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THE EFFICACY OF TECHNOLOGY-ENHANCED FORMATIVE ASSESSMENT ON STUDENTS' ACHIEVEMENT IN ELECTRONICS TECHNOLOGY EDUCATION

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Abstract

Formative assessments have undeniably not been left out of the current wave of technology in education, especially with the advent of technology-enhanced assessments. This research determined the efficacy of technology-enhanced formative assessment on students' achievement in electronics technology education. The study was steered with two research questions and two hypotheses, and the repeated measures research design was adopted. The study sample was 67 out of a population of 118 SS II students in Enugu-East LGA, Enugu State, using a multistage sampling procedure. A researcher developed the Electronics Technology Achievement Test (ETAT) with a Kuder-Richardson20 reliability index of 0.89, which was used for data collection. A statistically significant difference in the achievement scores of electronics technology education students due to technology-enhanced formative assessment emerged as a finding from the study; also, that male and female students do not differ significantly in their achievement in electronics technology education due to technology-enhanced formative assessment; and, students' gender interacted with the test occasions. The study concluded that technology-enhanced formative assessment effectively enhances students' achievement in electronics technology education. The researchers recommended that teachers and school management leverage technology to enhance formative assessments and provide support, training, and facilities for effective technology-enhanced formative assessments.

***Keywords*:** Formative assessment, technology-enhanced, repeated measures, students' achievement, electronic technology education

Introduction

Apparent global anomalies have prompted rapid advancements in technology, resulting in the adoption of digital technologies in the educational landscape. The resulting transformations have opened opportunities for enhanced learning experiences for students. Undeniably, assessment has been an effective means of collecting evidence on students' achievement at various levels of education, and one of the notable trends in modern education is the integration of technology into assessment practices. Spector et al. (2016) and Onyido and Nwaogu (2022) highlighted that the role of technology in the 21st century cannot be underestimated. Technology-enhanced formative assessments (TEFA) have become necessary in stimulating the development of information and communication technology (ICT) competency, which is essential to thrive in this technology-driven era (Ejiroghene, 2021). Tamoliūnė et al. (2024) advocate increasing technology-enhanced assessment in education. Gartner (2015), Kuo and Yang (2023), and Hart (2024) opine that integrating technology in assessment has garnered considerable attention due to its potential to improve students' engagement, personalise learning experiences and provide real-time feedback about the effectiveness of teaching and learning. Technology-enhanced formative assessment (TEFA), according to United Nations Educational, Scientific and Cultural Organization (UNESCO, 2012); JISC (2020); and Anderson and Dron (2020) refer to the use of digital platforms, tools, and technologies such as online quizzes, e-portfolios, interactive simulations, other multimedia resources and learning management systems to provide continuous, real-time feedback to students during the learning process. Unlike summative assessments that evaluate learning at the end of an instructional period, formative assessments are intended to support and enhance learning through regular, actionable feedback (Wylie & Lyon, 2021; Kumar & Saini, 2021). Khan and Jawaid (2020) believe that TEFA refers to assessment activities that leverage digital tools and technologies to provide ongoing feedback to students during the learning process. TEFA are designed to inform teaching and learning, allowing for dynamic and immediate feedback (Aparicio, Bacao & Oliveira, 2021). According to Wylie and Lyon (2021), formative assessments are important drivers of classroom learning, a practice in which teachers and students engage to analyse and interpret evidence of learning so that adjustments can be made to teaching and learning in support of the emerging learning needs of students. The purpose is to gauge students' understanding and guide instructional adjustments to enhance learning outcomes and improve students' achievement.

Improving students' achievement has been at the forefront of all learning interventions. According to Olatunde, Adebayo and Ayodele (2022), it reflects both the cognitive and skill-based outcomes as students' progress in their education. Chen and Zhang (2017) and Ogunleye, Adeyemi and Yusuf (2022) view students' achievement as the extent to which students have mastered the learning objectives. Students' achievement in this study refers to students' level of attainment in Electronics Technology Education, which is often measured through their ability to demonstrate theoretical understanding and or practical skills relevant to the field. Achievement indicators include test scores, project completion, practical assessments, and overall competency in technical tasks. They could be influenced by factors such as motivation, prior knowledge, and the quality of instructional methods.

Electronics Technology Education (ETE) encompasses educational programs and curricula to prepare students to work in electronics. According to Raymond and Uduafemhe (2018), ETE involves teaching and learning electrical and electronic systems, circuits, devices, and applications. Adeyemi (2021) opines that ETE equips students with both theoretical knowledge and practical skills related to the installation, maintenance, and repair of electronic equipment and the theoretical knowledge of electrical circuits, systems and devices, circuit design to the maintenance of complex systems in sectors like telecommunications, healthcare, and automation necessary for careers in the electronics industry. Salihu and Adeosun (2023) pointed out that vocational education is a crucial field, particularly in developing economies

like Nigeria, due to the pivotal nature of technical skills for economic growth and development. Ogbuanya and Nungse (2017) highlighted that electronics education has an unending potential to develop students' entrepreneurial skills, which translates to the national entrepreneurial indices accounted for in the gross domestic product (GDP). However, the worry about the development of electronics technology skills as electronics students' progress through the secondary school curriculum has been the major challenge.

The exigency of developing technical skills among secondary school students has raised concerns about the urgent need to address students' underachievement in Electronics Technology Education in Nigeria. Evidence shows that students in technical fields in Nigerian secondary schools face numerous challenges, including low engagement, lack of hands-on experience, and insufficient feedback mechanisms (Aderemi & Alabi, 2021). Students' underachievement in Electronics Technology Education in Nigeria is a well-documented concern. Factors contributing to this underachievement include inadequate teaching resources, outdated curricula, and a lack of proper training for instructors in modern educational tools (Aderemi & Alabi, 2021). Ogunleye, Adeyemi and Yusuf (2022) reported that despite the growing importance of electronics in Nigeria's technological development, students in the field consistently perform poorly in theoretical and practical assessments. The study attributes these challenges to inadequate teaching methods, lack of practical training opportunities, and poor student engagement. A report by the National Board for Technical Education (NBTE, 2022) indicated that many graduates in the field of electronics are ill-prepared for the workforce, often lacking the necessary practical skills required by industry employers. Furthermore, Okebukola (2021) revealed that Nigerian electronics students often struggle with applying theoretical concepts to real-world problems, suggesting a gap between learning and practical application that could be addressed through more effective formative assessments. Also, Salihu and Adeosun (2023) found that a significant number of students in Nigerian technical institutions struggled with theoretical knowledge and practical skills in electronics due to failure to acquire the required knowledge and skills at the secondary school level. This situation raises considerable worry, and the present study hopes that adopting technology in formative assessment processes could be a panacea.

Although technology in education is still evolving in Nigeria, there have been encouraging developments regarding applying TEFA. Olatunde, Adebayo and Ayodele (2022) and Adegoke and Olanrewaju (2023) found that the use of digital quizzes and online learning platforms significantly improved students' performance in science subjects, including electronics, in Nigerian secondary schools. Similarly, Huang, Mills and Tiangco (2024) showed that TEFA increased students' motivation and achievement in writing quality. These studies suggest that technology-enhanced formative assessment can positively impact students' achievement in technical fields. Moreover, TEFA has the potential to transform traditional assessment paradigms by offering immediate, personalised feedback, thereby addressing the common issue of delayed feedback in conventional assessment methods (Agboola & Adedeji, 2020). Online quiz platforms like Quizlet, Kahoot, Mentimeter, Socrative, and Google Forms have become mainstream assessment tools. These platforms allow immediate feedback and integration with learning management systems (Khan & Jawaid, 2020; Hart, 2024). By exploring its efficacy in the context of Electronics Technology Education, this research aims to contribute valuable insights that could inform technical education policies and practices in Nigeria. Despite the global push for technology integration in education, the application of technology-enhanced formative assessment in Nigerian technical education remains underexplored. This is further exacerbated by gender inequalities, especially in scientific and technologically inclined subjects (Arias, Canals, Mizala & Meneses, 2023). The underrepresentation of females in Science and Technology fields could be explained as a result of gender segregation in the labour market and social stereotypes and also rooted in achievement gender gaps (Bordo´n,

Canals & Mizala, 2020; Malespina & Singh, 2022). Therefore, the present study sought to examine the efficacy of technology-enhanced formative assessment (TEFA) on students' achievement in Electronics Technology Education (ETE) in Nigeria, where students' underachievement in technical fields is a pressing concern. The following questions steered the study:

1. What is the mean score of students in ETE before and after exposure to TEFA?
2. What is the interaction of gender and test occasions on the mean score of students in ETE?

Hypotheses.

HO_1: Students' mean scores in ETE do not significantly differ before and after exposure to TEFA.

HO_2: Gender and test occasions interaction on the mean score of students in ETE is not statistically significant.

Methodology

The simple repeated measure experimental research design was employed in the study. Ugwuanyi (2022) described the design as collecting measurements at different or multiple occasions on the dependent variable from the same subjects upon exposure to treatment, with the measurement occasions serving as control, one to another. The repeated measures research design was considered more appropriate for the study because of the small sample size, accessible due to the cost of internet services and the availability of smart devices required for the experiment. The present study collected two measurements before and two after the treatment (Technology-Enhanced Formative Assessment, TEFA, using the Mentimeter platform). This is represented as:

O_{M1} O_{M2} X O_{N1} O_{N2}

Where,

O_{M1} = First pretest X = Treatment (TEFA) O_{N1} = First posttest

O_{M2} = Second pretest O_{N2} = Second posttest

The same subjects participated in all four test occasions and the treatment. The study was conducted in the Enugu-East Local Government Area (LGA) of Enugu State, Nigeria. The LGA is one of the 17 LGAs in Enugu State and a part of the Enugu Education Zone. The sample for the study was 67 SS II (33 male and 34 female) students drawn from a population of 118 SS II students offering Electronics Technology Education. A multistage sampling procedure was used to draw the study sample. In the first stage, a purposive sampling technique was used to select the two LGA schools with students studying Electronics Technology. In the second stage, a proportionate random sampling technique was used to draw 31 and 36 students from the two schools to participate in the study. In the schools, students who participated were drawn using a dip-of-luck, simple random sampling technique.

The instrument for data collection was a researcher-developed 30-item **Electronics Technology Education Achievement Test** (ETEAT). The ETEAT has two sections. The first elicits students' demographic information, such as identification code and gender, and the second section contains 30-item objective questions with five response options for each, in which only one option is the key, and elicits information on electronics technology education. The questions were drawn from the Electronics Technology Education SS II curriculum, which covered basic electrical theory, magnetic field, electric field, electromagnetic induction/transformers, and digital electronic contents of the curriculum. A detailed test blueprint established the content validity. The ETEAT was face-validated by three experts in the Department of Electronics Technology Education, Faculty of Vocational Education, University of Nigeria, Nsukka. The internal consistency of the ETAT was determined using

the Kuder-Richardson 20, and the reliability index of 0.89 was obtained after pilot testing the instrument on SS II students in Enugu North LGA.

Two regular teachers of the students in the sampled schools were trained for the study and employed as the study assistants. Before the investigation, the research assistants were briefed on the purpose and experimental modalities and trained for four days on the use of the prepared lesson plan and the administration of the instrument. The treatment was a technology-enhanced formative assessment instructional procedure via the Mentimeter platform, which was followed by two pretest sessions and two posttest sessions. Each test session comes after an interval of two weeks. Therefore, the experiment lasted for a period of eight weeks. To control extraneous variables, the researchers used trained regular subject teachers in the sampled schools as research assistants who adopted the instructional guide to control for the Hawthorne effect. The time lag between the test occasions minimised the effect of test-wiseness. Also, subjects were not informed about the reoccurrence of the test. Since there was only one experimental group in the study, there was no chance of subject interaction. To control for subject mortality, informed consent of the schools' management ensured that the subjects were active throughout the experiment.

The data collected in this study was subjected to Repeated Measures Analysis using the 25th version of the Statistical Package for Social Sciences (SPSS) software. The research questions were addressed using mean and standard deviation while the hypotheses were tested using Simple Repeated Measures Analysis of Variance (ANOVA) at 5% significance level. The analysis relied on the within-subject effect and the assumption of sphericity. The associated exact probability value obtained was the basis for a decision on the null hypothesis; it was rejected only when it was less than 0.05, the level of significance. The Mauchly's W test of Sphericity showed a significance of (W=0.58, 5) p = 0.00 indicating sphericity in the normally distributed data collected.

Results

Table 1: Mean and standard deviation scores of ETE students before and after exposure to TEFA

Test Occasion		**Pretest**		**Posttest**	
	N	$\bar{X}$	**SD**	$\bar{X}$	**SD**
1	67	9.07	2.83	22.24	3.34
2	67	11.12	3.11	24.82	3.31

N = Sample size, $\bar{X}$ = Mean, SD = Standard Deviation

The result in Table 1 showed a mean score of 9.07 with a standard deviation of 2.83 at the first pretest and a mean score of 11.12 and a standard deviation of 3.11 at the second. In the posttest, the mean score was 22.24 with a standard deviation of 3.34 for the first and a mean score of 24.82 with a standard deviation of 3.31 for the second posttest. Based on the results, there is an increase in students' achievement scores in Electronics Technology Education (ETE), as shown in the post-test scores. Although the pretest scores had a lower standard deviation, the standard deviation of the posttest scores is not as high as one standard deviation from those of the pretest. This indicates that the scores cluster considerably around the means for each test occasion. Therefore, Technology-Enhanced Formative Assessment (TEFA) proved more effective in improving students' achievement in ETE.

Table 2: Significance in the mean scores of students in ETE due to TEFA

Tests of Within-Subjects Effects

Measure: ETE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test_Ocassion	Sphericity Assumed	12452.97	3	4150.99	421.37	.00	.87
	Greenhouse-Geisser	12452.97	2.19	5678.75	421.37	.00	.87
	Huynh-Feldt	12452.97	2.27	5482.76	421.37	.00	.87
	Lower-bound	12452.97	1.00	12452.97	421.37	.00	.87
Error(Test_Ocassion)	Sphericity Assumed	1950.53	198	9.85			
	Greenhouse-Geisser	1950.53	144.73	13.48			
	Huynh-Feldt	1950.53	149.91	13.01			
	Lower-bound	1950.53	66.00	29.55			

The result in Table 2 shows the significance of students' achievement on different test occasions of ETE. The associated probability of 0.00 was obtained for the significance of the mean test occasions before and after the TEFA treatment. Since the 0.05 level of significance exceeds the p-value of 0.00, the null hypothesis one (HO_1**:** Students' mean scores in ETE do not significantly differ before and after exposure to TEFA) was rejected. Therefore, the evidence shows that students' mean scores in ETE significantly differ before and after exposure to TEFA. The effect size of 0.87 indicated that an 87% increase in the ETE achievement scores of students was due to the TEFA. This shows a considerable difference in the mean achievement scores of students in ETE before and after exposure to TEFA.

Table 3: Gender and test occasion interaction on students' ETE mean scores

Test Occasion		**Pretest**			**Posttest**	
		N	$\bar{X}$	**SD**	$\bar{X}$	**SD**
1	Male	34	9.18	2.70	22.03	3.55
	Female	33	8.97	2.99	22.45	3.16
2	Male	34	11.91	3.35	23.94	2.96
	Female	33	10.30	2.64	25.73	3.45

N = Sample size, $\bar{X}$ = Mean, SD = Standard Deviation

The result presented in Table 3 for the first and second pretests showed male mean scores and standard deviations of 9.18, 2.70 and 11.91, 3.35 respectively, and female mean scores and standard deviations of 8.98, 2.99 and 10.30, 2.64 respectively. Also, Table 2 showed the first and second post-test male mean scores and standard deviations of 22.03, 3.55 and 23.94, 2.96, respectively, and female mean scores and standard deviations of 22.45, 3.16 and 25.73, 3.45, respectively. Based on the results, male students had higher achievement scores than the female students on the pretest, while the female students had higher achievement scores than the male students on the posttests. However, the male students had a lower standard deviation on the first pretest, while the female students had a lower standard deviation on the second. In the posttest, the female students had a lower standard deviation on the first posttest, while the male students had a lower standard deviation on the second posttest. This indicated an interaction between gender and test occasions in Technology-Enhanced Formative Assessment (TEFA) on students' Electronics Technology Education (ETE) achievement.

Table 4: Significance of the interaction between gender and test occasion

Tests of Within-Subjects Effects

Measure: ETE

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Test_Ocassion	Sphericity Assumed	12477.58	3	4159.19	438.24	.00	.87
	Greenhouse-Geisser	12477.58	2.21	5645.63	438.24	.00	.87
	Huynh-Feldt	12477.58	2.33	5363.31	438.24	.00	.87
	Lower-bound	12477.58	1.00	12477.58	438.24	.00	.87
Test_Ocassion * Gender	Sphericity Assumed	99.85	3	33.28	3.51	.02	.05
	Greenhouse-Geisser	99.85	2.210	45.18	3.51	.03	.05
	Huynh-Feldt	99.85	2.33	42.92	3.51	.03	.05
	Lower-bound	99.85	1.00	99.85	3.51	.07	.05
Error(Test_Ocassion)	Sphericity Assumed	1850.68	195	9.49			
	Greenhouse-Geisser	1850.68	143.66	12.88			
	Huynh-Feldt	1850.68	151.22	12.24			
	Lower-bound	1850.68	65.00	28.47			

Table 4 shows the significance of the interaction between test occasion and gender in ETE when exposed to TEFA. The associated probability of 0.03 was obtained for the significance of the interaction between test occasion and gender. Since the 0.05 level of significance exceeds the obtained p-value of 0.03, the null hypothesis two (HO_2**:** Gender and test occasions interaction on the mean score of students in ETE is not statistically significant) was rejected. Figure 1 also shows the considerable intersection (interaction) between the gender groups on the test occasion. Therefore, the evidence shows a substantial interaction between test occasions and gender on the mean score of students' achievements in ETE. This indicates that test occasion significantly interacts with students' gender in ETE due to exposure to TEFA. The effect size of 0.05 indicated a 5% increase in ETE students' achievement scores was due to the interaction between test occasion and gender.

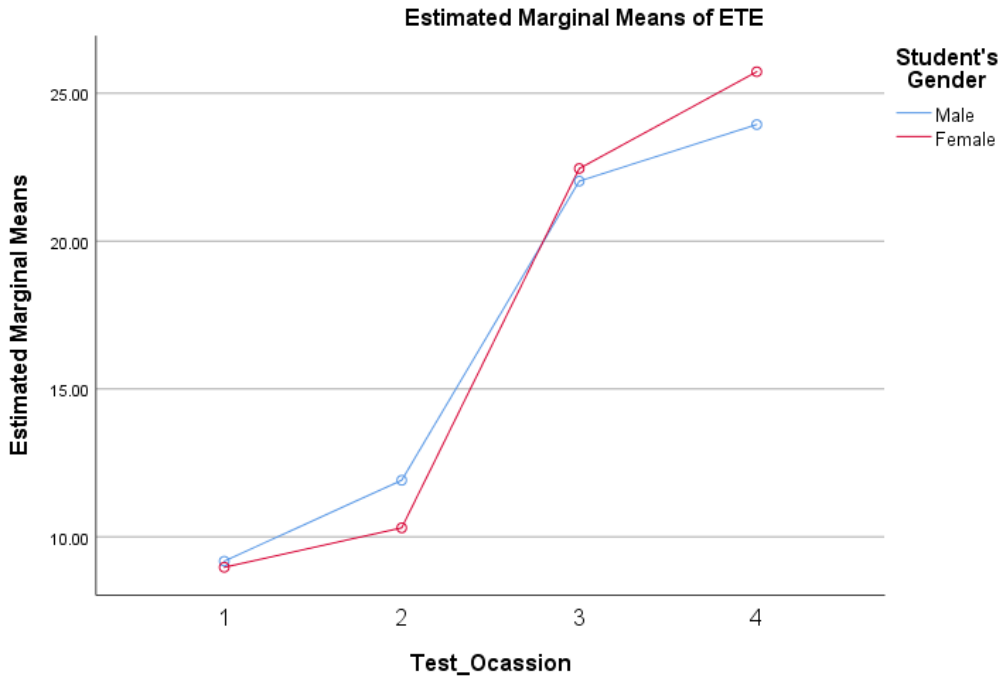

Figure 1: Gender and test occasion interaction on students' achievement in ETE

Discussion

The outcome of the study emphasised the effectiveness of technology-enhanced formative assessment (TEFA) in improving students' academic achievement in Electronics Technology Education (ETE). This means that adopting TEFA shows reasonable efficacy in enhancing ETE academic achievements in students. This result possibly holds because the formative assessments available through technology present a better picture of the problem, facilitating more profound learning. Also, the present technology-driven era may have been a factor in TEFA, which motivates students to perform better due to the technology-enhanced formative assessment instructional plan. The finding validates that of Olatunde, Adebayo and Ayodele (2022); Adegoke and Olanrewaju (2023); and Huang, Mills and Tiangco (2024), who found that the use of technology in enhancing formative assessment significantly improved students' performance in science subjects like electronics technology.

The study's outcome also revealed a better interaction with the TEFA among female students than male students. Also, the interaction was significant; this could be due to many educational programmes and jingles that encourage and motivate female students to challenge their male counterparts, especially in technology-inclined fields. Perhaps the incorporated interactive elements of the technology-enhanced assessment tool promoted collaborative and cooperative learning environments, which facilitated deeper discussions, shared knowledge, and peer support, causing female students to excel. Furthermore, female students may benefit more from this timely feedback in the TEFA as it enables them to quickly identify areas needing improvement and adjust their study strategies accordingly based on their ability to receive constructive criticism in real time, foster a growth mindset, and encourage persistence and resilience in the face of challenges. The finding disagrees with Bordo´n, Canals and Mizala (2020) and Malespina and Singh (2022).

Conclusion and Recommendations

Based on the study's findings, it was concluded that TEFA effectively enhances students' achievement in electronics technology education and that students' gender interacts with TEFA. Based on the outcome of this study, it was recommended, among others, that:

1. Teachers should leverage technology in formative assessments to enhance students' achievement.
2. School management should support technology-enhanced formative assessments in their schools for enhanced students' achievement.
3. The government should collaborate with experts to provide support, training, and facilities for effective technology-enhanced formative assessments in schools.
4. Finally, male students should be encouraged to improve their engagement with TEFA to improve their academic achievements.

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