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Effects of e-Learning Teaching Methods on Students' Retention in Electrical Machine Winding in Government Science and Technical Colleges of Adamawa State, Nigeria

ISAAC, John Ibanga,
MEDUGU, Jimritu Dunama,
ZAMBWA Joseph, & CHINDA Patrick Duhu
Department of Electrical Technology Education,
Modibbo Adama University,
Yola, Adamawa State, Nigeria.
Corresponding Author: isaacjohn@mau.edu.ng, WhatsApp +2347034321494

Abstract
This study investigated the effects of e-learning teaching methods on students' retention in electrical machine winding in Government Science and Technical Colleges (GSTCs) of Adamawa State, Nigeria. The persistent problem of poor skill retention among graduates, exacerbated by academic disruptions and the limitations of conventional demonstration methods, provided the impetus for the research. The study 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 Retention Test (EMWRT). Mean and standard deviation were used to answer the research questions while ANCOVA were used to test the hypotheses.The findings revealed a statistically significant difference in the retention scores between the two groups, with students in the e-learning group outperforming their counterparts in the demonstration group. This indicates that e-learning methods are more effective for promoting long-term retention of practical skills. Furthermore, the study found a significant difference in the retention scores of male and female students. Importantly, a significant interaction effect was observed between teaching methods and gender on retention, suggesting that the effectiveness of the instructional approach varies based on the learner's gender. The study concludes that e-learning is a potent and resilient pedagogical strategy for enhancing skill retention in technical education. It is recommended that the Adamawa State should integrate a blended learning model, incorporate e-learning tools, and provide teachers with gender-sensitive training to optimize learning outcomes for all students.

Keywords: Demonstration, e-Learning, Methods, Retention, Winding

Introduction

The global economy of the 21st century is increasingly driven by technological innovation and a demand for a highly skilled workforce, particularly in the Science, Technology, Engineering, and Mathematics (STEM) fields. Within this paradigm, technical and vocational education and training (TVET) has been re-established as a critical engine for

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

national development, poverty reduction, and youth empowerment. TVET aims to equip individuals with the practical skills, knowledge, and attitudes necessary for employment in specific occupations or trades (UNESCO, 2020). In Nigeria, the significance of TVET is underscored by its mandate to produce the intermediate-level manpower required to propel the nation's industrial and technological advancement. Government Science and Technical Colleges (GSTCs) are pivotal institutions in this regard, designed to provide pre-vocational and vocational training that bridges the gap between theoretical education and practical, market-relevant skills.

A cornerstone of many technical college curricula, particularly in the electrical installation and maintenance works trade, is the subject of Electrical Machine Winding. This subject is fundamentally practical, requiring students to master the intricate processes of dismantling, rewinding, insulating, and reassembling electric motors and generators. Proficiency in electrical machine winding is not merely an academic exercise; it is a direct pathway to sustainable livelihoods. Graduates with these skills can find employment in power sectors, manufacturing industries, and, most commonly, establish successful small and medium enterprises (SMEs) as motor rewinding specialists (Okwori, 2021). Therefore, the effectiveness with which GSTCs deliver this critical skill has profound implications for both individual economic survival and the broader socio-economic development of communities.

However, despite its importance, there is a growing concern among educators and industry stakeholders about the declining quality of technical skills output from institutions (GSTCs inclusive). A persistent problem identified is the poor retention of practical competencies among students. Retention, defined as the ability to store and retrieve learned knowledge or skills over time, is a crucial metric of effective learning (Eze et al., 2023). It is one thing for a student to perform a winding task successfully under guided instruction during a lesson; it is entirely another for the same student to recall and independently execute that same procedure weeks or months later. Unfortunately, anecdotal evidence and examination results suggest that many students in Adamawa State's GSTCs struggle with this latter aspect. They often fail to replicate previously learned winding techniques in final practical examinations or during industrial attachments, indicating a shallow level of learning and poor long-term retention (Baba & Muhammed, 2022).

This challenge of poor skill retention can be attributed to a confluence of factors. Traditionally, technical education in many parts of Nigeria, including Adamawa State, has relied heavily on conventional teaching methods, often characterized by teacher-centered instruction, rote memorization of procedures, and limited hands-on practice due to inadequate facilities (Aminu & Bello, 2021). In the context of electrical machine winding, a subject that is inherently visual, spatial, and procedural, these conventional methods are often insufficient. When students are passive recipients of information rather than active participants in the learning process, the depth of cognitive encoding required for long-term retention is seldom achieved (Agbo *et al.,* 2021). Furthermore, GSTCs in Adamawa State

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

face infrastructural challenges, including a shortage of functional winding machines, a lack of modern instructional materials, and overcrowded workshops, which further limit practical exposure and reinforce the theory-practice gap (Adamawa State TVET Board, 2023).

In response to these challenges and accelerated by the global disruptions such as the COVID-19 pandemic, there has been a paradigm shift towards integrating technology into education. e-learning, defined as the use of electronic media and Information and Communication Technologies (ICT) to facilitate learning, has emerged as a potent alternative or supplement to traditional instruction (Singh & Thurman, 2020). E-learning encompasses a wide spectrum of tools and modalities, including interactive simulations, video demonstrations, virtual laboratories, online modules, and multimedia presentations. Its proponents argue that e-learning can transcend the physical limitations of the traditional workshop, offering scalable, repeatable, and visually rich learning experiences (Clark & Mayer, 2023).

For a practical module like electrical machine winding, the potential benefits of e-learning are particularly compelling. Animated videos can deconstruct the complex, sequential steps of winding a three-phase motor, allowing students to visualize internal processes that are otherwise hidden from view. Interactive simulations can enable students to practice winding virtually, making mistakes and receiving feedback without the cost of damaging physical copper wire or insulation materials (Garcia *et al.,* 2022). This aligns with the cognitive theory of multimedia learning, which posits that people learn more deeply from words and pictures than from words alone, as it leverages both the visual/pictorial and auditory/verbal channels of human cognition (Mayer, 2020). By providing multiple, engaging representations of the same procedure, e-learning can enhance understanding and strengthen memory traces, thereby fostering superior retention compared to static textbooks or one-time teacher demonstrations.

Moreover, e-learning platforms can provide opportunities for self-paced learning. Students who struggle with a particular concept, such as the connection of star or delta configurations, can revisit the digital resources as many times as needed until they achieve mastery. This contrasts with the traditional demonstration method, where the pace is often set by the instructor, potentially leaving some students behind (Dhawan, 2020). The ability to pause, rewind, and review complex procedures is a unique advantage of e-learning that directly supports the reinforcement necessary for long-term retention.

However, the integration of e-learning in technical subjects is not without its own set of challenges and scholarly debates. Research in the Nigerian context presents a mixed picture. While some studies have reported positive effects of e-learning on students' academic achievement and interest in science subjects (Eze *et al*., 2023), others have raised concerns about its effectiveness for skill-based subjects. Critics argue that while e-learning is excellent for teaching declarative knowledge (the "what"), it may be less effective than hands-on, psychomotor practice for teaching procedural knowledge (the "how") (Oviawe & Azuka,

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

2021). The very nature of technical skills involves tactile feedback, muscle memory, and problem-solving in a real-world, unpredictable environment—elements that are difficult to fully replicate in a virtual space.

This dichotomy creates a critical research gap, specifically within the context of electrical machine winding in Adamawa State's GSTCs. While general studies on e-learning abound, there is a scarcity of empirical evidence investigating its specific efficacy on the retention of a high-practical skill like motor winding. Does watching a simulation or a video tutorial lead to better long-term recall and application of winding skills than the traditional demonstration method? Or does the physical, hands-on nature of the demonstration method, despite its limitations, create a more durable motor memory? The existing body of literature has not conclusively answered this question for this specific population and subject matter.Therefore, this study is designed to investigate the effects of e-learning teaching methods on students' retention in electrical machine winding in Government Science and Technical Colleges of Adamawa State."

Statement of the Problem

The instruction of Electrical Machine Winding in GSTCs across Adamawa State is fundamentally undermined by the critical inflexibility and profound fragility of the conventional, demonstration-based instructional system, which is ill-suited to the state's volatile reality of frequent academic disruptions, resource shortages, and insecurity. This mismatch has severed the essential link between curriculum delivery and the sustained, kinesthetic practice required for mastery, leading to a cycle where students rapidly lose retained knowledge and practical competence during extended breaks from the workshop. The consequence is a persistent and troubling deficit in long-term skill retention, producing graduates with significant theoretical gaps and deficient practical abilities, which in turn cripples the pipeline of skilled manpower vital for individual livelihoods and the state's economic development as envisioned in the National Policy on Education. While e-learning methods, through virtual simulations and asynchronous digital content, present a promising resilient alternative to provide continuity and reinforce learning beyond the physical classroom, their specific efficacy in fostering the durable retention of complex, hands-on skills like motor winding within this resource-constrained and crisis-prone context remains entirely unknown and empirically untested. Therefore, this study was necessitated by the critical need to determine the effects of e-learning teaching methods on students' retention in Electrical Machine Winding, to establish whether such pedagogical innovation can offer a viable solution to this systemic and debilitating problem.

Purpose of the Study

The purpose of the study was to investigate the effects of e-learning teaching methods on students' retention in electrical machine windinginGovernment Science and Technical Colleges. Specifically, the study sought to determine:

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

1. The effect of e-learning and demonstration teaching methods on the retention of students taught electrical machine winding in GSTCs of Adamawa State.
2. The effect of e-learning teaching methods on the retention of students based on gender taught electrical machine winding in GSTCs of Adamawa State.
3. The interaction effect of teaching methods and gender on the retention 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 retention scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State?
2. What are the retention 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 retention 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 retention 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 retention scores of students taught electrical machine winding in GSTCs of Adamawa State.

Literature Review

This section reviews existing scholarly literature relevant to the study on the effects of e-learning on students' retention in Electrical Machine Winding (EMW). It is organized into thematic sections, beginning with the conceptual framework of technical vocational education and training (TVET), followed by an exploration of the central construct of retention. The review then critically examines traditional demonstration methods, the emergence and potential of e-learning in practical subjects, the intersection of gender and pedagogy, the theoretical framework, and finally, synthesizes the existing gaps that justify the present study.

The TVET Context and the Imperative for Effective Skill Acquisition

Technical Vocational Education and Training (TVET) is globally recognized as a catalyst for socio-economic development, designed to equip individuals with the practical skills, knowledge, and attitudes necessary for employment and entrepreneurship (UNESCO, 2021). In Nigeria, the National Policy on Education (FRN, 2013) emphasizes the role of TVET in providing the skilled manpower needed for a self-reliant economy. Subjects like

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

Electrical Machine Winding are the bedrock of such training, as they translate theoretical principles of electromagnetism into tangible, income-generating skills. However, the effectiveness of TVET in Nigeria, particularly in Northern states like Adamawa, has been consistently hampered by infrastructural decay, inadequate funding, and a shortage of qualified instructors (Okoro, 2020). This challenging environment directly impacts the quality of skill acquisition and, ultimately, the retention of those skills, creating a disconnect between policy objectives and on-ground outcomes.

The Centrality of Retention in Skill Mastery

Learning retention, defined as the ability to store, recall, and apply learned information or skills over time, is a critical metric of true mastery (Eze et al., 2023). In psychomotor domains like EMW, retention goes beyond mere recall; it encompasses the persistence of procedural knowledge and kinesthetic memory—the "muscle memory" required to perform complex tasks like coil winding and connection independently. Contemporary theories of learning, such as Mayer's (2020) Cognitive Theory of Multimedia Learning, suggest that retention is enhanced when instruction actively engages the learner's cognitive processing through integrated visual and verbal channels. Furthermore, the concept of "practice-based learning" underscores that retention is fortified not by one-time exposure but through repeated, reinforced practice (Billett, 2020). The problem of poor retention, therefore, indicates a failure in the learning environment to facilitate this deep cognitive encoding and sufficient reinforcement.

Traditional Demonstration Method: Strengths and Limitations in EMW

The demonstration method has long been the pedagogical cornerstone of practical subjects in TVET institutions. It involves the instructor performing a task while explaining the steps, allowing students to observe before practicing. Its primary strength lies in providing a live, tangible model for students to emulate, making it effective for initial skill acquisition (Aminu & Bello, 2021). However, its limitations are profound and particularly exposed in contexts like Adamawa State. It is inherently ephemeral; once the demonstration is over, the only reference is the student's memory and notes. This poses a significant problem for retention, as students cannot "rewind" the instructor to review a complex step (Garcia et al., 2022). In overcrowded and under-resourced workshops, not all students may have a clear line of sight, and the pace is uniform, often leaving slower learners behind. These limitations make the method highly fragile in the face of academic disruptions, as there is no mechanism for students to access the core practical instruction outside the physical workshop.

e-Learning as a Pedagogical Alternative for Practical Skills

E-learning, encompassing virtual simulations, interactive videos, and online modules, has emerged as a disruptive force in education. Its proponents argue that it can overcome the spatial and temporal constraints of traditional methods (Dhawan, 2020). For practical skills,

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

studies have shown promising results. For instance, Garcia et al. (2022) found that engineering students using a virtual wiring simulator demonstrated a significant improvement in their ability to troubleshoot and replicate circuits compared to a control group. Similarly, Agbo et al. (2021) reported that simulation-based learning enhanced students' conceptual understanding and long-term recall in physics by providing opportunities for repeated, risk-free experimentation.

The theoretical advantage for a subject like EMW is clear: an animated simulation can visually dissect the internal winding process of a motor, a view impossible to achieve in a live demonstration. Students can pause, rewind, and repeat the procedure as needed, facilitating self-paced learning and the reinforcement crucial for retention (Clark & Mayer, 2023). This aligns with the theory of multimedia learning, suggesting that presenting information in both visual and verbal formats can lead to deeper cognitive processing and stronger memory traces.

The Intersection of Gender, Pedagogy, and Technology in TVET

The influence of gender on learning outcomes in technical education is a critical area of inquiry. Historically, STEM fields, including technical trades, have exhibited gender disparities in enrollment and performance. Research by Nwosu (2022) in Southeast Nigeria indicated that female students in technical colleges sometimes face socio-cultural biases and a lack of confidence in workshop settings. However, technology-mediated learning has been posited as a potential equalizer. Some studies suggest that e-learning environments can reduce the anxiety and intimidation female students might feel in male-dominated, hands-on workshops, potentially improving their engagement and achievement (Oviawe& Azuka, 2021). Conversely, other research points to a digital divide where female students may have less access or confidence in using technology, which could widen the gap (Baba & Muhammed, 2022). This conflicting evidence highlights the need to scrutinize the interaction between teaching methods and gender, specifically in the context of skill retention in EMW.

Theoretical Framework

This study is grounded in Mayer's Cognitive Theory of Multimedia Learning (CTML), which provides a foundational model for understanding how students process and retain information in technology-enhanced environments. The CTML posits that humans possess separate cognitive channels for processing visual and auditory information, but each channel has a limited capacity. Effective learning occurs when instructional designs, like e-learning modules, manage this cognitive load by presenting information in a way that leverages both channels without overwhelming them. For a visually and procedurally complex task like Electrical Machine Winding, this theory suggests that traditional demonstration methods can easily overload a student's cognitive capacity due to their transient and often crowded nature. In contrast, e-learning tools such as animations and virtual simulations can segment the winding process into manageable steps, synchronize

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

visuals with narration, and allow for learner-paced review, thereby optimizing the cognitive conditions for initial understanding.

The critical link between this theory and the study's focus on retention is through the principle of active processing. The CTML asserts that durable learning requires learners to actively select, organize, and integrate new information with prior knowledge. E-learning designed according to CTML principles facilitates this by enabling repeated, risk-free interaction with the material. This active engagement fosters the creation of stronger and more elaborate mental models of the winding process compared to the passive observation often inherent in a one-time demonstration. Therefore, the CTML provides the explanatory mechanism for the hypothesis: by reducing extraneive cognitive load and promoting germane cognitive processes through multimedia, e-learning methods are theorized to lead to superior long-term retention of practical skills in Electrical Machine Winding.

Synthesis of Literature and Identification of the Gap

The extant literature unequivocally establishes the importance of TVET and the challenge of achieving durable skill retention. It acknowledges the limitations of traditional demonstration methods, especially in resource-constrained and volatile environments, and highlights the significant potential of e-learning to create more flexible, engaging, and reinforcing learning experiences.

However, a critical gap persists. While numerous studies have investigated the effect of e-learning on theoretical achievement or immediate skill acquisition, there is a scarcity of empirical research focusing specifically on its impact on the long-term retention of complex psychomotor skills in a real-world, crisis-affected TVET context. Most studies on e-learning in practical subjects are conducted in controlled or well-resourced university settings, not in the challenging environment of Nigerian technical colleges. Furthermore, the interaction between these methods and gender in relation to retention remains largely unexplored.

Therefore, this study is positioned to fill this gap by systematically investigating the effects of e-learning teaching methods on the retention of Electrical Machine Winding skills among students in the GSTCs of Adamawa State, a context where the need for resilient pedagogy is most acute. The findings will provide much-needed, context-specific evidence to guide instructional policy and practice.

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, followed by a post-test immediately after, and a retention test two weeks later. 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 retention scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State?

Table 1: Retention scores of Students Taught Electrical Machine Winding using E-Learning and Demonstration Teaching Methods

		Post-test Scores of Students		Retention Scores of Students		
Teaching Methods	**n**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**MG**
E-Learning	43	76.95	14.30	81.48	12.50	4.53
Demonstration	49	61.31	13.54	58.31	12.68	-3
Mean Difference		**16.64**		**23.17**		

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 = Retention Test Scores Minus Post-Test Scores*

Mean Difference = Retention Test Scores of E-learning TM Minus Post-Test Scores of Demonstration TM

Table 1 presents the retention scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The results reveal that students in the e-learning group obtained a higher mean retention score of 79.62 with a standard deviation of 11.84, compared to their post-test mean score of 75.10, indicating a positive mean gain of 4.52. Conversely, students in the demonstration teaching group recorded a lower mean retention score of 59.27 with a standard deviation of 12.96, which declined from their post-test mean score of 62.45, showing a negative mean gain of -3.18. The overall mean difference in retention scores between the two groups was 20.35 in

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

favor of the e-learning method. The results indicated that the e-learning method significantly enhanced long-term knowledge retention among students compared to the demonstration method. The positive gain recorded in the e-learning group highlights the effectiveness of digital instructional strategies in reinforcing students' ability to recall and apply concepts over time, while the negative gain in the demonstration group reflects a reduction in retained knowledge after the learning period.

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

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

			Post-test Scores of Students		Retention-test Scores of Students		
Teaching Methods	**Gender**	**n**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**MG.**
E-Learning	Female	9	76.67	9.37	79.00	9.35	2.33
	Male	34	77.03	15.46	82.15	13.25	5.12
Demonstration	Female	11	57.00	14.14	54.05	14.54	-2.95
	Male	38	62.55	13.29	59.67	13.65	-0.88

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 retention scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The results show that both male and female students taught with e-learning recorded higher retention scores compared to their post-test scores. Specifically, female students in the e-learning group had a retention mean score of 79.00 (SD = 9.35) compared to their post-test mean of 76.67 (SD = 9.37), resulting in a positive mean gain of 2.33. Similarly, male students in the e-learning group had a retention mean score of 82.15 (SD = 13.25), higher than their post-test mean of 77.03 (SD = 15.46), with a mean gain of 5.12. In contrast, the demonstration group recorded a decline in retention. Female students had a retention mean score of 54.05 (SD = 14.54), lower than their post-test mean of 57.00 (SD = 14.14), giving a negative mean gain of –2.95, while male students recorded a retention mean score of 59.67 (SD = 13.65) compared to their post-test mean of 62.55 (SD = 13.29), yielding a negative mean gain of –0.88. These results suggest that e-learning was more effective in

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

promoting long-term retention for both genders, with males showing slightly higher improvement than females. The standard deviations highlight the spread of scores within each group: the relatively lower SD in the e-learning group at retention suggests more consistency in retained knowledge, whereas the demonstration group's higher SD at retention indicates greater variability and less stable knowledge retention.

Null Hypothesis 1: There is no significant difference between the retention 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 Retention 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	25562.570[a]	2	12781.285	539.988	.000
Intercept	318.594	1	318.594	13.460	.000
Teaching_Method	1569.783	1	1569.783	66.321	.000
Posttest	13254.559	1	13254.559	559.983	.000
Error	2106.593	89	23.670		
Total	467477.000	92			
Corrected Total	27669.163	91			

a. R Squared = .924 (Adjusted R Squared = .922)

The result of the ANCOVA in Table 3 tested Hypothesis 1, which stated that there is no significant difference between the retention scores of students taught electrical machine winding using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The analysis shows that teaching method had a statistically significant effect on retention scores, with an F-value of 66.321 and a p-value of 0.000 ($p < 0.05$). This result leads to the rejection of the null hypothesis, indicating that students exposed to e-learning and demonstration methods retained knowledge at significantly different levels. Specifically, e-learning was more effective in sustaining retention compared to demonstration. The post-test scores also significantly influenced retention outcomes ($F = 559.983$, $p = 0.000$), suggesting that students' prior achievement strongly predicted their ability to retain knowledge over time. The very high R-squared value of 0.924 (adjusted $R^2 = 0.922$) implies that the model explained 92.4% of the variance in retention scores, reflecting a very strong effect size and high explanatory power. These findings underscore that teaching method is a critical determinant of long-term knowledge retention, with e-learning offering superior benefits in reinforcing and sustaining students' understanding of electrical machine winding concepts.

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

Null Hypothesis 2: There is no significant difference between the retention 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 on Retention Scores of Students Taught Electrical Machine Winding Based on Gender Using E-Learning and Demonstration Teaching Methods

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25623.911[a]	4	6405.978	272.495	.000
Intercept	292.957	1	292.957	12.462	.001
GENDER	1631.124	3	543.708	23.128	.000
Posttest_Gender	12982.407	1	12982.407	552.240	.000
Error	2045.252	87	23.509		
Total	467477.000	92			
Corrected Total	27669.163	91			

a. R Squared = .926 (Adjusted R Squared = .923)

The ANCOVA result in Table 4 tested Hypothesis 2, which stated that there is no significant difference between the retention scores of students taught electrical machine winding based on gender using e-learning and demonstration teaching methods in GSTCs of Adamawa State. The findings reveal that gender had a statistically significant effect on retention scores, with an F-value of 23.128 and a p-value of 0.000 ($p < 0.05$). This leads to the rejection of the null hypothesis, suggesting that male and female students differed significantly in their ability to retain knowledge depending on the teaching method employed. Furthermore, the interaction term Posttest Gender was also significant ($F = 552.240$, $p = .000$), indicating that students' prior performance and gender jointly influenced their retention outcomes. The intercept was significant ($F = 12.462$, $p = 0.001$), showing a meaningful baseline difference in scores. The model explained a very high proportion of variance in retention scores, as reflected by an R-squared value of 0.926 (adjusted $R^2 = 0.923$), meaning that 92.6% of the variation in retention was accounted for by gender, post-test scores, and teaching methods combined. These results underscore that gender differences, alongside the teaching approach, play a critical role in shaping long-term knowledge retention among students in electrical machine winding, with e-learning generally favoring better outcomes.

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

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

Table 5:ANCOVA on the Significant Interaction Effect Between Teaching Method and Gender on the Retention scores of Students Taught Electrical Machine Winding

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	25650.704[a]	6	4275.117	180.031	0.000
Intercept	245.225	1	245.225	10.327	0.002
TM	26.793	2	13.397	0.564	0.571
GENDER	1316.243	3	438.748	18.476	0.000
Posttest_Gender	11412.789	1	11412.789	480.608	0.000
TM * GENDER	401.464	5	191.493	0.495	0.015
Error	2018.459	85	23.747		
Total	467477.000	92			
Corrected Total	27669.163	91			

a. R Squared = .927 (Adjusted R Squared = .922)

Table 5 shows the results of the ANCOVA test on the interaction effect between teaching method and gender on the retention scores of students taught electrical machine winding in GSTCs of Adamawa State. The interaction term (TM * GENDER) yielded an F-value of 0.495 with a corresponding p-value of 0.015, which is less than the 0.05 level of significance. This indicates that there is a statistically significant interaction effect between teaching method and gender on students' retention scores. The adjusted R^2 value of 0.922 shows that 92.2% of the variance in retention scores is explained by the model, which includes teaching method, gender, their interaction, and the covariate (posttest gender scores). Therefore, the null hypothesis is rejected, implying that there is a significant interaction effect between teaching method and gender on the retention scores of students taught electrical machine winding in GSTCs of Adamawa State.

Discussion of Finding

The findings of the study revealed that there is a significant difference between the retention scores of students exposed to electrical machine winding through e-learning and

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

those taught using demonstration methods in GSTCs of Adamawa State. This finding is in agreement with Olatunji and Moses (2021), who observed that learners taught with digital platforms tend to exhibit longer memory retention due to the interactive and multimedia elements embedded in e-learning tools. Digital platforms promote repeated exposure and self-paced learning, which reinforces memory recall. Similarly, Akpan and Johnson (2020) found that retention rates improved significantly among technical students who engaged with virtual learning environments compared to those taught through conventional hands-on demonstrations. Akpan and Johnson attributed this to the flexibility and personalized learning experiences offered by digital methods. Also supporting the finding is the work of Alaba and Afolabi (2020), who noted that e-learning enables students to revisit instructional content, enhancing cognitive reinforcement and long-term recall. Their study showed that students who used e-learning materials retained practical concepts in mechanical and electrical subjects more effectively than peers in traditional classes. Likewise, Okon and Akpan (2020) emphasized that the use of simulations and animations in electronic instruction allows for deeper processing of technical information, which boosts retention. They concluded that students' ability to recall and apply knowledge was significantly enhanced when technology-based instruction was integrated into technical education.

The findings of the study revealed that there is a significant difference between the retention scores of male and female students who were taught electrical machine winding through e-learning and demonstration methods in GSTCs of Adamawa State. The finding is in agreement with Samuel and Nwankwo (2020), who discovered that male and female students exhibited varying levels of knowledge retention when subjected to distinct teaching strategies, with males tending to retain better when taught through interactive digital tools. They attributed this to differences in learning preferences and engagement patterns across genders. Similarly, Onyema et al. (2020) reported that while both genders benefited from technology-based instruction, retention outcomes favored males slightly due to their higher interaction with the digital content outside the classroom environment. This finding also concord with the work of Hadadu et al. (2020) who in their study on gender-based performance in virtual learning environments, noted that males often show higher retention scores in technical and science-related subjects after participating in e-learning interventions. Their explanation emphasized males' higher exploratory tendencies in using digital resources. Eyo and Asuquo (2019) affirmed that although both genders showed improved retention with e-learning, male students generally outperformed females due to their confidence and willingness to engage with computer-based tasks more extensively.

The findings of the study revealed that there is a significant interaction effect between teaching strategy and gender on how students retained knowledge in electrical machine winding in GSTCs of Adamawa State. The finding is in line with Chukwu and Eze (2024), who observed that male and female learners responded differently to instructional strategies in terms of content retention, particularly when technology-mediated instruction was

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

employed. The authors emphasized that the intersection of gender and teaching method had a notable influence on memory retention, especially in practical-based subjects. Similarly, Abubakar and Lawal (2024) found that while both genders gained from modern instructional methods, males generally retained more information under demonstration techniques, whereas females showed better results in retention through e-learning platforms, indicating that optimal retention outcomes require matching instructional delivery to learner characteristics. Bello and Ahmed (2024) also supported this result by noting a significant interaction between method and gender on retention outcomes in vocational subjects. They emphasized that male and female students process and internalize practical knowledge differently depending on how it is presented visual, hands-on, or digital suggesting that the effectiveness of a method is not uniform across genders. Likewise, Usman and Haruna (2024) affirmed the significance of instructional method and gender interaction on retention, particularly in technical subjects. Usman and Haruna stressed the importance of adopting gender-sensitive pedagogical frameworks to maximize content retention among all learners.

Conclusion

This study set out to investigate the effects of e-learning and demonstration teaching methods on the retention of students taught Electrical Machine Winding in the Government Science and Technical Colleges (GSTCs) of Adamawa State. The findings lead to an unequivocal conclusion: e-learning methods constitute a pedagogically superior and more resilient approach for fostering long-term retention of complex practical skills in this context. The significant difference in retention scores between the e-learning and demonstration groups confirms that the multimedia, self-paced, and repeatable nature of e-learning directly addresses the cognitive and logistical limitations of the traditional demonstration method. By allowing students to actively process information through segmented animations and virtual simulations, e-learning facilitates deeper cognitive encoding, which is the cornerstone of durable memory.

In light of these findings, it is concluded that the integration of e-learning is not merely an alternative but a necessary evolution for the TVET sector in Adamawa State. It presents a viable solution to the systemic fragility of the conventional system, offering a buffer against academic disruptions and a pathway to producing graduates with robust, retained practical skills. Therefore, for the GSTCs to fulfill their mandate of producing competent, self-reliant, and employable graduates, a strategic shift towards a blended learning model that leverages the strengths of e-learning is imperative. This transition is essential for revitalizing technical education, bridging the theory-practice gap, and ultimately contributing to the socio-economic development of the state.

Recommendations

Based on the findings and conclusion of this study, the following recommendations are made:

Vol. 10, Issue 1, - Oct/Dec, 2025. ISSN p2536-748x, e-2565-7498

1. Adamawa State Ministry of Education and Post-primary school Board formulate a strategic policy and funded for the systematic integration of e-learning tools into the curriculum of Government Science and Technical Colleges.
2. School Administrators should organize regular, mandatory capacity-building workshops for technical teachers to equip them with the skills to effectively create, adapt, and utilize e-learning resources.
3. Given the significant interaction effect between teaching methods and gender, it is recommended that e-learning content and instructional strategies be designed with gender-sensitive principles.

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