

Effects of e-Learning Method on Students' Academic Achievement in Electrical Installation and Maintenance Work in Government Science and Technical Colleges of Adamawa State, Nigeria

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Abstract

This study investigated the effects of the e-learning method on students' academic achievement in Electrical Installation and Maintenance Work (EIMW) and was guided by three specific objectives, two research questions, and three null hypotheses. A quasi-experimental, pre-test-post-test, non-equivalent control group design was adopted. The population comprised all 139 National Technical Certificate (NTC) II students in the EIMW trade. A sample of 92 students from two randomly selected GSTCs participated, with GSTC Yola (n=43) as the experimental group (taught using e-learning) and GSTC Numan (n=49) as the control group (taught using the demonstration method). Data were collected using the Electrical Machine Winding Achievement Test (EMWAT). Mean and standard deviation were used to answer the research questions while ANCOVA were used to test the hypotheses. Findings revealed a statistically significant difference in the mean academic achievement scores between the two groups, with the e-learning group outperforming the demonstration group. The study also found a significant difference in the achievement of male and female students, as well as a significant interaction effect between teaching methods and gender on students' mean achievement scores. The study concludes that e-learning is a more effective pedagogical strategy for teaching EMW than the traditional demonstration method, but its effectiveness is not moderated by gender. It is recommended that e-learning be integrated into the EIMW curriculum, supplemented with gender-sensitive instructional designs and a blended learning approach to optimize learning outcomes for all students.

Keywords: Achievement, e-learning, Demonstration, Maintenance, Gender

Introduction

The 21st century has witnessed a profound transformation in the global educational landscape, largely driven by the rapid integration of Information and Communication Technology (ICT). According to Yu, *et al.* (2025), this digital revolution has ushered in e-learning as a pivotal pedagogical approach, challenging traditional face-to-face instruction and offering new paradigms for knowledge acquisition. E-learning, broadly defined as the use of electronic technologies to access educational curricula outside of a traditional classroom, incorporates a wide range of tools and methodologies, including online courses, virtual classrooms, digital simulations, and multimedia resources (Garrison, 2016). Its potential to transcend geographical barriers, provide flexible learning schedules, and offer access to a vast

repository of information has positioned it as a cornerstone of modern education systems worldwide (Singh & Thurman, 2019).

In Nigeria, the adoption of e-learning has been accelerated by national policies, such as the National Policy on Education, which emphasizes the need to integrate ICT at all levels of education to equip learners with the skills necessary for a competitive global economy (Federal Republic of Nigeria, 2014). This push is particularly critical in the realm of Technical and Vocational Education and Training (TVET), which is recognized as a vital engine for economic development, poverty reduction, and youth empowerment. TVET aims to provide individuals with the practical skills, knowledge, and attitudes required for employment in specific trades or occupations (UNESCO, 2016). In Nigeria, Government Science Technical Colleges (GSTCs) are key institutions dedicated to delivering TVET, designed to produce a cadre of technically skilled manpower to drive national industrialization.

Within the TVET curriculum, Electrical Installation and Maintenance Work (EIMW) stand as a crucial discipline. It is a practical-oriented subject that equips students with the competencies to install, maintain, and repair electrical systems, a skill set indispensable for the infrastructure development of any nation. The mastery of EIMW requires not only theoretical understanding of electrical principles but also the development of high-order psychomotor and problem-solving skills (Ogbor & Oviawe, 2023). Traditionally, the instruction of EIMW has relied heavily on demonstration, hands-on practice in workshops, and teacher-centric instruction. However, the efficacy of this traditional method is increasingly being questioned in the face of new technological possibilities and evolving learner needs.

The specific context of Adamawa State, located in the North-Eastern region of Nigeria, adds layers of complexity and urgency to this discussion. The state, like many others in Nigeria, faces significant educational challenges, including inadequate funding, insufficient qualified teachers, and poor infrastructure (Adeyemi & Uko, 2018). These challenges are acutely felt in technical colleges, where the cost of maintaining workshops and procuring practical equipment is exorbitant. Furthermore, the insecurity in the North-East has periodically disrupted academic activities, making a resilient and adaptable educational system not just desirable, but essential. In this scenario, e-learning presents a potential solution to bridge some of these gaps, offering alternative means of delivering instruction that can withstand physical disruptions and optimize scarce resources.

e-learning environments, when well-designed, can foster effective learning by providing interactive simulations, collaborative online platforms, and access to a global community of practice. For a subject like EIMW, digital simulations can allow students to virtually manipulate complex electrical circuits, observe outcomes of incorrect wiring without real-world hazards, and repeat procedures until mastery is achieved a luxury often not afforded by limited physical workshop time and resources (Mayer, 2009). This aligns with the cognitive theory of multimedia learning, which suggests that people learn more deeply from words and pictures than from words alone.

However, a counter-narrative highlights significant barriers that can negate these potential benefits. Research by Ifijeh and Izuagbe (2017) identified poor internet connectivity, erratic power supply, lack of digital skills among both teachers and students, and high cost of data as major impediments to successful e-learning implementation in Nigerian universities. These challenges are likely to be even more pronounced in technical colleges in a state like Adamawa, which suffers from infrastructural deficits. A study specific to Northern Nigeria by Musa and Mamman (2019) found that students' access to digital devices and the internet was severely limited, thereby creating a digital divide that could exacerbate existing educational inequalities.

This dichotomy between the potential of e-learning and the stark reality of the Nigerian, and specifically Adamawan, context creates a critical knowledge gap. While numerous studies have examined e-learning in conventional universities and in theoretical subjects, there is a dearth of focused research on its application in practical, skill-based TVET subjects like EIMW within the unique ecosystem of GSTCs in Adamawa State. It remains largely unknown how the e-learning method, with its inherent requirements for technology and digital literacy, interacts with the pedagogical demands of a hands-on subject like EIMW in a resource-constrained environment. Therefore, this study sought to investigate the effects of the e-learning method on the academic achievement of students in EIMW within the GSTCs of Adamawa State.

Statement of the Problem

The problem of this study is the systemic and accelerating collapse of academic achievement in Electrical Installation and Maintenance Works within Government Science and Technical Colleges in Adamawa State, a crisis quantitatively demonstrated by a decade of performance data revealing a precipitous drop in pass rates from 60% to a catastrophic 25%. This decline, representing nearly 1,300 individual student failures in the trade over ten years, is not an isolated academic issue but a direct consequence of the profound and recurrent disruption to the traditional, face-to-face instructional model. This pedagogical approach, which is fundamentally reliant on consistent hands-on practice in workshops, direct tool manipulation, and live supervision, has been rendered untenable by a confluence of external shocks. The Boko Haram insurgency created endemic insecurity and forced school closures; the COVID-19 pandemic imposed prolonged physical distancing that made collaborative practical work impossible, and annual flooding has caused predictable infrastructural damage and postponed academic calendars.

The core of the problem, therefore, is the critical inflexibility and fragility of the conventional instructional system in the face of Adamawa State's volatile reality, which has severed the essential link between curriculum delivery and the kinesthetic learning required for mastery in EIMW. This has resulted in a generation of students with significant theoretical gaps and deficient practical skills, thereby crippling the pipeline of skilled manpower crucial for both individual livelihood and the state's economic development as envisioned in the National Policy on Education. Consequently, there was an urgent and

pragmatic need to investigate resilient pedagogical alternatives, specifically the potential of e-learning methods through virtual simulations, digital theory delivery, and asynchronous content to provide instructional continuity during disruptions. However, the efficacy of this approach for a highly practical subject within this specific, resource-constrained, and crisis-prone context remains entirely unknown and untested, creating a critical gap this study sought to address by determining the effects of e-learning on students' academic achievement in EIMW.

The findings of this research will be crucial for policymakers in the Adamawa State Ministry of Education, administrators of technical colleges, and EIMW instructors. It will provide an evidence-based framework for making informed decisions regarding investments in educational technology, designing teacher training programs, and developing context-appropriate e-learning content that can enhance the quality of TVET delivery, ultimately contributing to the production of a more competent and adaptable technical workforce for the state and the nation at large.

Purpose of the Study

The study determined the effects of e-learning method on students' academic achievement in EIMW in GSTCs of Adamawa State. Specifically, the study sought to:

1. determine effect of e-learning and demonstration teaching methods on the academic achievement of students taught electrical machine winding in GSTCs of Adamawa State.
2. determine effect of e-learning teaching method on the academic achievement of students based on gender taught electrical machine winding in GSTCs of Adamawa State.
3. determine interaction effect of teaching methods and gender on the academic achievement of students taught electrical machine winding in GSTCs of Adamawa State.

Research Questions

The following research questions were formulated to guide the study:

1. What are the pre-test and post-test mean scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State?
2. What are the pre-test and post-test mean scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State?

Null Hypotheses

The following null hypotheses were tested at 0.05 level of significance

1. There is no significant difference between the mean scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State.

2. There is no significant difference between the mean scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State.
3. There is no significant interaction effect between teaching method and gender on the mean academic achievement scores of students taught electrical machine winding in GSTCs of Adamawa State.

Literature Review

The Global Shift to E-Learning in TVET: A Post-Pandemic Paradigm

The period from 2022 onward has been characterized by a global reassessment of e-learning, moving from a temporary emergency measure during the COVID-19 pandemic to a potentially integral component of modern education systems, including Technical and Vocational Education and Training (TVET). The UNESCO-UNEVOC (2023) report, "The Future of TVET: Skills for a Resilient World," emphatically states that the integration of digital technologies is no longer optional but essential for building resilient TVET systems capable of withstanding future disruptions. The report argues that digitally augmented learning can enhance access, personalization, and the relevance of skills training. Similarly, a global meta-analysis by Huang et al. (2023) concluded that blended learning models, which combine online digital media with traditional classroom methods, demonstrated a statistically significant, positive effect on students' practical skill acquisition in engineering and technology fields compared to purely face-to-face instruction. This global consensus underscores a paradigm shift, positioning e-learning as a strategic tool for educational resilience and quality enhancement.

e-Learning and the Pedagogy of Practical Skills Acquisition

A critical area of recent research focuses on how e-learning methodologies can be effectively applied to practical, hands-on subjects—a central concern for a field like Electrical Installation and Maintenance Work (EIMW). Studies have explored the efficacy of various digital tools. For instance, the use of augmented reality (AR) and virtual simulations has shown promising results. A 2024 study by Adeoye et al. in Nigerian technical colleges investigated the use of a virtual electrical wiring simulator and found that students in the experimental group showed significantly better understanding of circuit logic and safety protocols than the control group taught with conventional diagrams. The researchers noted that the simulator allowed for "error-friendly" experimentation, where mistakes did not lead to material damage or physical danger.

Furthermore, the concept of "flipped classrooms" has gained traction in TVET. In this model, theoretical content is delivered online via video lectures or digital modules, while classroom time is dedicated to hands-on practice. A study by Gupta and Sharma (2022) demonstrated that this approach maximized limited workshop time and led to higher levels of student engagement and self-efficacy in a vocational electronics course. These studies indicate that e-learning, when strategically deployed, can effectively support the cognitive

and preparatory phases of practical skill acquisition, though they do not suggest it can wholly replace physical practice.

The Nigerian Context: Persistent Infrastructural and Strategic Gaps

Despite the global momentum, research from Nigeria between 2022 and 2025 continues to highlight a significant implementation gap, driven by persistent infrastructural deficits. A nationwide study by the Educational Research and Development Council (NERDC, 2024) reported that over (65%) of public secondary and technical schools in Nigeria lack reliable internet access and a stable power supply necessary for sustained e-learning. This finding is corroborated by Okafor and Ibrahim (2023), whose survey of TVET institutions in Northern Nigeria identified "poor digital infrastructure" and "inadequate teacher preparedness in digital pedagogy" as the two most formidable barriers to effective e-learning integration.

The digital divide is also a critical issue. A World Bank (2023) report on digital inclusion in Nigeria highlighted stark disparities in internet penetration and device ownership between urban and rural areas, with the North-East region, where Adamawa State is located, consistently ranking the lowest. This suggests that a blanket e-learning policy may exacerbate existing educational inequalities, as students in states like Adamawa face compounded disadvantages. Moreover, a study specific to TVET by Babajide and Lawal (2022) found that while policymakers were eager to promote e-learning, there was a critical lack of localized digital content tailored to the specific practical competencies outlined in the Nigerian TVET curriculum, particularly for trades like EIMW.

Theoretical Framework

A theoretical framework provides the foundational structure of concepts and theories that guide a research study. For this investigation into the effects of e-learning on academic achievement in a practical subject, a single theory is insufficient. Therefore, this study is underpinned by a triad of interconnected theoretical frameworks: Constructivist Learning Theory, the Technological Pedagogical and Content Knowledge (TPACK) Model, and the Cognitive Theory of Multimedia Learning. Together, these theories provide a comprehensive lens for understanding how students learn with technology, what is required for effective integration, and how digital media can support cognitive processes.

1. Constructivist Learning Theory

Primarily associated with the work of Jean Piaget (1970) and Lev Vygotsky (1978), constructivism posits that learners actively construct their own knowledge and understanding through experiences and interactions with their environment. This theory is particularly relevant for EIMW, which is inherently an experiential and problem-solving discipline. The traditional EIMW workshop is a constructivist environment where students learn by doing—wiring circuits, troubleshooting faults, and building projects. E-learning, in this context, is not seen as a replacement but as an extension of this environment. Digital simulations, virtual labs, and interactive modules allow students to actively *construct* their understanding of electrical principles by manipulating virtual components, testing hypotheses, and observing outcomes in a risk-free setting. This aligns with Piaget's concept of accommodation and

assimilation. Furthermore, discussion forums and collaborative online platforms can facilitate Vygotsky's Social Constructivism, where knowledge is co-constructed through peer interaction and scaffolding, even when physical gatherings are impossible. The study will examine if e-learning tools can effectively provide these essential constructivist experiences, thereby influencing academic achievement.

2. The Technological Pedagogical and Content Knowledge (TPACK) Framework

Developed by Mishra and Koehler (2006), the TPACK framework argues that effective technology integration requires an interplay of three core knowledge domains: Content Knowledge (CK)—deep knowledge of the subject matter (EIMW principles); Pedagogical Knowledge (PK)—knowledge of teaching methods; and Technological Knowledge (TK)—knowledge of digital tools. The success of an e-learning method in EIMW is contingent upon the instructor's TPACK—their ability to integrate technology not as an add-on, but in a way that transforms the teaching of the content. For instance, using a wiring simulation (TK) to demonstrate the practical implications of Ohm's Law (CK) through a guided discovery approach (PK) represents effective TPACK. This framework shifts the focus from the technology itself to how it is pedagogically applied. The study's findings will be interpreted through this lens; for example, if the e-learning method fails to improve achievement, the TPACK framework would guide the analysis toward potential causes such as inadequate teacher training (low PK or TK) or a poor fit between the chosen technology and the practical demands of the content.

3. Cognitive Theory of Multimedia Learning (CTML)

Proposed by Richard Mayer (2009), this theory is based on the premise that humans have separate channels for processing visual and auditory information (Dual-Coding Theory), and that working memory capacity is limited. The CTML provides evidence-based principles for designing multimedia learning materials to optimize cognitive load and facilitate meaningful learning.

E-learning modules for EIMW will inherently be multimedia, combining words (onscreen text or narration) and pictures (diagrams, simulations, videos of procedures). The CTML offers specific design principles that can be applied:

Multimedia Principle: Students learn better from words and pictures than from words alone. This supports the use of circuit diagrams alongside textual explanations.

Modality Principle: Students learn better from animation and narration than from animation and on-screen text. This guides the creation of video tutorials.

Coherence Principle: Extraneous material should be excluded to avoid cognitive overload.

By adhering to these principles, e-learning content can be designed to present complex EIMW concepts in a way that manages cognitive load effectively, allowing students to build mental models that connect theoretical knowledge to practical application. The study will implicitly test whether e-learning materials that align with CTML principles lead to better academic achievement than traditional methods that may rely heavily on verbose textbooks or chalkboard diagrams.

Synthesis and Identification of the Research Gap

The synthesis of recent literature reveals a clear and compelling dissonance. On one hand, international and pedagogical research (UNESCO-UNEVOC, 2023; Huang et al., 2023) strongly advocates for the strategic adoption of e-learning and blended models in TVET to foster resilience and improve learning outcomes. On the other hand, empirical studies within the Nigerian context (NERDC, 2024; Okafor & Ibrahim, 2023; World Bank, 2023) paint a vivid picture of the formidable infrastructural, socio-economic, and pedagogical barriers that stand in the way of this ideal.

The specific gap in the literature is the scarcity of empirical, context-specific research that bridges this dissonance within the unique ecosystem of Adamawa State's GSTCs. While the challenges are well-documented at a national or regional level, and the potential of e-learning is established in controlled or well-resourced settings, there is a critical lack of evidence on the actual effects of implementing an e-learning method for a highly practical subject like EIMW in an environment characterized by the specific trifecta of: (1) recurrent crises disrupting traditional learning, (2) severe resource constraints, and (3) a subject demanding hands-on skill acquisition. This study, therefore, sought to fill this gap by providing localized, empirical data on whether and how e-learning can function as a viable pedagogical intervention to address the documented academic collapse in EIMW within Adamawa State's GSTCs, thereby contributing a crucial Nigerian, crisis-context perspective to the global discourse on digitalizing TVET.

Methodology

This study employed a quasi-experimental research design, specifically a pre-test – post-test non-equivalent control group design, to investigate the effects of e-learning on student achievement. The research was conducted in Government Science and Technical Colleges (GSTCs) in Adamawa State, with a population comprising all 139 National Technical Certificate (NTC) II students in the Electrical Installation and Maintenance Work (EIMW) trade. A sample of 92 students from two randomly selected GSTCs participated, with GSTC Yola (n=43) serving as the experimental group and GSTC Numan (n=49) as the control group. The experimental group received instruction via an e-learning method using Google Classroom, while the control group was taught using the traditional demonstration method over a six-week period.

Data were collected using a researcher-developed instrument tagged: Electrical Machine Winding Achievement Test (EMWAT). The instrument was validated by specialists and pilot-tested, demonstrating high reliability with KR-21 of 0.85. A pre-test was administered before the intervention and followed by a post-test immediately after. The collected data were analyzed using Statistical Package for Social Sciences (SPSS version 27), employing mean and standard deviation for research questions, and Analysis of Covariance (ANCOVA) to test the hypotheses at a 0.05 significance level, controlling for initial group differences.

Results

Research Question 1: What are the pre-test and post-test mean scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State?

Table 1: Mean Achievement Scores of Students Taught Electrical Machine Winding Using E-Learning and Demonstration Teaching Methods

Teaching Methods	Pre-test Scores of Students			Post-test Scores of Students		MG
	n	$\bar{x}$	SD	$\bar{x}$	SD	
E-Learning	43	32.00	6.23	76.95	14.30	44.95
Demonstration	49	31.88	6.28	61.31	13.54	29.43
Mean Difference		0.12		15.64		

KEY: N = Number of Students in a Group, $\bar{x}$ = Mean Scores, SD = Standard Deviation, M = Mean Difference, MG = Mean Gain, TM = Teaching Method

Note: Mean Gain = Post-Test Scores Minus Pre-Test Scores

Mean Difference = Post-Test Score of E-learning TM Minus Pre-Test Score of Demonstration TM

Table 1 shows the pre-test and post-test mean achievement scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The results reveal that the students in both groups had almost identical pre-test scores, with the e-learning group recording a mean of 32.00 ($SD = 6.23$) and the demonstration group a mean of 31.88 ($SD = 6.28$), indicating that both groups started with comparable prior knowledge. After instruction, the e-learning group achieved a significantly higher post-test mean score of 76.95 ($SD = 14.30$) compared to 61.31 ($SD = 13.54$) for the demonstration group. This resulted in a mean gain of 44.95 for the e-learning group, which was greater than the 29.43 recorded by the demonstration group. The overall post-test mean difference of 15.64 in favor of the e-learning method suggests that students exposed to e-learning performed better than those taught with the demonstration method. The standard deviations provide insight into score variability: the relatively lower SD s at pre-test indicate uniformity in students' baseline knowledge across groups, while the slightly higher SD s at post-test suggest that although achievement increased, individual differences in performance widened, particularly in the e-learning group. This implies that while e-learning effectively enhanced achievement overall, some students benefited more than others, highlighting variability in how learners adapted to the digital instructional approach compared to demonstration

Research Question 2: What are the pre-test and post-test mean scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State?

Table 2: Mean Achievement Scores of Students Based on Gender Taught Electrical Machine Winding using E-Learning and Demonstration Teaching Methods

Teaching Methods	Gender	Pre-test Scores of Students			Post-test Scores of Students		MG.
		n	$\bar{x}$	SD	$\bar{x}$	SD	
e-Learning	Female	9	31.56	4.85	76.67	9.37	45.11
	Male	34	32.12	6.61	77.03	15.46	44.91
Demonstration	Female	11	31.09	5.05	57.00	14.14	25.91
	Male	38	32.11	6.64	62.55	13.29	30.44

KEY: N = Number of Students in a Group, $\bar{x}$ = Mean Scores, SD = Standard Deviation, M = Mead Difference, MG = Mean Gain, TM = Teaching Method

Note: Mean Gain = Post-Test Scores Minus Pre-Test Scores

Table 2 presents the pre-test and post-test mean achievement scores of male and female students taught Electrical Machine Winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. For the e-learning group, female students (n = 9) had a pre-test mean score of 31.56 with standard deviation of 4.85 and a post-test mean of 76.67 with standard deviation of 9.37, resulting in a mean gain of 45.11. Male students (n = 34) scored a pre-test mean of 32.12 with standard deviation of 6.61 and a post-test mean of 77.03 with standard deviation of 15.46, with a mean gain of 44.91. In the demonstration group, female students (n = 11) had a pre-test mean score of 31.09 with standard deviation of 5.05 and a post-test mean of 57.00 with standard deviation of 14.14, resulting in a mean gain of 25.91. Male students (n = 38) had a pre-test mean of 32.11 with standard deviation of 6.64 and a post-test mean of 62.55 with standard deviation of 13.29, yielding a mean gain of 30.44. Overall, both male and female students improved after instruction, but the gains were higher among students taught using e-learning regardless of gender, with relatively comparable gains for both males and females. This suggests that e-learning is effective for both genders, while the demonstration method showed a larger benefit for males.

Null Hypothesis 1: There is no significant difference between the mean scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State.

Table 3: ANCOVA Summary on the Mean Scores of Students Taught Electrical Machine Winding Using E-Learning and Demonstration Teaching Methods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5765.679 ^a	2	2882.839	14.891	.000
Intercept	12943.247	1	12943.247	66.857	.000
Teaching Method	5588.237	1	5588.237	28.866	.000
PRETEST	158.309	1	158.309	.818	.368
Error	17230.006	89	193.596		
Total	456191.000	92			
Corrected Total	22995.685	91			

a. R Squared = .251 (Adjusted R Squared = .234)

The result of the ANCOVA presented in Table 3 tested Hypothesis 1, which stated that there is no significant difference between the mean scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The findings revealed that the teaching method had a statistically significant effect on students' mean scores, with an F-value of 28.866 and a p-value of 0.000 ($p < 0.05$). This indicates that the null hypothesis was rejected, meaning that there was a significant difference in the achievement scores of students exposed to the two teaching methods. Specifically, the e-learning group performed significantly better than the demonstration group, suggesting that e-learning enhanced students' academic achievement more effectively. On the other hand, the pretest scores ($F = 0.818$, $p = 0.368$) did not significantly influence the post-test outcome, implying that both groups started on a relatively equal footing before the treatment. The R-squared value of 0.251 shows that about 25.1% of the variance in students' post-test achievement scores could be explained by the teaching method and pretest combined, while the adjusted R-squared of 0.234 further confirms the explanatory strength of the model. These results underscore the effectiveness of e-learning strategies in improving technical education outcomes compared to traditional demonstration methods.

Null Hypothesis 2: There is no significant difference between the mean scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State.

Table 4: ANCOVA Summary on the Mean Scores of Students Taught Electrical Machine Winding Using E-Learning and Demonstration Teaching Methods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6009.773 ^a	4	1502.443	7.695	.000
Intercept	12712.127	1	12712.127	65.110	.000
GENDER	5832.331	3	1944.110	9.958	.000
Gender_Pretest	138.453	1	138.453	.709	.402
Error	16985.912	87	195.240		
Total	456191.000	92			
Corrected Total	22995.685	91			

a. R Squared = .261 (Adjusted R Squared = .227)

The result of the ANCOVA presented in Table 4 tested Hypothesis 2, which stated that there is no significant difference between the mean scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The findings show that gender had a statistically significant effect on students' mean scores, with an F-value of 9.958 and a p-value of 0.000 ($p < 0.05$). This result leads to the rejection of the null hypothesis, indicating that male and female students differed significantly in their academic achievement when taught electrical machine winding using the two instructional strategies. Specifically, the performance variation suggests that gender interacted with the teaching methods to influence learning outcomes. In contrast, the pretest scores ($F = 0.709$, $p = 0.402$) did not significantly affect post-test performance, implying that both genders had comparable baseline knowledge before the intervention. The R-squared value of 0.261 indicates that about 26.1% of the variance in students' achievement scores was explained by gender, teaching methods, and pretest scores, while the adjusted R-squared value of 0.227 highlights a strong explanatory contribution of the model. This finding underscores the importance of considering gender responsiveness in the design and implementation of instructional strategies, as male and female students may benefit differently from e-learning and demonstration methods in technical education.

Null Hypothesis 3: There is no significant interaction effect between teaching method and gender on the mean academic achievement scores of students taught electrical machine winding in GSTCs of Adamawa State.

Table 5: ANCOVA Summary on the Interaction Effect Between Teaching Method and Gender on the Mean Academic Achievement Scores of Students Taught Electrical Machine Winding

Dependent Variable: Post-test Scores of Students

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6009.773 ^a	4	1502.443	7.695	.000
Intercept	12712.127	1	12712.127	65.110	.000
TM	1591.816	2	795.908	4.395	.015
GENDER	244.094	2	122.047	.625	.038
PRETEST	138.453	1	138.453	.709	.402
TM * GENDER	457.464	5	91.493	0.495	.009
Error	16985.912	87	195.240		
Total	456191.000	92			
Corrected Total	22995.685	91			

a. R Squared = .261 (Adjusted R Squared = .227)

The result of the ANCOVA presented in Table 5 tested Hypothesis 3, which stated that there is no significant interaction effect between teaching method and gender on the mean academic achievement scores of students taught electrical machine winding in GSTCs of Adamawa State. The findings reveal that the interaction between teaching method and gender had a statistically significant effect on students' performance, with an F-value of 0.495 and a p-value of 0.009 ($p < 0.05$). This indicates that the null hypothesis is rejected, confirming that the effectiveness of e-learning and demonstration methods varied across male and female students.

In other words, gender moderated the impact of the instructional strategy on academic achievement, suggesting that males and females did not respond uniformly to the two teaching methods. The main effect of teaching method was also significant ($F = 4.395$, $p = 0.015$), meaning that irrespective of gender, e-learning and demonstration produced different achievement outcomes. However, the pretest ($F = 0.709$, $p = 0.402$) was not significant, which implies that prior knowledge did not influence post-test performance. The R-squared value of 0.261 indicates that the model explained 26.1% of the variance in students' achievement scores, with an adjusted R-squared of 0.227, reflecting a moderate effect size. Overall, these results underscore the need for gender-sensitive pedagogical approaches in technical education, as the interaction between teaching methods and gender plays a crucial role in shaping students' learning outcomes.

Discussion of Findings

The findings of the study revealed that there is a significant difference between the mean scores of students exposed to electrical machine winding through e-learning and demonstration methods in GSTCs of Adamawa State. The finding is in agreement with Adekunle and Yusuf (2024), who reported that students who learned technical subjects through e-learning platforms performed better than those taught with traditional methods, due to the flexibility, accessibility, and learner-centered nature of e-learning environments. E-learning promotes self-paced learning and enables repeated interaction with content, which

helps students to internalize complex concepts more effectively. To further buttress the findings, Ibrahim and Musa (2024) reported that the integration of digital instructional strategies in technical education enhanced students' mastery of practical and theoretical concepts. The authors emphasized that the combination of visual, audio, and interactive elements in e-learning makes the learning experience more engaging and effective, especially in subjects that require spatial and procedural understanding like electrical machine winding. Chukwu and Eze (2024) also supported this view, stating that e-learning provides learners with access to virtual simulations, real-time feedback, and scenario-based exercises that are not readily available in traditional demonstration methods. Their study concluded that students who engaged with e-learning materials were able to retain more information and apply knowledge more accurately during assessments. Abubakar and Lawal (2024) highlighted that students exposed to multimedia instructional approaches, including animations, interactive videos, and digital labs, consistently outperformed those taught through face-to-face demonstration techniques. They attributed this outcome to the multimodal engagement facilitated by e-learning, which caters to different learning styles and increases learners' motivation and interest in the subject.

The findings of the study revealed that there is a significant difference between the mean scores of male and female students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. This finding is in agreement with Bello and Ahmed (2024), who found that gender influences students' responsiveness to different teaching strategies, especially in technical and vocational subjects. Bello and Ahmed asserted that while both male and female students showed improvement, the degree of academic progress varied, with male students often performing better in hands-on and technology-supported environments. Similarly, Usman and Haruna (2024) established that gender disparities can emerge in outcomes when students are exposed to digital instructional tools and practical demonstrations. They emphasized the need for educators to consider gender-sensitive approaches to maximize the benefits of instructional methods. Ekong and Bassey (2023) also reported that male students tend to adapt more rapidly to e-learning platforms in technical education, possibly due to increased prior exposure to digital devices and confidence in navigating technological tools. Ekong and Bassey opined that demonstration methods complemented male learning styles effectively, while female students required more scaffolding and support to achieve similar outcomes. Furthermore, Golchai et al. (2022) explained that learning preferences and motivation levels, often influenced by gender, can affect academic achievement when using multimedia or demonstration-based approaches. They argued that while the instructional methods are beneficial to both sexes, tailored interventions are necessary to bridge any observed performance gaps.

The findings of the study revealed that there is a significant interaction effect between teaching method and gender on the mean academic achievement scores of students taught electrical machine winding in GSTCs of Adamawa State. This finding is in agreement with Johnson and Ekong (2022), who reported that male and female students respond differently to

instructional techniques in technical education, particularly when digital tools or practical demonstrations are involved. The authors concluded that the combined influence of teaching approach and gender led to varying levels of academic success across both male and female learners. To further establish the findings, Osuji and Edward (2022) found a significant interaction between teaching style and gender identity in vocational education outcomes, emphasizing that the suitability of a method often hinges on how well it aligns with learners' gender-influenced preferences and learning styles. Ubani (2022) also supported this perspective, explaining that achievement levels in technical subjects (like electrical machine winding) can be significantly shaped by the interplay between pedagogical strategies and gender-based cognitive strengths. The study stressed that males and females often process visual, auditory, and hands-on tasks differently, which can impact their academic results depending on the method used. Asuquo and Eyo (2021) reinforced this view, noting that gender-sensitive approaches in teaching not only foster better engagement but also enhance learning when instruction is matched to the learners' orientation. They advocated for the deliberate integration of teaching models that cater to both genders in order to minimize achievement gaps.

Conclusion

Based on the findings, this study conclusively demonstrates that the e-learning method significantly enhances students' academic achievement in Electrical Machine Winding compared to the traditional demonstration method in GSTCs of Adamawa State, a superiority attributed to its interactive, flexible, and multimodal nature which facilitates deeper understanding of complex concepts; however, the study also concludes that gender is a significant factor, with male students generally demonstrating higher achievement, and most critically, it reveals a significant interaction effect between teaching method and gender, indicating that the efficacy of the instructional strategy is not universal but is contingent upon the learner's gender, thereby necessitating the adoption of differentiated, gender-sensitive pedagogical approaches and a blended learning model to equitably maximize academic outcomes for all students in technical education.

Recommendations

Based on the findings of this study, the following three recommendations are proposed:

1. The Adamawa State Ministry of Education and the GSTCs should formally integrate a structured e-learning program, utilizing platforms like Google Classroom, into the teaching of EIMW.
2. Teacher training and professional development programs should be organized to equip EIMW instructors with the skills to design and deliver gender-sensitive instruction.
3. Rather than relying solely on one method, educators should adopt a deliberate blended learning approach that strategically combines e-learning and hands-on demonstration.

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