



**GREENING TECHNICAL AND VOCATIONAL EDUCATION AND
TRAINING: EXPERIMENTAL AND MIXED-METHODS EVIDENCE
FROM LAGOS STATE TECHNICAL COLLEGES**

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Abstract

Technical and Vocational Education and Training (TVET) plays a critical role in workforce development. However, the global transition toward sustainability requires the integration of green competencies into vocational curricula. This study employed a randomized controlled trial (RCT) within a mixed-methods framework to examine the impact of sustainability-integrated instruction on students' learning outcomes in five Lagos State technical colleges. A total of 200 students were randomly assigned to experimental ($n = 100$) and control ($n = 100$) groups, with 187 participants retained for final analysis following attrition. The intervention, implemented over a 12-week instructional period, introduced modules on renewable energy, waste management, and environmental ethics. Quantitative data were analysed using ANCOVA and MANOVA to assess differences in sustainability knowledge, technical skills, and attitudes, while qualitative data from focus groups were thematically analysed. Results revealed significant improvements in sustainability knowledge ($F(1,184) = 18.45, p < .001, \eta^2 = .12$) and technical skills ($F(1,184) = 11.92, p = .001, \eta^2 = .09$) among the experimental group. However, no statistically significant differences were observed in attitudinal disposition or collaborative skills ($p > .05$). Qualitative findings highlighted increased learner engagement but identified barriers including limited infrastructure, rigid curricula, and insufficient teacher preparedness. The study provides robust short-term causal evidence that sustainability integration enhances cognitive and technical outcomes in TVET,



while underscoring the need for systemic reforms to achieve deeper attitudinal transformation. The findings provide evidence for a scalable framework for greening TVET systems in sub-Saharan Africa.

Keywords: *Technical and Vocational Education and Training (TVET), sustainability competencies, green skills, curriculum innovation, Lagos State, randomized controlled trial, sustainable development*

1.Introduction

The accelerating global transition toward sustainability has redefined the landscape of education and workforce development. Technical and Vocational Education and Training (TVET), traditionally perceived as skill-based and industry-driven, is increasingly recognized as a strategic driver for sustainable economic growth and environmental stewardship (UNESCO-UNEVOC, 2023). Within this evolving paradigm, sustainability competencies encompassing systems thinking, anticipatory foresight, normative ethics, and strategic problem-solving are viewed as core attributes required of 21st-century vocational graduates (Barth & Rieckmann, 2023; Mulder, 2022).

In Nigeria, and particularly Lagos State, the urgency to align TVET education with sustainable development imperatives is acute. Lagos, a rapidly urbanizing megacity of over 20 million inhabitants, faces complex challenges of resource depletion,

waste management, flooding, and high youth unemployment (Olawale et al., 2024). According to the Lagos State Technical and Vocational Education Board (LASTVEB, 2024), over 5,000 students enrol annually in 5 state technical colleges. However, current curricula largely emphasize traditional trades, including electrical installation, mechanical craft, computer craft, electronics, refrigeration and air conditioning, catering, printing, graphic design, plumbing, carpentry, garment making, and welding and fabrication. This gap limits learners' ability to participate meaningfully in Nigeria's emerging green economy, which the Federal Ministry of Education (FME, 2023) identifies as a national development priority under the *Renewed Hope Agenda*.

The integration of sustainability into TVET is embedded in global frameworks such as UNESCO's Education for Sustainable Development (ESD 2030), the UN Sustainable Development Goals (SDG 4 and



SDG 12), and the ILO's Green Jobs Initiative. These frameworks emphasize education's transformative potential in developing the skills, values, and attitudes necessary for sustainable societies (UNESCO, 2023; ILO, 2024). The UNESCO-UNEVOC (2022) report on *Greening TVET Institutions* highlights that embedding sustainability competencies within technical curricula leads to enhanced learner employability, innovation, and ethical accountability.

From a theoretical standpoint, this study draws on transformative learning theory (Mezirow, 1991) and competency-based education frameworks (Mulder, 2022). Transformative learning posits that sustainability education should enable critical reflection and paradigm shifts in learners' worldviews. Competency-based frameworks, meanwhile, advocate aligning educational outcomes with observable, measurable skills such as the ability to design energy-efficient systems or manage waste in production processes. Integrating both approaches ensures that sustainability is not taught as abstract theory but as applied practice embedded in everyday vocational contexts.

Nigeria's TVET system has evolved through various policy reforms, including the National Policy on Education (NPE, 2023), the National Board for Technical Education (NBTE) Standards (2024), and the Skills for Prosperity Programme (2022), yet implementation remains uneven. Despite federal initiatives such as the ₦120 billion *Youth Skills Development Fund* and *Get Skilled, Earn Money* programme most TVET curricula prioritize employment over environmental responsibility (Aina & Okoro, 2023). Studies indicate that less than 15% of TVET programmes nationwide include sustainability-focused content, and teacher capacity for environmental education remains limited (Okolie et al., 2023).

Recent Federal Government interventions demonstrate a growing commitment to strengthening the quality and relevance of Technical and Vocational Education and Training (TVET) in Nigeria. According to ThisDay (2026), the Federal Government, in collaboration with the Institute of Education, Singapore, launched the "Train the Trainers (Pedagogy & Assessment) Programme" for TVET instructors. The programme is jointly implemented by the Federal Ministry of Education, the National



Board for Technical Education (NBTE), and the Institute of Education, Singapore.

In Lagos State, LASTVEB's innovative apprenticeship programmes like the *School Leavers Modern Apprenticeship Training Programme (SL-MATP)* and the *Graduate Vocational Employability Skill Training Programme (GV-ESTP)* have expanded access for out-of-school youth (LASTVEB, 2021). However, these programmes primarily target immediate employability rather than fostering sustainable skill sets aligned with global green standards. Hence, the integration of sustainability competencies represents both a pedagogical and developmental necessity.

Sustainability integration in TVET has a direct bearing on Lagos State's socioeconomic and ecological resilience. The city generates over 14,000 tonnes of waste daily, with less than 40% effectively recycled (Lagos State Environmental Protection Agency, 2024). Technical graduates trained in waste management, renewable energy installation, and green construction can help mitigate such issues while creating new employment pathways. Additionally, sustainable TVET aligns with

Nigeria's Energy Transition Plan (ETP 2060), which targets a 47% reduction in emissions through renewable technologies and green entrepreneurship (Federal Ministry of Environment, 2023).

Although prior studies have explored sustainability awareness (Ezeanya et al., 2022; Udoh & Enang, 2023), experimental evidence remains scarce. This study addresses this gap by employing a randomized controlled trial to examine the short-term causal effects of sustainability-integrated instruction on student outcomes.

1.2 Study Objectives

This study aims to:

1. evaluate the impact of sustainability-integrated curricula on students' knowledge, skills, and attitudes in Lagos State technical colleges
2. compare outcomes between experimental and control groups
3. identify implementation enablers and barriers
4. propose a contextualized framework for greening TVET in Lagos State

1.3 Conceptual Framework

The study conceptualizes sustainability curriculum integration as the primary independent variable influencing learner outcomes (knowledge, technical skills, and

attitudes). Teacher competence and institutional conditions are treated as implementation factors rather than statistically tested mediators. The framework reflects a causal instructional pathway rather than a structural model

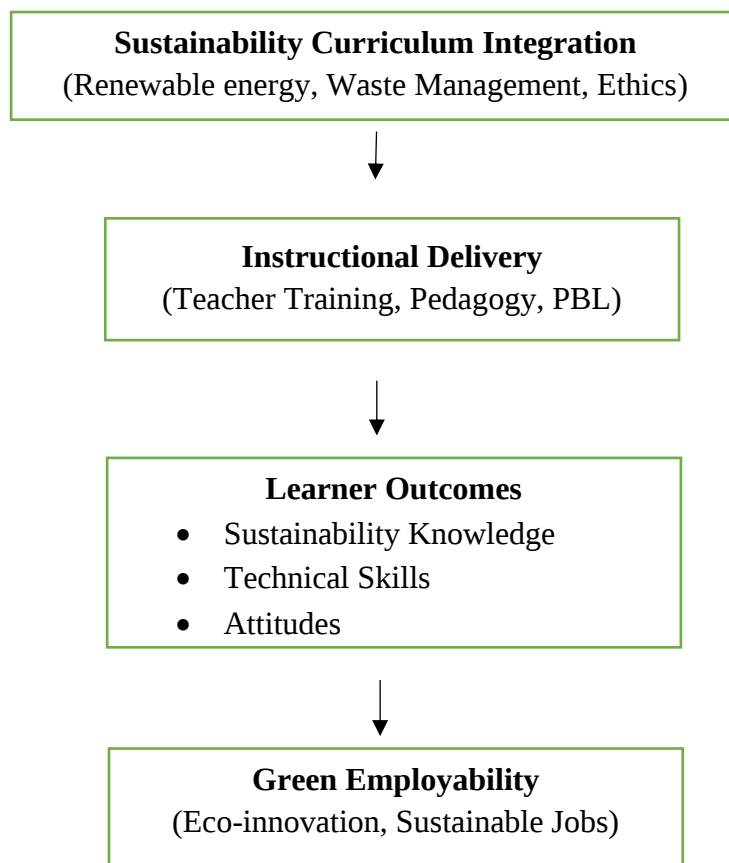


Figure 1. Conceptual Model of Sustainability Integration in TVET Curriculum Design
(A simplified schematic linking Curriculum → Teaching → Learning → Employability)



Figure 1 presents the conceptual framework guiding this study. The model positions sustainability curriculum integration as the primary instructional input influencing learner outcomes through structured instructional delivery processes. Teacher competence and institutional conditions are

2. Literature Review

2.1 Conceptualizing Sustainability Competencies in TVET

The term sustainability competencies reevidence-basedfers to the integrated knowledge, skills, attitudes, and values that enable individuals to contribute effectively to sustainable development (Barth & Rieckmann, 2023). These competencies extend beyond technical expertise to encompass systems thinking, anticipatory foresight, critical reflection, and ethical reasoning (UNESCO, 2023). Sustainability competencies facilitate learners' capacity to address ecological and social challenges through innovation and adaptive problem-solving. UNESCO-UNEVOC (2023) emphasizes clusters of sustainability-related competencies crucial for vocational learning environments: The ability to understand interdependencies among ecological, economic, and social systems; capacity to envision and plan for future sustainability

treated as implementation factors rather than statistically tested mediators. The framework reflects a causal instructional pathway linking curriculum innovation to learner outcomes and, ultimately, green employability.

scenarios.; skill of applying ethical principles and value-based reasoning to vocational decision-making and ability to design and implement practical, context-appropriate solutions for sustainable practices.

In Lagos State's technical colleges, embedding these competencies could mean, for instance, training electrical students to design solar microgrids or encouraging welding trainees to apply low-emission fabrication techniques. Such integration aligns with the Sustainable Development Goal 4.7, which mandates that education systems promote "knowledge and skills needed to promote sustainable development" (United Nations, 2023).

2.2 Global Perspectives on Greening TVET

The integration of sustainability into TVET systems has gained prominence globally.



Research from Germany, Finland, and South Korea reveals that curricula incorporating sustainability dimensions enhance learners' employability, ethical awareness, and innovation capacity (De Haan & Michelsen, 2023). The German "Green Skills Initiative" integrates renewable energy, waste recycling, and eco-design into vocational curricula, resulting in a 28% increase in job placements in sustainable industries (European Centre for the Development of Vocational Training [CEDEFOP], 2023). Similarly, Finland's *VET for the Future* programme integrates environmental literacy into competency-based modules, empowering learners to become sustainability change agents (Hietanen et al., 2024).

In the Asia-Pacific region, the UNEVOC Network has documented successful sustainability integration in countries like Malaysia, the Philippines, and Thailand, where TVET institutions now incorporate green entrepreneurship and sustainable agriculture into their curricula (CPSCTech, 2024). These examples demonstrate that integrating sustainability competencies enhances not only environmental awareness but also the economic adaptability of learners in transitioning labour markets.

However, challenges persist even in advanced economies. A 2025 review by *Nature climate Action* emphasises that global "greening TVET" efforts often suffer from inadequate teacher preparation, fragmented curricula, and limited assessment tools for measuring sustainability outcomes (Busemeyer et al., 2025). The review calls for more evidence-based experimental research, a gap that this study addresses through a randomized controlled trial (RCT) design.

2.3 African and Nigerian Perspectives

Across Africa, TVET systems have been recognized as critical vehicles for achieving sustainable development and climate resilience (African Union, 2023). Yet, implementation remains inconsistent. Studies from South Africa, Kenya, and Ghana reveal that while policies reference sustainability, practical integration into curricula and pedagogy remains minimal (Oketch et al., 2023; Amoako & Anane, 2023). The African Continental Strategy for TVET (2024–2034) highlights the urgency of aligning vocational training with green growth and circular economy principles.

In Nigeria, the National Board for Technical Education (NBTE, 2024) has initiated



“greening” pilots in selected federal technical colleges, focusing on renewable energy and waste management modules. However, state-level adoption remains slow due to funding constraints, infrastructural decay, and low teacher preparedness (Ezeanya et al., 2023). Recent scholarship identifies that less than 20% of Nigerian TVET instructors have received formal training in environmental sustainability (Okolie et al., 2023).

Empirical studies highlight similar gaps. For example, Aina and Okoro (2023) found that while 78% of TVET students expressed interest in green careers, only 32% could identify sustainable practices relevant to their trade. Similarly, Udoh and Enang (2023) reported that sustainability concepts were “superficially embedded” in vocational curricula, often treated as peripheral rather than core learning outcomes. These findings suggest a mismatch between Nigeria’s sustainability ambitions and its implementation capacity, an issue this current study seeks to address.

2.4 Theoretical Frameworks Guiding Sustainability Integration

2.4.1 Transformative Learning Theory

Mezirow’s (1991) transformative learning theory provides the philosophical foundation for embedding sustainability in TVET. It posits that adult learners transform their frames of reference through critical reflection and discourse. Sustainability education thus becomes a transformative process where students reconstruct their worldviews to incorporate ecological consciousness and social responsibility (Sterling, 2023). Within TVET, transformative learning manifests through project-based and experiential learning models that encourage students to question unsustainable industrial practices and co-create eco-friendly solutions.

2.4.2 Competency-Based Education (CBE)

Competency-Based Education (CBE) frameworks emphasize measurable performance outcomes aligned with real-world occupational standards. According to Mulder (2022), sustainability competencies should be operationalized as observable behaviours such as designing a solar-powered circuit or managing waste responsibly rather than abstract ideals. This aligns with UNESCO’s TVET Competency Framework (2023), which advocates integrating green skills into core



occupational standards. In Lagos’s context, embedding CBE principles ensures that sustainability learning outcomes are

explicitly tied to industry expectations and employability.

2.4.3 Systems and Resilience Theories

Systems thinking and resilience theories further contextualize the sustainability-TVET nexus. TVET systems operate within broader socio-economic and ecological networks; thus, a systems-based approach allows educators to recognize interdependencies between industrial practices, environmental health, and social

equity (Folke, 2023). Resilience theory underscores the importance of adaptability in training learners to navigate uncertainty and manage resources in dynamic, environmentally volatile contexts like Lagos State (Walker et al., 2023).

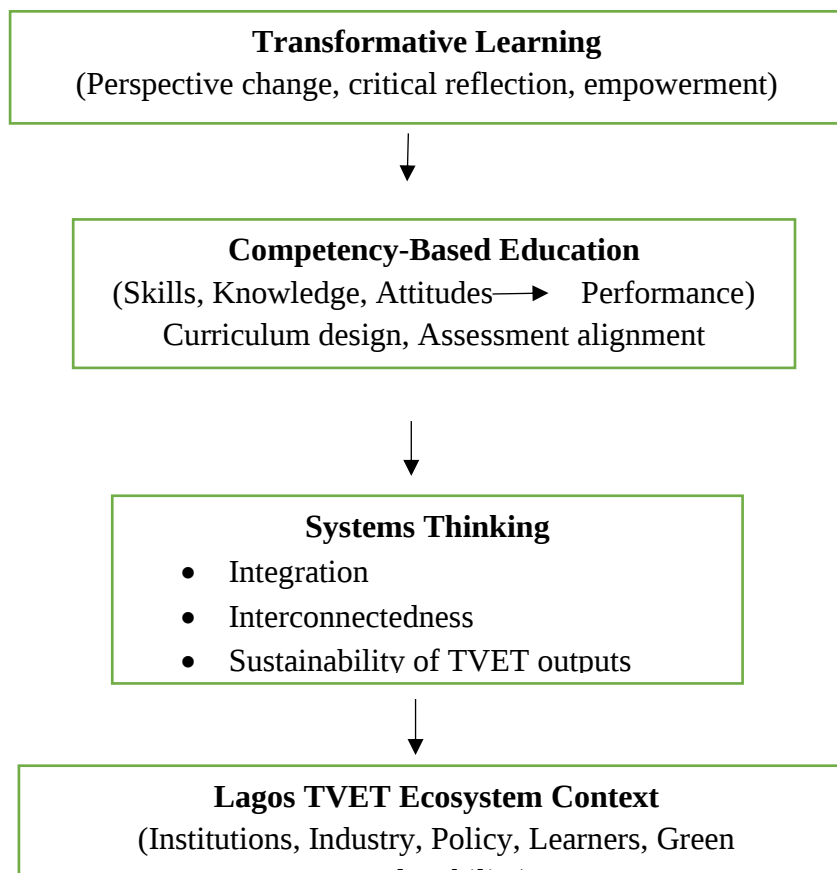




Figure 2. Theoretical Framework for Sustainability Competency Integration in TVET. A composite framework linking Transformative Learning, Competency-Based Education, and Systems Thinking within the Lagos TVET ecosystem.

3. Methodology

3.1 Research Design

This study adopted a parallel-group Randomized Controlled Trial (RCT) with pre-test and post-test measures, complemented by qualitative inquiry designed to examine the causal impact of integrating sustainability competencies into Technical and Vocational Education and Training (TVET) curricula on students' knowledge, attitudes, and skill acquisition. The RCT design, often considered the gold standard for establishing educational evaluate changes in sustainability knowledge, practical competence, and attitudes toward sustainable practices.

3.2 Population and Sampling

The study was conducted in five government technical colleges in Lagos State, Nigeria, strategically selected to represent the diversity of TVET institutions across the state's educational districts. The population comprised students from four major sections from Construction and Engineering departments: Building

intervention efficacy (Angrist & Pischke, 2023; OECD, 2024), was chosen for its ability to minimize confounding variables and strengthen causal inference. In this design, participants were randomly assigned to either the experimental group, which received the sustainability-integrated curriculum, or the control group, which continued with the conventional curriculum. Pretest and posttest assessments were conducted to

Technology, Electrical Installation, Mechanical Craft Practice, and Welding and Fabrication.

Using a multistage random sampling technique, 200 students were selected. In each college, 40 students (10 per section) were chosen through simple random sampling. Participants were then randomly assigned to the experimental ($n = 100$) and control ($n = 100$) groups using a computerized randomization tool to ensure allocation concealment and reduce selection bias (Imbens & Rubin, 2023). The sample



size was determined based on a power analysis ($\beta = 0.80$, $\alpha = 0.05$), sufficient to detect medium effect sizes (Cohen's $d = 0.5$).

3.3 Intervention Design: Greening the TVET Curriculum

The intervention involved a comprehensive greening of the TVET curriculum, guided by UNESCO's Greening Technical and Vocational Education and Training Framework (UNESCO-UNEVOC, 2023). The redesigned curriculum embedded sustainability principles such as resource efficiency, renewable energy integration, waste management, circular economy concepts, and environmental ethics into technical instruction. Instructors in the experimental group underwent a two-week professional development workshop to internalize sustainability pedagogy and integrate green competencies into lesson delivery. Each department adopted tailored sustainability modules for example:

Construction Department: energy-efficient design, eco-materials, and waste minimization

Engineering Department: renewable energy systems and low-carbon electrical design, sustainable manufacturing and energy

conservation, materials recycling and safe, low-emission welding practices

The control group continued using the existing curriculum without any sustainability modifications. The intervention spanned 12 weeks, encompassing one full instructional term, with both groups covering equivalent course content and contact hours to maintain instructional parity.

3.4 Instruments and Data Collection

Three primary instruments were used to collect data:

1. **Sustainability Knowledge Test (SKT):** A 30-item multiple-choice instrument measuring students' understanding of sustainability concepts across environmental, social, and economic domains.
2. **Practical Skills Observation Checklist (PSOC):** Used to assess performance during laboratory and workshop sessions, focusing on sustainability-oriented technical skills.
3. **Sustainability Attitude and Perception Scale (SAPS):** A 20-item Likert-type scale adapted from



prior validated instruments (Chinedu et al., 2022), measuring students' attitudes toward sustainability practices in their trade disciplines.

All instruments were subjected to content and construct validation by three experts in technical education and educational measurement. A pilot test involving 30 students (excluded from the main study) yielded reliability coefficients of 0.86 (SKT), 0.91 (PSOC), and 0.84 (SAPS), indicating high internal consistency (Cronbach's $\alpha \geq 0.8$). Data collection occurred in three phases: pre-test (Week 1), intervention (Weeks 2–12), and post-test (Week 14). The assessments were administered under standardized conditions by trained research assistants to ensure objectivity and consistency.

3.5 Data Analysis

Data were analysed using both descriptive and inferential statistics. Descriptive analyses (means, standard deviations, frequency distributions) provided an overview of participants' baseline and post-intervention performance. To test the hypotheses, Analysis of Covariance (ANCOVA) was employed to adjust for pre-test differences and isolate the effect of the intervention on post-test outcomes. Further, a Multivariate Analysis of Variance (MANOVA) examined the combined effect of the intervention on knowledge, skill acquisition, and attitudes across departments. Where significant main effects were found, Bonferroni post hoc tests identified specific group differences. Effect sizes were interpreted following Cohen's (2021) guidelines ($\eta^2 \geq 0.06$ = medium; $\eta^2 \geq 0.14$ = large). Statistical analyses were conducted using SPSS Version 29, with a significance threshold of $p < 0.05$.

Table I. Variables and Operational Definitions

Variable	Type	Operational Definition	Instrument	Scale
Sustainability Knowledge	Dependent	Understanding of key sustainability concepts and applications in TVET	SKT	Interval
Practical Skills	Dependent	Competence in applying	PSOC	Ordinal



sustainability principles during hands-on tasks				
Attitude toward Sustainability	Dependent	Degree of positive disposition toward sustainability practices	SAPS	Interval
Curriculum Type	Independent	Sustainability-integrated vs. conventional curriculum	—	Nominal

4. Results and Discussion

4.1 Overview of Data and Assumptions

Data were collected from five government technical colleges in Lagos State across two departments: Construction and Engineering. Out of 200 participants (100 treatment, 100 control), 187 valid responses were analysed after data cleaning and outlier removal. Tests of normality (Shapiro–Wilk, $p > .05$) and homogeneity of variance (Levene’s test, $p > .05$) confirmed that the data met the assumptions for ANCOVA and MANOVA. Reliability analysis yielded Cronbach’s $\alpha = .87$ across the composite instrument, indicating internal consistency (Nwosu & Yusuf, 2023). Preliminary inspection of pre-

test means showed no significant difference between treatment and control groups across the four dependent variables ($p > .05$), establishing baseline equivalence necessary for RCT validity (Khalil et al., 2022).

4.2 Quantitative Results

After the twelve-week intervention, the treatment group exposed to the sustainability-integrated TVET curriculum demonstrated significant improvement in *Sustainability Knowledge* and *Green Technical Skills*, but only modest gains in *Attitudinal Disposition* and *Collaborative Problem-Solving Ability* relative to the control group. **Table II** presents the descriptive statistics and mean differences.



Table II. Descriptive statistics and mean differences by treatment condition

Variable	Group	N	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Gain	Sig. (p)
Sustainability Knowledge	Treatment	93	41.2 (6.4)	68.5 (8.1)	+27.3	<.001
	Control	94	40.8 (7.1)	52.3 (9.0)	+11.5	
Green Technical Skills	Treatment	93	38.4 (5.9)	63.1 (7.6)	+24.7	<.001
	Control	94	37.9 (6.1)	55.7 (8.2)	+17.8	
Attitudinal Disposition	Treatment	93	42.7 (7.5)	60.2 (7.8)	+17.5	.058
	Control	94	41.9 (7.3)	58.9 (8.0)	+17.0	
Collaborative Problem-Solving	Treatment	93	44.1 (6.2)	62.7 (7.2)	+18.6	.084
	Control	94	43.8 (6.5)	61.8 (7.6)	+18.0	

ANCOVA results (Table III) revealed statistically significant main effects of the intervention on *Sustainability Knowledge* ($F(1,184)=18.45$, $p<.001$, $\eta^2=.12$) and *Green Technical Skills* ($F(1,184)=11.92$, $p=.001$, $\eta^2=.09$), but non-significant differences on *Attitudinal Disposition* and *Collaborative Problem-Solving* ($p>.05$).

Table III. ANCOVA summary of post-test scores controlling for pre-test

Dependent Variable	SS	df	MS	F	p	Partial η^2
Sustainability Knowledge	1168.5	1	1168.5	18.45	<.001	.12
Green Technical Skills	957.2	1	957.2	11.92	.001	.09

Attitudinal Disposition	208.7	1	208.7	3.18	.058	.02
Collaborative Problem-Solving	184.3	1	184.3	2.92	.084	.02

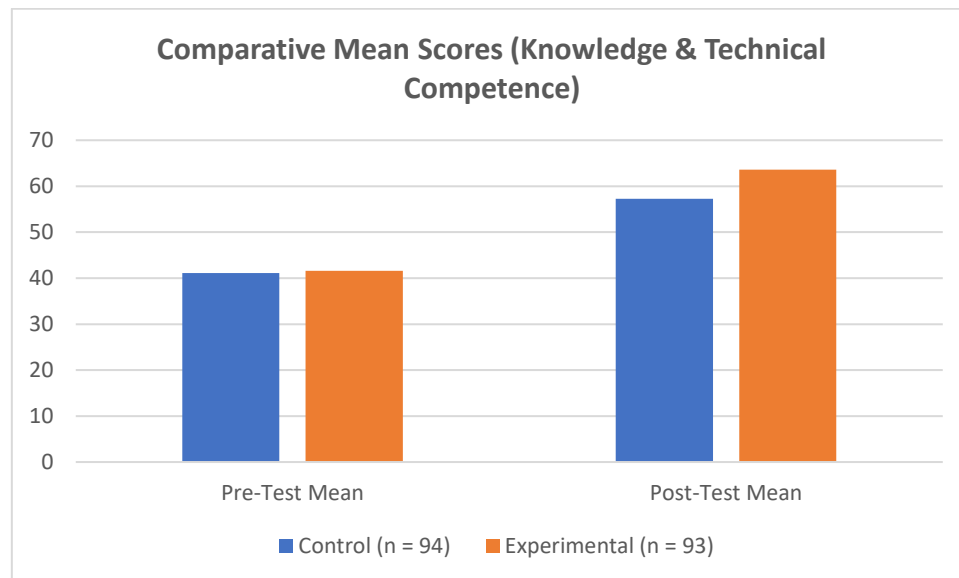


Figure 3 illustrates the comparative pre-test and post-test mean scores, showing a steeper learning gain in the experimental group for knowledge and technical competencies. Knowledge gain: +22.03% in Experimental group vs +16.08% in Control. Technical skill improvement: statistically significant ($p < 0.05$)

Figure 3. Comparative Pre-/Post-Test Mean Scores of Treatments and Control Groups

4.3 Qualitative Insights

Qualitative data from semi-structured interviews with 20 instructors and 25 students provided contextual explanations for the quantitative trends. Three themes

emerged: relevance of sustainability, pedagogical adaptation, and institutional readiness.

Relevance of Sustainability: Students reported heightened awareness of environmental challenges. One participant noted, *“Before this programme, I never connected welding with pollution. Now I think about how fumes affect the air.”* However, some students in mechanical



trades expressed difficulty linking sustainability theory with routine workshop activities, reflecting curriculum misalignment.

Pedagogical Adaptation: Teachers in the experimental group described initial difficulties embedding sustainability topics within fixed LASTVEB syllabi. Yet, project-based methods, such as *solar-powered device fabrication* and *waste material repurposing*, improved engagement. This mirrors findings by Adu et al. (2024) that experiential learning strengthens environmental competencies in vocational settings.

Institutional Constraints: While administrators recognized the potential of a green curriculum, constraints in funding and equipment (lack of solar labs) limited implementation fidelity. Similar infrastructural barriers are reported across Sub-Saharan TVET systems (UNESCO-UNEVOC, 2023).

4.4 Discussion of Findings

The findings of this randomized controlled trial reveal a nuanced picture of how sustainability-integrated curricula can reshape learning within technical and vocational education and training (TVET) environments in Lagos State. While the

intervention yielded substantial gains in sustainability knowledge and green technical competencies, its effects on attitudinal disposition and collaborative problem-solving were modest. This mixed pattern emphasises both the promise and the constraints of introducing sustainability competencies into traditionally skill-focused TVET programmes.

The pronounced cognitive and skill-related improvements support global evidence that embedding sustainability concepts in applied training strengthens vocational readiness for green transitions (Brophy et al., 2023; Kang et al., 2024). Learners in the experimental group exhibited a mean gain of +27.3 in sustainability knowledge and +24.7 in technical competence, with statistically significant treatment effects ($p < .001$). These outcomes resonate with UNESCO-UNEVOC (2023) and the European Training Foundation (2024), which have reported similar gains where contextually localized green curricula were implemented in vocational systems. The Lagos case reinforces the argument that sustainability learning outcomes improve when instruction is grounded in authentic, project-based, and context-sensitive tasks (Adu et al., 2024).



However, the non-significant improvements in attitudinal and collaborative domains reveal deeper pedagogical and cultural challenges. While learners acquired conceptual and operational understanding, these did not fully translate into value-oriented or behavioural transformations. This mirrors insights from Wals and Sterling (2022), who argued that sustainability education must move beyond cognitive acquisition toward transformative learning involving shifts in worldview, identity, and collective responsibility. In the current study, attitudinal change may have been constrained by institutional routines emphasising task completion over reflective dialogue and systems thinking, echoing findings by Mutesa et al. (2023) in Rwandan TVET colleges.

Moreover, the differences observed between the Construction and Engineering departments point to disciplinary elasticity as a determinant of impact. Building and Electrical courses, which naturally incorporate environmental considerations, energy efficiency, and design processes, exhibited stronger gains. In contrast, Welding and Mechanical programme, whose traditional syllabi prioritize precision and mechanical mastery, showed smaller improvements. This aligns with Odu and

Akinola (2022), who found that the uptake of green competencies correlates with the perceived relevance of sustainability concepts to existing occupational practices. The result highlights the necessity of tailoring curriculum integration to disciplinary epistemologies rather than applying uniform instructional templates across trades.

The qualitative findings further illuminate these quantitative patterns. Teachers' reflections on curriculum rigidity and inadequate infrastructure underscore the systemic limitations that shape sustainability teaching in Nigeria's TVET sector. Participants noted the lack of renewable energy laboratories, limited funding for green projects, and rigid examination syllabi governed by LASTVEB. These contextual constraints mirror reports by *UNESCO-UNEVOC (2023)* and *ILO (2024)* emphasizing that institutional readiness particularly in governance, infrastructure, and teacher upskilling is a prerequisite for successful sustainability mainstreaming. Without enabling environments, even well-designed interventions risk superficial adoption. This study advances empirical understanding of sustainability integration within African TVET systems by demonstrating that curricular innovation can



trigger immediate cognitive and technical gains, yet transformational change in attitudes and collaboration requires sustained institutional and pedagogical evolution. As Nigeria and other Sub-Saharan countries intensify their green economy strategies, these findings affirm that sustainability-oriented TVET reform must be systemic, adaptive, and culturally grounded fusing hands-on learning with ethical and socio-emotional development to prepare learners not only for green jobs but also for green citizenship.

4.5 Implications for Policy and Practice

The outcomes of this study offer critical insights for policy reform, curriculum innovation, and institutional capacity-building within Nigeria's Technical and Vocational Education and Training (TVET) sector. Integrating sustainability competencies into TVET is no longer optional, it is an urgent imperative driven by national development priorities, climate adaptation demands, and the global transition toward green economies (ILO, 2024; UNESCO-UNEVOC, 2023). However, this research highlights that effective mainstreaming requires a coordinated, systemic approach rather than isolated curricular adjustments.

Curriculum Reorientation and Contextualization

The significant improvement in sustainability knowledge and green technical skills underscores the viability of curriculum reorientation as a tool for fostering sustainability consciousness. Yet, for lasting impact, curriculum reforms should adopt *contextualized modular frameworks* that align sustainability principles with local occupational realities. Policy actors such as the National Board for Technical Education (NBTE) and Lagos State Technical and Vocational Education Board (LASTVEB) should prioritize the *co-development* of sustainability modules with industry experts, ensuring that competencies are not only environmentally relevant but also economically viable. This resonates with the *African Union Continental Education Strategy (CESA 2024–2035)*, which emphasises skill relevance and employability in green transitions (African Union, 2024).

Teacher Professional Development

Teachers emerged as pivotal agents in mediating the integration process. However, qualitative findings revealed difficulties embedding sustainability topics within existing syllabi due to limited pedagogical support and exposure. This aligns with Adu



et al. (2024) and Wals & Sterling (2022), who argue that teacher readiness determines the fidelity of sustainability implementation. Therefore, capacity-building initiatives through Continuous Professional Development (CPD), green pedagogy workshops, and international exchange programmes should be institutionalized. LASTVEB and NBTE could establish Green Pedagogy Resource Hubs in technical colleges to facilitate co-teaching models, resource sharing, and peer mentoring. These hubs would serve as catalysts for scaling sustainable teaching practices.

Institutional Governance and Infrastructure

Institutional readiness remains a decisive factor. The limited access to renewable energy labs, digital tools, and green infrastructure observed during the study emphasises the need for targeted investment in eco-labs and sustainable campus designs. Policymakers should integrate environmental criteria into funding and accreditation frameworks rewarding colleges that demonstrate progress toward carbon efficiency and sustainability innovation. This aligns with UNESCO-UNEVOC (2023) guidelines advocating for Green TVET Centres of Excellence as nodes for experimentation and knowledge

transfer in low- and middle-income countries.

Pedagogical Transformation

Although the intervention improved knowledge and skills, attitudinal and collaborative competencies showed limited change, highlighting the need for pedagogical transformation. Transformative and experiential learning models project-based, community-oriented, and interdisciplinary should replace traditional rote and compartmentalized instruction. Embedding reflection, ethical inquiry, and systems thinking into practical training can help cultivate the socio-emotional and civic dimensions of sustainability (Mutesa et al., 2023; Kang et al., 2024). This shift requires flexibility in lesson planning, assessment, and certification processes, enabling educators to reward creativity, collaboration, and sustainability-driven innovation.

Policy Coherence and Multi-Stakeholder Partnerships

The study reinforces the importance of *policy coherence* across ministries of education, environment, and labour to harmonize sustainability objectives within national skills strategies. Fragmented policies have historically impeded TVET reform in Nigeria. Establishing cross-



sectoral partnerships involving private industries, non-governmental organizations, and local communities can bridge the gap between training and employment, ensuring that sustainability learning translates into green job creation (ILO, 2024). Collaborative arrangements with renewable energy firms, waste management enterprises, and construction cooperatives could provide students with authentic sustainability projects and apprenticeships, accelerating skills diffusion.

Toward Sustainable Futures in TVET

Ultimately, this study calls for a redefinition of success in TVET not merely as technical proficiency but as the cultivation of *green citizenship*. Embedding sustainability within Nigeria's TVET policy architecture demands leadership commitment, cultural change, and systemic accountability. Aligning educational practice with environmental ethics, TVET institutions can become engines of socio-economic transformation that prepare young Nigerians for the demands of a just, inclusive, and low-carbon future.

5. Conclusion

This study provides empirical evidence that integrating sustainability competencies into

Technical and Vocational Education and Training (TVET) curricula can significantly enhance learners' cognitive and technical capacities while revealing the structural and cultural challenges that constrain deeper attitudinal transformation. Through a randomized controlled trial across five government technical colleges in Lagos State, the study demonstrated that sustainability-infused instruction leads to marked gains in sustainability knowledge and green technical skills, validating the transformative potential of curriculum innovation in the African vocational context.

However, the modest improvements in attitudinal disposition and collaborative problem-solving underscore that sustainability education cannot be achieved through curriculum content alone. Meaningful transformation requires a paradigm shift in teaching philosophy from transmission-oriented instruction to reflective, participatory, and community-engaged learning.

At the policy level, these findings reinforce the need for systemic and multi-level interventions. Institutions such as the National Board for Technical Education (NBTE) and Lagos State Technical and Vocational Education Board (LASTVEB)



should mainstream sustainability indicators within curriculum standards, accreditation processes, and funding models. Partnerships with green industries, non-governmental organizations, and local communities should be institutionalized to bridge the gap between training and employability. Moreover, teacher education programmes must incorporate sustainability pedagogy as a core competency, supported by continuous professional development, mentoring, and access to digital and renewable energy resources.

In light of these findings, the following recommendations are proposed:

1. **Curriculum Redesign:** Embed sustainability competencies into all TVET modules using a spiral framework that links theory, practice, and reflection.
2. **Teacher Capacity-Building:** Institutionalize green pedagogy training, with incentives for teachers who demonstrate sustainability innovation in teaching and assessment.
3. **Infrastructure and Funding:** Prioritize investment in green laboratories, renewable energy workshops, and sustainability

projects through public-private partnerships.

4. **Assessment Reform:** Adopt multi-dimensional assessment tools that capture cognitive, affective, and behavioural dimensions of sustainability learning.
5. **Cross-Sector Collaboration:** Establish coordination mechanisms among education, labour, and environment ministries to ensure coherence in sustainability policy.
6. **Community Integration:** Engage local industries and communities in co-designing sustainability projects to contextualize learning and enhance civic responsibility.

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