample of 55 stakeholders (educators, administrators, industry experts) from four institutions in Lagos State, data were collected via the Stakeholders' Perspectives Questionnaire (SPQ). Analysis using one-way ANOVA revealed no significant differences in perceptions across stakeholder groups ($p > .05$). Key findings indicated a moderate level of technology integration, with AI and automation tools being utilised in instruction and assessment. However, major systemic barriers were identified, including inadequate digital infrastructure, insufficient instructor training, outdated curricula, and weak policy support. Stakeholders strongly endorsed strategic interventions such as industry partnerships, instructor upskilling, curriculum modernisation, and targeted investment in smart workshops to enhance global skills competitiveness. The study concludes that a holistic, policy-driven approach is essential for transforming TVET delivery and aligning graduate competencies with industry 4.0 demands.

Keywords: TVET, Digital Integration, Skills Competitiveness, Institutional Challenges, Strategic Interventions.

1. Introduction

Technological advancements driven by Artificial Intelligence (AI), the Internet of Things (IoT), robotics, and automation are rapidly transforming construction and manufacturing industries worldwide, setting new standards for skills development and workplace efficiency. Reports by the International Labour Organisation (ILO) note that these technologies are reshaping task structures, increasing precision, and creating new job roles that require advanced digital competencies (ILO, 2020). In Nigeria, however, adoption of these technologies within the Technical and Vocational Education and Training (TVET) sector, especially in Building Technology and Woodwork Technology, remains limited. This gap raises concerns about the preparedness of graduates to participate effectively in a digitalising labour market.

Evidence from UNESCO-UNEVOC indicates that many TVET systems in sub-Saharan Africa still rely on conventional training methods and analogue equipment, making it difficult for learners to acquire emerging technology skills needed for the Fourth Industrial Revolution (UNESCO-UNEVOC, 2022). Nigerian studies similarly report outdated curricula, obsolete machinery, and poor maintenance of technical workshops across public TVET institutions (NBTE, 2021; Bello & Muhammad, 2021). In Building Technology programmes, workshop facilities often lack digital surveying tools, Building Information Modelling (BIM) software, automated mixing systems, and smart safety devices. Woodwork Technology departments commonly operate with worn-out hand tools, limited access to CNC routers, and little exposure to digital fabrication systems, constraining students' ability to engage with modern production processes.

The integration of AI and IoT into technical courses is essential given their growing relevance in construction and woodworking. AI-enabled applications such as BIM-supported design analysis, automated estimation tools, and intelligent structural modelling are increasingly used in global construction training (World Bank, 2021). Similarly, IoT devices, ranging from sensor-embedded building materials to smart workshop monitoring systems, are transforming project management, safety tracking, and equipment maintenance. Yet, few Nigerian TVET institutions teaching Building Technology incorporate these digital tools into coursework, resulting in a mismatch between training content and industry practices (Ibrahim, et al., 2025). The absence of structured learning experiences around these technologies limits students' exposure to the digital workflow used by contemporary construction firms.

Robotics and automation also have significant

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implications for both courses. In Building Technology, automated bricklaying systems, robotic surveying equipment, and precision-based concrete dispensing technologies are increasingly common in international training models (McKinsey Global Institute, 2020). In Woodwork Technology, computer-numerically-controlled (CNC) machines, robotic carving systems, automated joinery equipment, and laser-cutting technologies now dominate industrial production. Studies from the African Union's TVET Cluster highlight that graduates lacking familiarity with these systems face reduced employability and limited entrepreneurial capacity (African Union, 2020). However, the majority of Nigerian TVET institutions still operate with fully manual tools and offer little or no training in programming or maintaining automated equipment.

Instructor capacity remains a critical barrier to integrating these technologies. UNESCO's Global TVET Review observes that most teachers in developing countries have not received training in digital pedagogy, smart machinery operation, or AI-supported assessment tools (UNESCO, 2020). In Nigeria, NBTE reports indicate that instructors in construction-related courses often lack competence in BIM applications, digital surveying instruments, and automated testing devices, while Woodwork instructors rarely have experience with CNC or CAD/CAM systems (NBTE, 2021). Without targeted professional development, teachers cannot effectively incorporate emerging technologies into workshop practice or assessment strategies.

Equity and inclusion also pose structural challenges. According to the World Bank, digital inequalities disproportionately affect rural learners, women, and persons with disabilities, limiting their participation in technology-driven TVET programmes (World Bank, 2022). In Building and Woodwork Technology specifically, inaccessible workshop layouts, poorly adapted tools, and gender-biased enrolment patterns reduce equitable participation. Practical inclusion requires accessible workstations, adjustable benches, digitally-supported learning aids, and adaptive safety equipment, recommendations echoed in UNESCO's framework on inclusive skills development (UNESCO, 2021). Incorporating ethical considerations is also essential, as AI-assisted tools used for assessment or design may reproduce bias, while digitisation of indigenous woodworking patterns raises issues of ownership and cultural preservation.

Despite growing global literature on smart TVET, there remains limited empirical research on how AI, IoT, robotics, and automation can be systematically integrated into Nigerian TVET Building Technology and Woodwork Technology programmes, particularly regarding workshop modernisation, instructor upskilling, curriculum revision, and equity-focused implementation. Therefore, this study aims to examine the integration of AI, IoT, robotics, and automation in TVET Building and Woodwork Technology programmes in Nigeria, to identify existing gaps, infrastructural constraints, instructional needs, and strategies for enhancing global skills competitiveness.

2. Statement of the Problem

Historically, Technical and Vocational Education and Training (TVET) in building and woodwork technology in Nigeria has relied on traditional, tool-based instructional methods that emphasise manual craftsmanship and basic construction skills (Sritharan, 2020). While these approaches were once adequate for a labour-intensive construction sector, they have seen little evolution despite rapid technological changes in global construction and woodwork industries (Chukwu et al., 2024). As a result, Nigerian TVET has struggled to keep pace with emerging digital and automated construction practices.

Currently, the state of the art in construction training globally involves the integration of artificial intelligence, robotics, the Internet of Things (IoT), and automation, which are increasingly embedded in vocational education systems to enhance productivity and workforce competitiveness (Muhammad et al., 2023). In contrast, Nigerian TVET institutions face inadequate digital infrastructure, limited access to modern training equipment, and insufficient instructor capacity to teach emerging technologies due to weak professional development structures (Gondwe, 2021; Owoko, 2024). National surveys and employer reports consistently reveal significant skills gaps among TVET graduates, particularly in digital skills, technological adaptability, and problem-solving, rendering many graduates unprepared for technology-driven roles in the construction and woodwork sectors (Ejilah et al., 2023; Ginigaddara et al., 2024).

Moreover, weak collaboration between industry and TVET institutions has resulted in outdated curricula that fail to reflect current workplace technologies and practices (Aithal & Maiya, 2023). Consequently, Nigeria risks falling further behind global skills standards as its TVET system remains misaligned with the demands of a rapidly digitising construction industry (Kayode, 2023). Therefore, the core problem addressed in this study is the insufficient integration of emerging technologies, inadequate instructional capacity, and limited institutional support within Nigerian TVET programmes in building and woodwork technology, which collectively undermine graduates' readiness for the modern labour market.

3. Purpose of the Study

1. Examine the current extent of integration of emerging technologies, such as Artificial Intelligence (AI), the Internet of Things (IoT), robotics, and automation, in TVET programs related to building and woodwork technology.
2. Identify the key challenges, gaps, and opportunities affecting the upscaling of technology-enhanced TVET for improving learners' global skills competitiveness

and employability in the construction and woodworking sectors.

3. Determine strategic interventions and institutional frameworks needed to transform TVET delivery through the structured adoption of smart technologies and innovation-driven teaching practices.

4. Research Questions

1. To what extent have emerging technologies such as AI, IoT, robotics, and automation been integrated into TVET programs related to building and woodwork technology?
2. What challenges, gaps, and opportunities influence the upscaling of technology-enhanced TVET for improving learners' global skills competitiveness and employability in the construction and woodworking sectors?
3. What strategic interventions and institutional frameworks can be adopted to transform TVET delivery through the structured use of smart technologies and innovation-driven teaching practices?

5. Hypotheses (H_0)

H_{01}: There is no significant difference in the level of integration of emerging technologies (AI, IoT, robotics, and automation) in TVET programs for building and woodwork technology across relevant stakeholder groups.

H_{02}: Institutional factors, specifically infrastructure, instructor capacity, and policy support, have no significant effect on the upscaling of emerging technologies in TVET for building and woodwork technology.

H_{03}: There is no significant relationship between the integration of emerging technologies in TVET programs and the global skills competitiveness of learners in building and woodwork education.

6. Methodology

This study adopted a descriptive survey research design to obtain the views of key stakeholders, TVET educators, administrators, and industry experts, on the integration of emerging technologies in Building and Woodwork TVET programs across four major institutions in Lagos State, Nigeria: The University of Lagos (UNILAG), Lagos State University of Education (LASUED), Yaba College of Technology (YABATECH), and the Federal College of Education (Technical), Akoka (FCE(T)). The study population comprised individuals actively engaged in teaching, policy administration, and industrial application of technical and vocational skills, and a purposive sampling technique was used to select 55 participants (20 Educators, 15 Administrators, and 20 Industry Experts). This technique was justified because the study required respondents with specialised knowledge and direct experience in the implementation and evaluation of technology-enhanced TVET systems. Data were collected using a researcher-developed instrument titled the Stakeholders' Perspectives Questionnaire (SPQ), which consisted of three sections: Section A (demographic information), Section B (22 items measuring the level of integration of AI, IoT, robotics, and automation), and Section C (18 items assessing institutional challenges, policy support, staff capacity, and readiness for technology-driven TVET). All items were rated on a 5-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1). To ensure content and face validity, the draft instrument was reviewed by three experts, two from UNILAG and one from LASUED, whose recommendations were incorporated to improve clarity, relevance, and alignment with the study objectives. Reliability was confirmed through a pilot test conducted on respondents from an institution not included in the main study, yielding a Cronbach's alpha coefficient of 0.86, which exceeds the acceptable threshold of 0.70 for internal consistency (Cronbach, 1951). For data analysis, a one-way ANOVA was used to test the null hypotheses at the 0.05 level of significance, and prior to running ANOVA, the assumptions of normality and homogeneity of variance were assessed using the Shapiro–Wilk test and Levine's test, respectively. Ethical approval for the study was obtained from the institutional research ethics committee, and all participants were informed of the study's purpose, assured of confidentiality, and provided voluntary consent before participating.

7. Results

Table 1 presents the extent to which emerging technologies, specifically Artificial Intelligence (AI), the Internet of Things (IoT), robotics, and automation, have been integrated into Building and Woodwork TVET programs as perceived by three stakeholder groups: TVET educators, administrators, and industry experts. Across all items, the mean scores for the stakeholders range between 3.68 and 3.80, indicating a generally high and positive level of agreement with statements relating to technology integration. This suggests that emerging technologies are perceived to be moderately to strongly embed in current instructional, assessment, and workshop practices.

The results show that all stakeholder groups reported strong agreement (Means = 3.68–3.79), particularly regarding the use of AI tools in instruction and assessment, as well as the training of instructors to apply AI and automation. Industry experts showed the highest means across AI-related items, suggesting a stronger awareness or higher expectations of technology integration from an industrial perspective.

Responses relating to IoT applications also reflect high levels of agreement (Means = 3.71–3.79). Stakeholders consistently indicated that IoT-driven simulations and practical applications are incorporated into building technology instruction. Educators and administrators reported very similar perceptions, reflecting institutional alignment around IoT adoption.

All groups agreed that robotics is included in the current curriculum and that institutions provide access to robotics and automation tools (Means = 3.70–3.79).

Table 1: Extent of Integration of Emerging Technologies in Building and Woodwork TVET Programs

S/N	**Item Statement**	**TVET Educators Mean (SD)**	**TVET Administrators Mean (SD)**	**Industry Experts Mean (SD)**
AI Integration				
1	AI tools are actively used in the delivery of woodwork training.	3.68 (0.47)	3.73 (0.46)	3.76 (0.48)
2	AI-powered tools are used for student assessment in woodwork education.	3.72 (0.49)	3.78 (0.48)	3.79 (0.45)
3	Instructors are trained to use AI and automation in woodwork instruction.	3.78 (0.46)	3.76 (0.43)	3.79 (0.47)
IoT Integration				
4	IoT applications are integrated into building technology practicals.	3.71 (0.46)	3.74 (0.46)	3.78 (0.49)
5	Learners are exposed to real-time building simulations using smart technology.	3.79 (0.47)	3.78 (0.46)	3.76 (0.44)
Robotics Integration				
6	Robotics is included in the current TVET curriculum for woodwork.	3.75 (0.47)	3.79 (0.44)	3.79 (0.49)
7	Institutions provide access to robotics and automation for instructional use.	3.70 (0.45)	3.73 (0.48)	3.74 (0.42)
Automation and Smart Tools Integration				
8	Automation systems are used in school workshops for hands-on training.	3.80 (0.48)	3.75 (0.46)	3.78 (0.42)
9	3D modelling and smart fabrication tools are part of the learning experience.	3.76 (0.43)	3.78 (0.46)	3.75 (0.47)
10	Technology-enhanced learning is encouraged in building/woodwork classes.	3.79 (0.47)	3.68 (0.44)	3.76 (0.46)
Grand Mean (SD)		**3.80 (0.47)**	**3.75 (0.46)**	**3.77 (0.44)**

Table 2: One-Way ANOVA Summary for Differences in Mean Responses on Integration of AI, IoT, Robotics, and Automation in Building and Woodwork TVET Programs

Source	**SS**	**df**	**MS**	**F**	**p**	**η²**
Between Groups	0.0355	2	0.0177	0.10	0.90	0.004
Within Groups	8.8496	52	0.1702	—	—	—
Total	**8.8851**	**54**	—	—	—	—

Although the values are slightly lower than those recorded for AI and IoT, the means still indicate substantial integration. The slight variation among groups may reflect differences in exposure to robotics-based instructional facilities.

Automation technologies appear to be the most integrated of all categories assessed, with educators recording the highest mean value in the entire table for automation systems (Mean = 3.80). Stakeholders also agreed on the use of 3D modelling, smart fabrication tools, and technology-enhanced learning practices, further supporting the perception that institutions are transitioning towards smart workshop environments.

The grand means for educators (3.80), administrators (3.75), and industry experts (3.77) all fall within the upper range of the scale, indicating a strong consensus that emerging technologies are substantially integrated into Building and Woodwork TVET programs. The relatively narrow standard deviations (0.43–0.49) show consistency in responses within each group, suggesting a stable shared perception across institutions. Collectively, the findings demonstrate that AI, IoT,

Table 3: Challenges and Institutional Gaps in Upscaling Technology in Building and Woodwork TVET Programs

S/N	Item Statement	TVET Educators Mean (SD)	TVET Administrators Mean (SD)	Industry Experts Mean (SD)
A. Infrastructure and Technical Support Challenges				
11	Lack of infrastructure limits the use of emerging technologies in woodwork training.	3.70 (0.46)	3.48 (0.42)	3.75 (0.45)
12	There is a lack of ongoing technical support for smart technology maintenance.	3.80 (0.43)	3.79 (0.48)	3.80 (0.47)
B. Instructor Capacity and Workforce Gaps				
13	Insufficient training for staff on how to use AI, IoT, or robotics in TVET.	3.70 (0.45)	3.70 (0.44)	3.79 (0.48)
14	Resistance to change among staff affects technology adoption in TVET.	3.24 (0.41)	3.45 (0.46)	3.55 (0.42)
15	Institutions face difficulty in recruiting skilled, tech-savvy instructors.	3.73 (0.46)	3.74 (0.47)	3.71 (0.42)
C. Funding and Resource Limitations				
16	Budget constraints hinder the purchase and maintenance of smart equipment.	3.45 (0.41)	3.46 (0.43)	3.48 (0.43)
D. Curriculum and Policy-Related Gaps				
17	The curriculum is outdated and does not reflect current technological trends.	3.49 (0.41)	3.45 (0.42)	3.56 (0.43)
18	Policies do not adequately support the integration of emerging technologies.	3.03 (0.40)	3.02 (0.42)	3.25 (0.44)
E. Institutional Leadership and External Collaboration				
19	Limited collaboration between TVET institutions and technology providers.	3.71 (0.41)	3.75 (0.42)	3.76 (0.44)
20	Institutional leadership lacks commitment toward digital transformation in TVET.	3.45 (0.41)	3.79 (0.48)	3.80 (0.48)
Grand Mean (SD)		**3.53 (0.43)**	**3.56 (0.44)**	**3.65 (0.45)**

robotics, and automation are perceived to be well integrated into TVET delivery in the building and woodwork specialization. The high level of agreement across the three groups indicates that technological transformation in TVET is progressing positively, positioning learners to acquire globally relevant and industry-responsive skills.

Table 2 presents the one-way ANOVA results comparing the mean responses of TVET educators, administrators, and industry experts on the extent of integration of AI, IoT, robotics, and automation in Building and Woodwork TVET programs. The analysis shows that there was no statistically significant difference in the perceptions of the three stakeholder groups, F (2, 52) = 0.10, *p* = .90. This indicates that the respondents, regardless of their institutional roles, held highly consistent views about the level of emerging technology integration in TVET programs.

The between-groups sum of squares (SS = 0.0355) was extremely small relative to the within-groups sum of squares (SS = 8.8496), demonstrating minimal variation attributable to stakeholder categories. The corresponding effect size ($\eta^2 = .004$) further confirms that the proportion of variance explained by group differences was negligible. In practical terms, this means that educators, administrators, and industry experts shared similar assessments of how AI, IoT, robotics, and automation are embedded in instructional and workshop practices, suggesting a unified perception across the TVET ecosystem.

The non-significant result also implies that technology integration practices are being implemented uniformly across the institutions sampled, with no stakeholder group reporting substantially higher or lower levels of adoption. Such convergence is important for policy harmonization, curriculum alignment, and strategic decision-making in technology-enhanced TVET.

Table 3 presents the mean ratings and standard deviations of TVET educators, administrators, and industry experts regarding the key challenges and institutional gaps affecting the upscaling of emerging technologies in Building and Woodwork TVET programs. Overall, the results show moderate to high agreement across stakeholder groups, with mean scores ranging from 3.03 to 3.80, indicating that several systemic and institutional barriers significantly hinder effective technology integration. Stakeholders strongly agreed that inadequate infrastructure poses a substantial barrier, with mean scores between 3.48 and 3.75. The highest means in the entire table were recorded for the lack of ongoing technical support (Educators = 3.80; Administrators = 3.79; Industry Experts = 3.80), highlighting widespread concern about the sustainability and maintenance of smart technologies in TVET institutions.

Insufficient staff training (Means = 3.70–3.79) and limited availability of tech-savvy instructors (Means = 3.71–3.74) also emerged as notable constraints. Resistance to change among staff produced moderately high means (Educators = 3.24; Administrators = 3.45; Industry Experts = 3.55), indicating persistent human-resource challenges that may slow the adoption of digital innovations. Budget constraints were consistently rated as a major impediment (Means = 3.45–3.48). This suggests that institutions may struggle to procure, upgrade, or maintain automation systems, robotics tools, smart workshop equipment, and AI-driven instructional technologies.

Two of the **lowest-rated items** were found in this category. Stakeholders expressed moderate concern regarding outdated curricula (Means = 3.45–3.56), but the most critical issue identified was inadequate policy support, with the lowest means across the entire table (Educators = 3.03; Administrators = 3.02; Industry Experts = 3.25). These low values reflect systemic policy gaps that hinder large-scale adoption of emerging technologies in TVET. Moderately high agreement (Means = 3.71–3.76) suggests that limited collaboration between institutions and technology providers remains a challenge. Additionally, administrators (Mean = 3.79) and industry experts (Mean = 3.80) perceived a stronger leadership-related gap than educators, implying possible misalignment between frontline staff and institutional management regarding digital transformation readiness.

The grand means, 3.53 for educators, 3.56 for administrators, and 3.65 for industry experts, show consistent perceptions across stakeholder groups. Industry experts reported slightly higher concerns overall, likely reflecting their direct awareness of industry expectations and technological standards. Collectively, the results reveal that challenges in infrastructure, staff capacity, leadership commitment, curriculum relevance, and policy alignment significantly affect the scaling of emerging technologies in Building and Woodwork TVET programs. Addressing these barriers is essential for achieving sustainable digital transformation in the sector.

Table 4 presents the results of a one-way ANOVA conducted to determine whether significant differences existed in the perceptions of TVET educators, administrators, and industry experts regarding the challenges associated with integrating emerging technologies into Building and Woodwork TVET programs. The analysis shows that the differences in mean perceptions among the three groups were not statistically significant, $F(2, 52) = 0.25$, $p = .78$. This non-significant outcome, accompanied by a very small effect size ($\eta^2 = .009$), indicates that stakeholder group membership explains only a negligible proportion of the variation in responses. In practical terms, all three groups share similar views about the major obstacles confronting technology-enhanced TVET, such as inadequate infrastructure, limited technical support, insufficient staff training, funding constraints, outdated curricula, and weak policy support. The assumptions required for ANOVA were satisfied, as tests of normality and homogeneity of variance showed no violations. Overall, these findings suggest that the challenges identified are broad and systemic, affecting all categories of stakeholders equally, and thus require coordinated institutional and policy-level interventions rather than group-specific solutions.

Table 5 summarises stakeholders' views on strategic approaches for strengthening global skills competitiveness through enhanced technology integration in Building and Woodwork TVET programs. Overall, the results show a strong level of agreement across educators, administrators, and industry experts, with mean scores ranging from 3.74 to 4.14. This indicates that respondents broadly support

Table 4: One-Way ANOVA Summary for Differences in Perceptions of Technology-Related Challenges Among TVET Stakeholders

Source	SS	df	MS	F	p	η²
Between Groups	0.084	2	0.042	0.25	0.78	0.009
Within Groups	8.873	52	0.171	—	—	—
Total	**8.957**	**54**	—	—	—	—

Table 5: Strategic Approaches for Enhancing Global Skills Competitiveness through Technology Integration in Building and Woodwork TVET

S/N	Item Statement	TVET Educators Mean (SD)	TVET Administrators Mean (SD)	Industry Experts Mean (SD)
A. Industry Collaboration and Partnerships				
21	Partnerships with tech industries improve training relevance.	3.95 (0.49)	3.78 (0.54)	3.85 (0.49)
22	Smart workshops (IoT, CNC, robotics) enhance learner skills.	4.10 (0.52)	4.05 (0.50)	3.80 (0.49)
23	Participation in global competitions enhances skill benchmarking.	4.12 (0.51)	4.00 (0.52)	4.01 (0.48)
B. Instructor Upskilling and Capacity Development				
24	Upskilling instructors in AI and automation improves competitiveness.	3.80 (0.48)	3.81 (0.51)	3.87 (0.49)
C. Curriculum and Training Innovation				
25	Aligning curriculum with global tech standards prepares global-ready graduates.	4.02 (0.52)	4.00 (0.49)	4.02 (0.50)
26	Innovation hubs promote creativity and higher-order skills.	4.00 (0.53)	3.82 (0.49)	4.02 (0.49)
27	Encouraging AI-driven innovation boosts employability.	3.79 (0.49)	3.76 (0.47)	3.74 (0.46)
D. Certification, Policy, and Investment Strategies				
28	International certifications improve graduates' job opportunities.	4.06 (0.54)	4.08 (0.48)	4.05 (0.49)
29	Strategic investment in digital TVET tools strengthens competitiveness.	4.14 (0.49)	4.03 (0.48)	4.04 (0.47)
30	Technology-driven policy reforms elevate global recognition of TVET.	4.14 (0.51)	4.10 (0.54)	3.82 (0.49)
Grand Mean (SD)	**—**	**4.01 (0.51)**	**3.94 (0.50)**	**3.92 (0.49)**

Table 6: One-Way ANOVA Summary for Differences in Perceived Strategic Approaches for Enhancing Global Skills Competitiveness

Source	SS	df	MS	F	p	η²
Between Groups	0.087	2	0.043	0.17	0.84	0.007
Within Groups	13.004	52	0.250	—	—	—
Total	**13.091**	**54**	**—**	**—**	**—**	**—**

the proposed strategies and perceive them as essential for improving the global relevance of TVET. Stakeholders consistently emphasised the importance of industry partnerships and collaboration, particularly the establishment of smart workshops equipped with IoT, CNC, and robotic systems. These items received some of the highest ratings, reflecting the belief that industry-linked, technology-rich learning environments are critical for producing graduates who can compete internationally. Participation in global competitions such as World Skills was also highly endorsed, suggesting that stakeholders view these platforms as valuable opportunities for benchmarking learner performance against global standards.

The results further highlight the significance of instructor upskilling, especially in AI and automation, with mean scores approaching 4.0 across all groups. This highlights the consensus that instructors must be adequately trained to deliver technology-focused curricula and prepare learners for rapidly evolving industry requirements. Items related to curriculum innovation, such as aligning programs with international technology standards and establishing institutional innovation hubs, also received strong support. These findings point to the need for TVET systems to move beyond traditional teaching approaches and embed creativity, problem-solving, and digital competence into program design.

Finally, respondents strongly agreed on the critical role of policy reform and strategic investment in digital tools. The highest overall mean scores were recorded for items related to investment in technology infrastructure and the implementation of supportive policies. This demonstrates a shared understanding that meaningful improvement in global competitiveness must be supported by robust institutional and governmental commitment. Taken together, these findings show that stakeholders view technological integration in TVET not only as a pedagogical enhancement but as a strategic pathway for preparing globally competitive graduates. The high grand means across all groups suggest a clear, collective direction for policy and institutional action.

Table 6 presents the one-way ANOVA results examining whether TVET educators, administrators, and industry experts differ in their perceptions of strategic approaches for enhancing global skills competitiveness through technology integration. The analysis indicates no statistically significant difference across the three stakeholder groups, $F(2, 52) = 0.17$, $p = .84$. This finding suggests a high level of consensus regarding the proposed strategies, including industry partnerships, instructor upskilling, curriculum innovation, international certification, and technology-focused policy reforms. The effect size was extremely small ($\eta^2 = .007$), meaning that differences between groups accounted for less than 1% of the variance in responses. Assumption checks confirmed that normality and homogeneity of variance were upheld, supporting the validity of the ANOVA results. Overall, the data show that educators, administrators, and industry experts share similar perspectives on the strategic actions required to enhance the global competitiveness of TVET graduates, reinforcing the need for coordinated and system-wide implementation of these strategies.

8. Discussion of Findings

Findings from Table 1 indicate that the integration of emerging technologies into Building and Woodwork TVET programs is occurring, but at a moderate and uneven pace. Stakeholders reported relatively high mean ratings (Educators = 3.80; Administrators = 3.75; Industry Experts = 3.77), demonstrating recognition that tools such as AI-based assessment, IoT-enabled building simulations, 3D modelling, and basic robotics are beginning to appear within training environments. These results directly address Research Question 1 by showing that although technology integration is progressing, it has not yet reached a comprehensive or fully institutionalised level.

The observed trend supports Soto's (2020) assertion that TVET systems in emerging economies are typically positioned in transitional phases of digital adoption, demonstrating partial rather than full integration. This also mirrors the findings of Iweuno et al. (2024), who argue that while awareness and initial adoption of smart technologies are growing within African TVET institutions, depth and sustainability remain limited. The implication for practice is that Building and Woodwork TVET programs must move beyond surface-level adoption toward structured, curriculum-embedded use of emerging technologies if graduates are to meet global digital competency requirements.

Results presented in Table 3 reveal several persistent institutional challenges that continue to hinder the upscaling of emerging technologies. These include inadequate infrastructure, insufficient technical support, limited instructor training, outdated policies, weak institutional leadership, and moderate resistance to change among staff. Policy-related barriers received the lowest ratings across groups (Means = 3.02–3.25), indicating that national and institutional policies remain misaligned with the needs of technology-driven TVET. These findings address Research Question 2 by confirming that systemic and structural constraints significantly impede the modernisation of Building and Woodwork programs.

The findings align with those of Bhattacharjya (2025), who emphasises that infrastructural deficits, outdated curricula, and recurring funding constraints hinder the modernisation of TVET systems across developing regions. The present study also agrees with Imran (2023), who warns that the lack of policy alignment and insufficient digital maintenance widen the digital divide in education. The ANOVA results (Tables 2 and 4) showed no significant differences among stakeholder groups ($p > .05$), indicating a shared recognition of the challenges facing digital transformation efforts within TVET. This supports Dochia's (2025) argument that successful digital innovation requires not only technological investment but also institutional and cultural readiness. These findings suggest that TVET institutions offering Building and Woodwork programmes must strengthen digital infrastructure, provide systematic professional development for instructors, update institutional policies, and implement change management strategies capable of reducing resistance to technology adoption.

Evidence from Table 5 shows strong consensus among educators, administrators, and industry experts regarding the most effective strategies for enhancing global skills competitiveness in Building and Woodwork TVET. High grand mean ratings (Educators = 4.01; Administrators = 3.94; Industry Experts = 3.92) indicate strong stakeholder support for approaches such as strengthening collaboration with industry, improving the digital skills of instructors, establishing innovation hubs, aligning curricula with international standards, and investing in digital infrastructure.

These findings address Research Question 3 by highlighting the strategic measures perceived as necessary for preparing TVET graduates to compete globally. The results reinforce the position of Ayieko et al. (2023), who argue that strong industry–TVET linkages are essential for training that responds to international labour market needs. Similarly, the importance placed on policy and institutional readiness aligns with Vranayova's (2024) emphasis on the need for structural support to implement technology-enabled training in construction-related programs.

The ANOVA results in Table 6 indicated no significant differences across stakeholder groups ($p = .84$), suggesting unified agreement on the strategies needed for global skills competitiveness. The minimal effect size ($\eta^2 = .007$) further demonstrates that this consensus is consistent across the three groups surveyed. These findings suggest the importance of coordinated investments in industry collaboration, digital facilities, instructor upskilling, curriculum modernisation, and supportive policy frameworks.

Across all research questions, the study shows strong alignment among educators, administrators, and industry experts regarding the current state of technology integration, the challenges faced, and the strategic pathways required for improvement. The consistency in perceptions, confirmed by the non-significant ANOVA results across Tables 2, 4, and 6, suggests that the modernisation of Building and Woodwork TVET programs in Nigeria requires holistic, system-wide interventions.

The findings collectively imply that achieving global competitiveness will depend on coordinated actions involving digital infrastructure upgrades, stronger industry partnerships, continuous instructor capacity building, curriculum reforms aligned with global standards, and the establishment of national and institutional policies that support technology-driven TVET transformation. Without such an integrated approach, students may remain underprepared for the rapidly evolving global labour market.

9. Conclusion

This study examined the integration of AI, IoT, robotics, and automation within Building and Woodwork Technology TVET programs, the institutional challenges affecting their adoption, and the strategic approaches required to enhance global skills competitiveness. Findings showed that although emerging technologies are being introduced into TVET institutions, their integration remains moderate and uneven, with usage often limited to isolated instructional activities rather than fully embedded curriculum practices. These results demonstrate that the digital transformation of Building and Woodwork TVET is still at an early developmental stage. The study also revealed persistent institutional barriers, particularly inadequate infrastructure, limited technical support, insufficient instructor capacity, outdated curricula, and weak policy frameworks, which collectively impede the upscaling of smart technologies. Stakeholder perceptions across all groups were statistically similar, indicating widespread recognition of the systemic constraints that hinder meaningful technology adoption.

In terms of strategic directions, participants strongly supported measures such as enhanced industry collaboration, instructor upskilling, curriculum alignment with global standards, and investment in smart workshops. These strategies were viewed as essential for improving global skills competitiveness and preparing learners for technology-driven construction and woodworking environments. Overall, the study contributes to knowledge by providing empirical evidence on the current readiness and constraints of technology integration in Building and Woodwork TVET in Nigeria. It further contributes to practice by identifying actionable, stakeholder-endorsed strategies that institutions and policymakers can adopt to strengthen digital capacity, modernise training delivery, and align TVET outcomes with international skill standards.

10. Recommendations

Based on the empirical findings regarding the extent of technology integration, the challenges encountered, and the strategic approaches identified by stakeholders, the following recommendations are proposed for strengthening Building and Woodwork Technology TVET programs:

1. Findings from Table 1 showed moderate integration of AI, IoT, robotics, and automation. TVET

institutions should therefore embed these technologies more systematically into course content, practical modules, and assessment frameworks to ensure consistent and industry-aligned implementation.

2. Challenges related to inadequate staff training (Table 3) indicate a need for continuous professional development. Institutions should adopt targeted upskilling programs focused on digital pedagogy, smart tools operation, and technology-supported instruction.

3. Infrastructure deficits and limited maintenance support were among the highest challenges identified. Institutions should invest in upgrading digital facilities and establish dedicated technical support units to ensure the reliability and sustainability of technology-enhanced workshops.

4. With policy-related gaps rated lowest by stakeholders, there is an urgent need for policy revision to support technology-driven TVET. This includes policy frameworks that mandate digital integration, guide resource allocation, and support innovation in Building and Woodwork programs.

5. Stakeholders strongly endorsed industry partnerships as a key strategy for global competitiveness (Table 5). Institutions should formalise collaborations to access equipment, internships, joint research, and workplace-based learning opportunities.

6. High support for international certification and competitions suggests their perceived value in enhancing graduate competitiveness. TVET institutions should incorporate internationally benchmarked assessments and encourage participation in global skills competitions, such as WorldSkills.

7. The strong endorsement of digital investment strategies indicates the need for phased, data-driven procurement of emerging technologies. Institutions should prioritise cost-effective tools aligned with program needs and sustain them through planned maintenance cycles.

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