COMPARATIVE ASSESSMENT OF SCIENCE STUDENTS' OUTCOME USING TECHNOLOGY-ENHANCED LEARNING (TEL) AND TRADITIONAL INSTRUCTION METHOD (TIM)

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Abstract
The study examined the impact of Technology-Enhanced Learning (TEL) and Traditional Instruction Method (Tim) on science students' assessment outcomes, focusing on the engagement and intrinsic motivation. Guided by Constructivist, Cognitive Load, and Self-Determination theories, two research questions and 2 hypotheses were tested. A quasi-experimental design with experimental and control groups was employed. A sample of 200 undergraduate science students were drawn. Data were collected via pretests and posttests on Biology, engagement and motivation questionnaires. Analyses were conducted using independent t-tests and multiple regression. Findings showed that students exposed to TEL achieved significantly higher posttest scores than peers receiving traditional instruction, reflecting improved conceptual understanding, problem-solving skills, and practical competencies. TEL enhanced engagement and intrinsic motivation. Among TEL features, interactive multimedia and virtual labs had the strongest impact, while adaptive quizzes reinforced assessment performance. The study concluded that TEL Significantly enhances science learning outcomes. students taught in/with TEL environments showed significantly higher posttest scores than those in traditional classrooms. Also, they showed a positive or high engagement and motivation. Recommendations among others include integrating interactive simulations and adaptive assessments, strengthening teacher TEL competencies, and ensuring equitable access to technological resources.

Keywords: Digital-Assessment, Technology-Enhanced Learning, Engagement, Intrinsic Motivation, Science Education.

Introduction

Technology-Enhanced Learning (TEL) refers to the use of digital tools and platforms that aid in enhancing the learning and evaluation experience. It also pertains to the incorporation of digital tools and resources to enhance and facilitate the teaching and learning process. TEL includes a wide variety of technologies like interactive multimedia, virtual environments, online learning platforms, simulations, mobile applications, and learning analytics (Ibrahim et al., 2025). Studies on TEL increasingly indicate that when effectively incorporated, these tools can boost student involvement, tailor learning experiences, and facilitate better academic outcomes (Ibrahim et al., 2025; Tawafak et al., 2018). In science education, TEL tools offer significant potential as science entails conceptual comprehension, experimentation, and advanced thinking skills that can be supported by interactive digital mediums.

Technology-Enhanced Learning (TEL) involves the purposeful and strategic application of digital tools, platforms, and data-oriented technologies to enhance teaching, learning, and assessment activities (Scanlon & Taylor, 2016). In science education, TEL offers transformative possibilities by linking classroom learning to real scientific practices, enhancing deep conceptual understanding, and facilitating reflective assessment practices that are iterative and based on evidence. TEL provides the opportunity to surpass conventional teaching, enabling learners to interact with dynamic simulations, authentic data sets, and immersive environments that reflect modern scientific exploration. Yusuf et al., (2021) that TEL can positively influence academic achievement. For example, use of TEL modules has been shown to significantly improve student performance in physics topics such as waves and sound. These findings align with the principles of self-determination theory Deci & Ryan, 1985), which emphasize the role of autonomy and interactive learning environment in enhancing intrinsic motivation.

Technology-Enhanced Learning (TEL) encompasses a range of tools and approaches, including simulations, online assessments, interactive platforms, and data analytics, that support research-informed teaching and assessment (Kirkwood & Price, 2024). By leveraging TEL, Nigerian science educators can potentially integrate evidence-based instructional strategies, personalize learning experiences, and enhance assessment practices, ultimately improving science achievement and engagement. In response, educational systems have increasingly adopted Technology-Enhanced Learning (TEL) strategies—such as virtual laboratories, simulations, and digital collaboration platforms—to improve science instruction. Yusuf et al. (2021) reported that Form Four students in Malaysia exposed to TEL modules on waves and sound achieved significantly higher scores than those taught

using conventional methods. Similarly, Okoye et al. (2024) found that senior secondary school students in Nigeria performed better in physics when TEL interventions were employed, demonstrating the potential of digital tools to enhance understanding and retention of scientific concepts. Udemba and Adenji (2024) investigated thefactors that undermine the adoption of electronic assessment (e-assessment) in public secondary schools in Ekiti State, Nigeria. It used a survey research design, collected data from teachers randomly selected from four public secondary schools, and analyzed the results. The study discussed challenges related to implementing e-assessment, offering insights relevant to educators and policymakers. It was revealed that the listed challenges significantly affect e-assessment in the study area.

Traditional instruction method (TIM), commonly characterized by teacher-centred, lecture-based delivery and structured classroom interaction, has historically dominated formal education systems. Empirical research suggests that traditional instructional approaches can produce meaningful gains in student achievement, particularly when they incorporate clear learning intentions, guided practice, and formative feedback. Traditional instruction method in science education is a long- aged method of that allows the teachers and students participate fully in the learning process. This method only allows the teachers to be more involve in the process, which is also called lecture-based, memorization-focused or textbook -driven teaching method. It is effective in teaching large class size, less focus on critical thinking and does not allow the combination of other teaching methods. Research has showed that lecture-based teaching point out shortcomings in promoting higher-order thinking, deep comprehension, and lasting involvement. In a significant meta-analysis of 225 studies in STEM education by Freeman et al. (2014), discovered that students subjected to traditional lecturing were 1.5 times more likely to fail than those participating in active learning settings. In addition, average test scores increased by roughly 6% in active learning settings. These results indicate that although conventional teaching can be beneficial, its effectiveness may be limited in contrast to more engaging educational approaches. Consequently, the empirical literature depicts conventional teaching as pedagogically valid but possibly restricted in fostering deeper cognitive involvement when applied alone.

Assessment outcomes

Assessment is a process that involves testing, with the use of test tool. Test is a vital tool in the hands enables he/her collect the sample beahavour of students in particular subjects or courses of study, which is done before or after treatment (learning) (Ubi and Udemba, 2021**)** Test is used to measure academic achievement

such as test scores, practical exam results, and evaluation scores. Assessment in Nigerian science classrooms is still largely dominated by traditional, summative approaches that emphasize rote memorization rather than conceptual understanding, scientific reasoning, and practical skills. This disconnect undermines the potential impact of educational research and contributes to poor learning outcomes, low student motivation, and limited development of higher-order thinking skills (López-Pastrana,2022).

Assessment outcomes are measurable indicators of student learning, including test scores, practical examination results, and performance-based evaluation (ScienceDirect, 2025). Effective assessments provide feedback on conceptual understanding, skills acquisition, and problem-solving ability. TEL has the potential to influence these outcomes through interactive assessments, adaptive quizzes, and immediate feedback mechanisms, which enable both formative and summative evaluation of learning (Yusuf et al., 2021).

Science Education, TEL and TIM

Scientific education traditionally relies on teacher-centered lectures and laboratory practical. However, challenges such as limited instructional time, inadequate lab resources, and large class sizes can constrain student engagement and reduce opportunities for active learning (Okoye et al., 2024). In response, TEL environments — including simulations, multimedia tutorials, and adaptive assessments — offer flexible opportunities for students to interact with scientific concepts outside the constraints of traditional classrooms. TEL is often linked with self-paced learning, immediate feedback, and data-driven instructional decisions (ScienceDirect, 2025), all of which can potentially influence students' assessment outcomes.

Science education requires both conceptual understanding and procedural knowledge. Traditional teacher-centered methods often struggle to provide individualized attention, particularly in large classes with limited laboratory resources (Okoye et al., 2024). TEL interventions such as virtual labs, simulations, and multimedia tutorials can bridge these gaps by providing experiential learning opportunities and scaffolding complex scientific concepts (Ghosh & Patil, 2023). Moreover, TEL can enhance motivation and engagement, factors known to correlate with better assessment outcomes.

This study is supported by Constructivism and Self-Determination Theories. Constructivism asserts that learners actively build knowledge via experiences and reflection (Piaget, 1972). TEL adheres to constructivist principles by offering interactive, problem-solving, and inquiry-driven digital settings. Virtual laboratories and simulations enable students to explore and examine hypotheses in

secure, structured environments, enhancing their conceptual grasp and leading to better assessment results. While Self-Determination Theory (Deci & Ryan, 1985) emphasizes the significance of autonomy, competence, and connection in motivation. TEL promotes independence via self-directed learning, enhances skill development with immediate feedback, and encourages collaborative learning opportunities. Heightened motivation stemming from these elements can indirectly boost assessment results by improving engagement and perseverance.

Statement of the Problem

Despite sustained reforms in science education, students' achievement, conceptual understanding, and scientific reasoning skills remain uneven and, in many contexts, below expected standards. Traditional teacher-centered instructional approaches continue to dominate classrooms, often emphasizing content coverage over inquiry, critical thinking, and metacognitive development. As a result, many learners demonstrate fragmented understanding of scientific concepts, limited problem-solving ability, and low engagement. It was observed that Science education challenges continue to persist in many educational systems. Traditional instructional methods often fail to sufficiently engage students or foster deep conceptual understanding, leading to unexceptional assessment performance. Although TEL offers promising ways to enhance student learning, there is limited systematic evidence on its direct impact on science students' assessment outcomes, particularly in diverse educational contexts like Nigeria. Mixed findings also exist in global research: while many studies report positive effects of TEL on academic performance (Yusuf et al., 2021; Ghosh & Patil, 2023), others suggest that its effectiveness depends on implementation fidelity, teacher readiness, and access to technological infrastructure (ScienceDirect, 2025). Consequently,

Therefore, the central problem of this study is the lack of a systematic comparative assessment of science education outcomes under TEL-based and TIM-aligned instructional approaches. Without such comparative evidence, educators and policymakers lack clear guidance on how best to design, integrate, and evaluate instructional strategies that optimize student learning in science. This study seeks to address this gap by rigorously examining and comparing the effectiveness of TEL, TIM, and their integration in enhancing science learning outcomes.

Research Objectives

The main objective of this study is to compare the assessment scores of science students exposed to technology-enhanced learning (TEL) and traditional instruction method (TIM). Specifically, the study examined

1. The difference in the pretest and posttest scores of science students exposed to

TEL and those taught using traditional instructional method (TIM),

2. The difference in students' engagement and motivation levels between those taught with TEL and those taught with TLM.

Research Questions

1. What is the difference in the pretest and posttest scores between science students exposed to TEL and those taught using traditional instructional method (TIM)?
2. What is the difference in students' engagement and motivation levels between those taught with TEL and those taught with TLM?\\

Research Hypotheses

1. There is significant difference in the mean scores of pretest and posttest of science students taught with TEL and those taught with TLM.
2. TEL features, engagement motivation do not significantly predict science students' assessment outcome**.**

Method

The research employed a quantitative, quasi-experimental design featuring a control group with pretest and posttest measurements. This design facilitates the comparison of students' assessment results prior to and following the TEL intervention while managing external variables. The research also includes survey tools to assess engagement and motivation as intermediary variables. The study group includes students from the 300 and 400 Levels in the Science Education department at the Faculty of Education, Federal University Oye-Ekiti (FUOYE). The emphasis on these students is warranted since they possess sufficient access to digital devices and internet connections. Additionally, the science curricula at this stage include intricate concepts, laboratory techniques, and problem-solving activities that can be improved by TEL interventions. A group of 120 science students was drawn employing a purposive sampling method. A total of 120 students were randomly allocated to the experimental (TEL intervention) group and the control (traditional instruction) group. (60 experimental, 60 control) to guarantee adequate statistical strength for evaluation. Prior to data collection, tailored TEL modules were created, consisting of: Interactive multimedia lessons (animations, videos), Virtual lab simulations, Adaptive quizzes with immediate feedback exercises, and Mobile learning apps for review. The assessment tools for data collection included pretest and posttest standardized science tests, adopted from Ibrahim et al. (2025) and Deci & Ryan (1985), aimed at evaluating conceptual

understanding, practical skills, problem-solving abilities, engagement, and motivation.

The scales of the questionnaire for engagement dimensions are attention, participation, and persistence. Motivation dimensions include autonomy, competence, and relatedness. The research's reliability was established through a pilot test conducted with science students at Ekiti State University (EKUS), resulting in a Cronbach's alpha of 0.81, indicating that the instrument is reliable for the study. Content validity established through science education experts who ensured for face validity, content accuracy, usability, and alignment with curriculum objectives. Under data collection procedure; the researchers obtain ethical approval from the HOD of Science Education Department and informed consent from the targeted students and laboratory staff. Thereafter, the researchers administer pretests and engagement/motivation surveys to both experimental and control groups. The TEL intervention (customized TEL modules) was Implemented for 2 weeks in the experimental group while the control group received traditional instruction. Afterwards, the researchers administered posttest and engagement/motivation surveys immediately after the intervention. Next data collected were coded and analyzed using descriptive (mean and standard deviation) and Inferential Statistics (t-test and Multiple regression analysis) at 0.05 level of significance.

Results

Research question 1: What is the difference in the pretest and posttest scores between science students exposed to TEL and those taught using traditional instructional method (TIM)?

Table 1: Descriptive Statistics of pretest and posttest difference

Groups	Pretest Mean (SD)	Posttest Mean (SD)	Gain score Mean (SD)
Experimental	55.2 (8.3)	78.6 (7.1)	23.4 (5.4)
Control	54.8 (7.9)	61.5 (6.8)	6.7 (4.2)

From table 1 above, both groups had comparable pretest scores indicating baseline equivalence. However, the experimental group demonstrated a substantially higher mean gain score compare to the control group. This implies that students exposed to TEL experienced greater improvement in science assessment outcomes than those receiving traditional instruction.

Research question 2: What is the difference in students' engagement and motivation levels between those taught with TEL and those taught with TLM?

Table 2. descriptive Statistics of difference between engagement and Motivation

Variables	Experimental Mean (SD)	Control Mean (SD)
Engagement	4.2 (0.5)	3.1(0.6)
Motivation	4.0(0.6)	3.0 (0.7)

From table 2. It indicates that students in the TEL groups reported higher engagement and motivation compared to the control group.

Hypothesis 1: There is no significant difference in the mean scores of pretest and posttest of science students taught with TEL and those taught with TLM.

Paired -samples T-test statistics **(within groups pretest and posttest comparison)**

Table 3.1 Paired -samples T-test statistics **(within groups pretest)**

Group	t-value	p-value	Remark
Experimental Vs Control	12.3	0.002	significant

Results in table 3.2 show that there is a statistically significant difference in posttest scores between the two groups. Students exposed to TEL performed significantly better than those who received traditional instruction.

Hypothesis 2: TEL features, engagement motivation do not significantly predict science students' assessment outcome**.**

Table 4: Multiple Regression analysis of TEL features and Assessment outcome of science students

Predictor		T	p-value	Remark
Interactive Multimedia	0.32	4.5	0.002	significant
Virtual Lab and Simulation	0.28	3.9	0.003	significant
Adaptive Quizzes	0.24	3.3	0.002	significant
Engagement	0.35	3.3	0.003	Sign
Motivation	0.29	4.2	0.002	Sign

From the table 4 indicates that all TEL features significantly predict assessment outcome. Engagement and motivation showed strong positive effects. This implies that TEL features positively predict and influencescience students' academic outcome, in the study area.

Discussion

The results for research questions revealed that there are differences in the pretest and posttest scores between science students exposed to TEL and those taught using traditional instructional method (TIM).This implies that students exposed to TEL experienced greater improvement in science assessment outcomes than those receiving traditional instruction. This result supports the findings of Freeman et al. (2014) demonstrated that active learning with technology significantly enhances student performance and reduces failure rates in comparison with traditional lecturing. These improvements are attributed to increased cognitive engagement, peer interaction, and formative feedback opportunities. Importantly, the empirical evidence suggests that technology alone does not drive achievement gains. Rather, gains emerge when TEL is embedded within pedagogically sound frameworks that promote interaction, retrieval practice, feedback, and self-regulation. Also, the result is in line with Yusuf et al., (2021) that TEL can positively influence academic achievement. For example, use of TEL modules has been shown to significantly improve student performance in physics topics such as waves and sound. These findings align with the principles of self-determination theory Deci & Ryan, 1985), which emphasize the role of autonomy and interactive learning environment in enhancing intrinsic motivation.

This indicates that TEL has a stronger effect on students' academic performance. Also, students exposed to TEL performed significantly better than those who received traditional instruction. This supports the report from Yusuf et al. (2021) reported that Form Four students in Malaysia exposed to TEL modules and conventional methods result revealed that there was 87% improvement in performance of students taught with TEL. Similarly, this report support Okoye et al. (2024) found that senior secondary school students in Nigeria performed better in physics when TEL interventions were employed, demonstrating the potential of digital tools to enhance understanding and retention of scientific concepts. Result revealed that there was 87% improvement in performance of students. This supports the report from Udemba and Adenji (2024), that digital learning and assessment enhance students performance. This study also supports constructivism theory Piaget, (1972) that virtual laboratories and simulations allow students to experiment and test hypotheses in safe, guided settings, facilitating deeper conceptual understanding and improved assessment outcomes

Finally, the study revealed that all TEL features significantly predict assessment outcome. Engagement and motivation showed strong positive effects, confirming their mediating roles within the conceptual framework. This report supports Ibrahim et al., (2025) the study stated that TEL also supports student engagement and attitudes toward learning, factors which indirectly affect assessment outcomes. For instance, also it was revealed that TEL has been associated with higher engagement levels and positive attitudes toward learning in primary classrooms. The result also is in agreement with Ghosh and Patil, (2023) findings point to the compelling role of TEL not only as an instructional tool but also as an assessment enhancer that may improve how science learning is measured and experienced. This study agrees with Self-Determination Theory (Deci & Ryan, 1985) that TEL fosters autonomy through self-paced learning, increased motivation resulting from these factors can indirectly improve assessment outcomes by enhancing engagement and persistence.

Conclusions and Recommendations

It was revealed in the study that TEL Significantly Enhances Science Learning Outcomes. Students in TEL environments showed significantly higher posttest scores than those in traditional classrooms. Also, they shown a positive or high-level Engagement and Motivation to Learning. The study also revealed that TEL's effect on assessment outcomes operates through increased student engagement and intrinsic motivation. It was also found in the study that TEL features differ in effectiveness; Interactive multimedia, virtual labs, and adaptive quizzes contributed most to improved performance.

Based on the findings the following recommends were made;

1. Educators should Integrate interactive simulations and adaptive quizzes into science curricula, provide scaffolding to ensure students maximize engagement.
2. School Administrators should improve infrastructure and access to devices; they should offer professional development to enhance teachers' TEL competencies.
3. Research study should investigate long-term retention and practical skills development through TEL. Explore TEL implementation across diverse socio-economic and geographic contexts.

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