

EVALUATION OF INTELLIGENT TUTORING SYSTEM ON COGNITIVE AND PSYCHOMOTOR RETENTION IN BASIC-ELECTRONICS TECHNICAL COLLEGES IN LAGOS STATE, NIGERIA

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Abstract

This study examined the effectiveness of an Intelligent Tutoring System (ITS) on cognitive and psychomotor retention among Basic Electronics students in technical colleges in Lagos State, Nigeria. ITS, a computer-based learning system designed to deliver student-centered instruction, remains underutilised in technical education, limiting its potential to enhance retention. The objectives were to investigate the effect of ITS on students' cognitive retention in Basic Electronics and to determine its effect on psychomotor retention. A quasi-experimental design was employed, involving 233 participants comprising students, teachers, instructional designers, and technologists selected through multi-stage sampling. Data were collected using validated instruments, including the Basic Electronics and Psychomotor Achievement Test and expert validation forms, with reliability indices ranging from 0.70 to 0.96. Pre-tests, post-tests, and retention tests were administered over eight weeks, and analyses conducted with ANCOVA at 0.05 significance level revealed that experts rated the Basic-Electronics Intelligent Tutoring System (BEITS) highly. Students taught with BEITS achieved significantly superior cognitive and psychomotor performance compared to those taught conventionally, with retention outcomes also favouring BEITS. Findings confirmed that BEITS enhances individualised learning, retention, and performance, establishing it as an effective instructional innovation. Recommended among others, that broad integration of ITS into technical college curricula, alongside educator training and infrastructural investment, to maximize its impact on students' cognitive and psychomotor development.

Keywords: Achievement, Basic-Electronics, Cognitive Retention, Intelligent Tutoring System, Psychomotor Retention, Technical Colleges

Introduction

Education remains the bedrock of national development, serving as a driver of social, economic and technological progress through strategies such as digital learning, vocational training and policy reforms. Within this framework, science and technology education plays a pivotal role in shaping innovation and competitiveness, particularly in a knowledge-driven global economy. The integration of Educational Technology into teaching and learning has become indispensable, bridging conventional pedagogical approaches with modern technological advancements to equip learners with the skills required for a rapidly evolving world (Imam *et al.*, 2023).

Technical education, especially in fields such as Basic Electronics, demands instructional approaches that enhance both cognitive and psychomotor learning outcomes. Cognitive achievement reflects learners' mastery of theoretical knowledge, often assessed through tests and examinations, while psychomotor achievement involves the acquisition of practical skills, typically evaluated through hands-on performance tasks (Amorim *et al.*, 2024). Retention of knowledge and skills in both domains is critical, as it ensures learners can recall and apply competencies over time.

Studies such as Hiromitsu *et al.* (2024) and Alkhabra (2023) highlighted that retention is influenced by reinforcement, instructional design and memory capacity, underscoring the need for innovative strategies that foster long-term learning. Within technology-enhanced learning environments, emerging evidence indicates that adaptive systems can strengthen retention by aligning instruction with learners' evolving needs. Empirical studies have consistently reported that Intelligent Tutoring Systems improve cognitive retention through personalised feedback and mastery-based progression (Arici & Karaci, 2018; Karaci *et al.*, 2018), thereby reinforcing theoretical understanding over time.

Basic Electronics, as offered in Nigerian technical colleges, equips students with competencies in designing, maintaining and repairing electrical and electronic devices such as oscilloscopes, modulators, transmitters and integrated circuits (FRN, 2014; NBTE, 2018; Orji *et al.*, 2022). Technical colleges are mandated to produce craftsmen and master craftsmen capable of solving practical problems through applied scientific principles. Given the dual emphasis on theory and practice, instructional strategies must be robust enough to strengthen both cognitive retention and psychomotor proficiency, ensuring learners are adequately prepared for workforce demands. While much of the early ITS literature concentrated on cognitive gains, recent scholarship has drawn attention to its potential for structured skill acquisition in practice-oriented disciplines.

Studies by Dascalu *et al.* (2022) and Neagu (2022) demonstrated that adaptive tutoring environments can scaffold procedural learning and improve performance accuracy in simulated technical tasks, suggesting meaningful implications for psychomotor retention. Clément *et al.* (2024) further emphasised the importance of adaptive sequencing and learner choice in sustaining engagement and supporting skill consolidation, highlighting ITS adaptability as a mechanism for strengthening long-term competence.

Rooted in this imperative, Intelligent Tutoring Systems have emerged as a promising intervention. Drawing on artificial intelligence, ITS provides adaptive and interactive learning experiences by simulating the functions of human tutors, thereby bridging the gap between theoretical understanding and practical application. Its architecture typically comprises an expert model, that is, knowledge domain; a student model, that is, performance tracking; a tutoring model, that is, instruction delivery; and a user interface, that is, an interactive environment that accommodates personalised instruction and real-time feedback (Huq *et al.*, 2024).

In Basic Electronics education, ITS can simplify complex concepts such as circuit design while simultaneously supporting hands-on skill development through guided practice (Bhuttah *et al.*, 2024). Empirical findings have shown that ITS environments enhance knowledge retention by providing immediate corrective feedback and opportunities for repeated practice tailored to learner errors (Arici & Karaci, 2018; Karaci *et al.*, 2018). However, research also indicates that ITS effectiveness is influenced by learner characteristics and contextual variables. Cerezo *et al.* (2020) highlighted the role of self-regulated learning processes in moderating outcomes within intelligent systems, while Schmidt (2022) reported subgroup variations in performance gains, suggesting that adaptability and inclusivity are central to sustained impact.

The evaluation of ITS effectiveness therefore requires a careful examination of its impact on both cognitive and psychomotor retention. Cognitive retention reflects learners' ability to recall and apply theoretical knowledge, whereas psychomotor retention denotes the sustained capacity to perform practical tasks with proficiency. Although cognitive outcomes have been widely documented (Arici & Karaci, 2018; Karaci *et al.*, 2018), comparatively fewer studies have examined long-term psychomotor retention within ITS environments. Emerging evidence from technical and simulation-based domains nonetheless suggests that adaptive scaffolding and structured practice can enhance procedural fluency and performance durability (Dascalu *et al.*, 2022; Neagu, 2022). This distinction underscores a critical gap in the literature, particularly within vocational and technical education contexts where psychomotor competence is central.

As a result, evaluation is not merely a measure of ITS performance but a critical process for determining its adaptability and inclusivity across diverse learning environments (Wang, 2019; Chou *et al.*, 2022). Integrating instructional design models such as ADDIE—analysis, design, development, implementation and evaluation ensures that ITS development and assessment remain systematic and curriculum-aligned (González-Pérez *et al.*, 2022). Evaluation methods often employ pretests and posttests to measure learning gains, alongside formative and summative assessments to track usability, engagement and adaptability (Pollock *et al.*, 2023; Kazemitabaar *et al.*, 2024). Experimental designs comparing intervention and control groups are particularly valuable in establishing causal relationships between ITS usage and student performance. Evidence from global contexts demonstrates ITS effectiveness in improving problem-solving skills, programming proficiency and retention across diverse disciplines (Troussas *et al.*, 2020; Liu *et al.*, 2024), while also acknowledging contextual and learner-related variations (Cerezo *et al.*, 2020; Schmidt, 2022).

Countries such as Australia, Finland and Sweden have successfully integrated ITS into technical and vocational education, reporting significant improvements in both cognitive and psychomotor domains (Imam *et al.*, 2023). For Nigerian technical colleges, where Basic Electronics education aims to produce skilled craftsmen, ITS offers a transformative opportunity to enhance instructional quality and learner outcomes. Its personalised feedback, adaptive sequencing and learner-centred pathways align with the vocational emphasis on practical skill mastery and sustained competence (Clément *et al.*, 2024; Amorim *et al.*, 2024; Wong *et al.*, 2024).

Given the challenges facing Nigerian technical education, including limited resources and the need for modernised instructional strategies, evaluating ITS integration is both timely and necessary. Research emphasises the importance of assessing not only immediate learning gains but also learners' ability to transfer and generalise knowledge for sustained success (Ssemugenyi, 2023). In light of the relative scarcity of studies addressing psychomotor retention within ITS frameworks, particularly in technical college contexts, a focused investigation into both cognitive and psychomotor outcomes is warranted. Embedding ITS within technical college curricula could therefore strengthen dual-domain retention, enhance educational quality and prepare students for the demands of a dynamic technological workforce (Conati *et al.*, 2021).

Statement of the Problem

Despite the strategic importance of technical education in Nigeria, persistent challenges undermine the effectiveness of instructional delivery in Basic Electronics programmes. Conventional teaching methods in technical colleges remain largely teacher-centred, relying heavily on chalk-and-talk approaches and limited demonstrations. These methods often fail to adequately engage learners, resulting in poor comprehension of theoretical concepts and weak mastery of practical skills. Consequently, students struggle with cognitive retention, as knowledge acquired during lessons is quickly forgotten and psychomotor retention, as practical skills are inconsistently applied or lost over time (Oteyola, 2022).

The problem is compounded by inadequate instructional resources, overcrowded classrooms and insufficient access to modern learning technologies. Many technical colleges lack structured interventions that can personalise learning, provide immediate feedback, and adapt instruction to individual learner needs. As a result, graduates of Basic Electronics programmes frequently demonstrate gaps in both theoretical understanding and practical competence, limiting their employability and capacity to meet industry demands (Okolie, *et al.*, 2020).

Intelligent Tutoring Systems (ITS) offer a potential solution by providing adaptive, interactive and learner-centred instruction. However, empirical evidence on their effectiveness in Nigerian technical colleges, particularly in enhancing cognitive and psychomotor retention, remains scarce (Okolie, *et al.*, 2020). Without rigorous evaluation, stakeholders cannot determine whether ITS can address the persistent learning challenges in Basic Electronics education. This study therefore seeks to evaluate the impact of ITS on students' retention of both theoretical knowledge and practical skills, aiming to

provide evidence-based insights into its suitability as an instructional innovation for technical education in Lagos State.

Purpose of the Study

The main purpose of the study was to evaluate an Intelligent Tutoring System (ITS) on Cognitive and Psychomotor Retention in Basic-Electronics Technical Colleges in Lagos State, Nigeria. Specifically, this study:

1. investigated the effect of Intelligent Tutoring System on students' cognitive retention in Basic Electronics.
2. determined the effect of Intelligent Tutoring System on students' psychomotor retention in Basic Electronics.

Research Questions

The study provided answers to the following research questions:

1. What is the effect of using an Intelligent Tutoring System on students' Cognitive retention in Basic-Electronics programme in technical college?
2. What is the influence of using an Intelligent Tutoring System on students' psychomotor retention in the Basic-Electronics programme in technical college?

Research Hypotheses

The following null hypotheses were tested at 0.05 level of significance:

- Ho₃: There is no significant difference between the mean scores of Experimental group and Control group in the Cognitive retention of students in Basic-electronics programme in technical college.
- Ho₄: There is no significant difference between the mean scores of Experimental group and Control group in the Psychomotor retention of students in Basic-electronics programme in technical college.

Methodology

A quantitative research method was adopted for this study, employing a quasi-experimental design. The design involved the use of intact classes (existing groups) rather than randomly assigning students to experimental and control groups. The design involved two groups: the experimental group taught basic electronics concepts using the ITS and the control group taught through conventional lecture methods. Both groups participated in pre-tests, post-tests and retention test to measure their academic performance.

The design represented thus:

Experimental: -	O1	X	O2	Y	O3
Control: -	O1	-	O2	Y	O3

Where:

O1 represents pretest (observation or measurement before the treatment);

O2 represents post-test (observation or measurement after treatment);

O3 represents retention-test (to be conducted two weeks after the posttest).

X represents experimental treatment (with Basic Electronics Intelligent Tutoring System instructional tool); – indicates no treatment (that is, the use of conventional methods)

Y indicates a delayed period of two weeks after posttest

The study was conducted among technical colleges in Lagos State, with the target population consisting of NTC II students who were currently enrolled in Basic-Electronics. A multistage sampling technique was employed, beginning with the use of a simple random sampling procedure to select two technical colleges out of the six technical colleges in Lagos State, Nigeria. Secondly, a random sampling procedure was used to allocate one technical college to the experimental group with thirty-six (36) and the control group with thirty-nine (39) NTC II basic electronics students out of two hundred and thirty-three (233), or vice versa. An intact class was chosen for each of the two selected technical colleges. The research instrument used for data collection were Basic Electronics Achievement Test (BEAT) and Basic Electronics Psychomotor Achievement Test (BEPAT) developed by the researcher to assess students' retention of key basic-electronics concepts.

To ensure validity, the instrument was subjected to expert review by specialists in the Department of Educational Technology, University of Ilorin, Instructional designers and Basic-electronics Teachers. Their feedback guided revisions to improve clarity, content relevance, and alignment with curriculum objectives. The reliability of the instruments was established using the test–retest method, and reliability coefficients of 0.82 and 0.96 for BEAT and BEPAT respectively were obtained using Kuder Richardson formula 20, indicating that the instruments were reliable for the study.

Ethical considerations were duly observed throughout the study. Permission was obtained from the school authorities before data collection. The purpose of the study was clearly explained to the participants and their teachers, and their voluntary participation was ensured. Confidentiality of participants' information and responses was strictly maintained, and no student was disadvantaged as a result of participation or non-participation. The study also ensured that the activities posed no psychological or physical harm to the students.

Results

Research Question One: What is the effect of using Intelligent Tutoring System on students' Cognitive retention in Basic-Electronics programme in technical college? The results showing the effect of using ITS on students' Cognitive retention in Basic-Electronics programme in technical college is presented in Table 1.

Table 1: Post-test and Retention-test Mean Cognitive Retention Scores of Students Taught Basic-Electronics Using Intelligent Tutoring System and Conventional Teaching Method

Groups	Post-test			Retention –test		
	N	Mean	SD	Mean	SD	Retention Rate
Experimental Group	36	80.03	1.46	75.39	.96	94.2%
Control Group	39	68.85	1.69	60.08	1.61	87.2%

Table 1 presents the effect of using the Intelligent Tutoring System on students' cognitive retention in the Basic-Electronics programme in technical college. The result shows that the experimental group, taught using the Intelligent Tutoring System, had a post-test mean score of 80.03 (SD = 1.46) and a retention-test mean score of 75.39 (SD = 0.96), resulting in a retention rate of 94.2%. In contrast, the

control group, taught using the conventional teaching method, had a post-test mean score of 68.85 (SD = 1.69) and a retention-test mean score of 60.08 (SD = 1.61), with a retention rate of 87.2%. This indicated that students taught Basic-Electronics with the Intelligent Tutoring System retained more of the cognitive content over time compared to those taught using the conventional method.

Research Question Two: What is the influence of using an Intelligent Tutoring System on students' psychomotor retention in the Basic-Electronics programme in technical college? The results showing the influence of using an ITS on students' psychomotor retention in the Basic-Electronics programme in technical college is presented in Table 2.

Table 2: Post-test and Retention-test Mean Psychomotor Retention Scores of Students Taught Basic-Electronics using Intelligent Tutoring System and Conventional Teaching Method

Groups	Post-test			Retention –test		
	N	Mean	SD	Mean	SD	Retention Rate
Experimental Group	36	83.28	1.08	77.69	2.03	93.2%
Control Group	39	75.74	1.46	67.00	2.35	88.5%

The influence of Intelligent Tutoring System influences on students' psychomotor retention in the Basic-Electronics programme in technical college is presented in Table 2. The result shows that the experimental group, which was taught using the Intelligent Tutoring System, had a post-test mean score of 83.28 (SD = 1.08) and a retention-test mean score of 77.69 (SD = 2.03), resulting in a retention rate of 93.2%. In contrast, the control group taught using the conventional teaching method had a post-test mean score of 75.74 (SD = 1.46) and a retention-test mean score of 67.00 (SD = 2.35), yielding a retention rate of 88.5%. This indicated that students taught Basic-Electronics with the Intelligent Tutoring System retained psychomotor skills more effectively over time compared to those taught using the conventional method.

Hypotheses Testing

The results of hypotheses tested in this study are presented in subsequent tables. All hypotheses were tested at significant level of 0.05.

Hypothesis One:

H₀₁: There is no significant difference between the mean scores of Experimental group and Control groups in the Cognitive retention of students in Basic-electronics programme in technical college. Results for testing hypothesis three is presented in Table 3.

Table 3: Analysis of Covariance for the Test of Significant Difference between the Mean Scores of Experimental group and Control group in the Cognitive Retention of Students

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4391.044 ^a	2	2195.522	1222.544	.000
Intercept	1156.070	1	1156.070	643.740	.000
Pretest	2.023	1	2.023	1.126	.292

Group	4323.865	1	4323.865	2407.679	.000*
Error	129.302	72	1.796		
Total	345497.000	75			
Corrected Total	4520.347	74			

a. R Squared = .971 (Adjusted R Squared = .971)

Table 3 presents the results for the test of significant difference between the mean scores of the experimental group and the control group in the cognitive retention of students in the Basic-Electronics programme in technical college. The result shows an F-value of 2407.68 and a p-value of .000 ($p < 0.05$), indicating a statistically significant difference between the two groups. This implies that students taught using the Intelligent Tutoring System demonstrated significantly higher cognitive retention compared to those taught using the conventional method. Based on this result, the null hypothesis is rejected. It can therefore be concluded that the Intelligent Tutoring System had a significant positive effect on students' cognitive retention in the Basic-Electronics programme.

Hypothesis Two:

H₀₂: There is no significant difference between the mean scores of Experimental group and Control group in the Psychomotor retention of students in Basic-electronics programme in technical college. Results for testing hypothesis four is shown in Table 4.

Table 4: Analysis of Covariance for the Test of Significant Difference between the mean scores of Experimental group and Control group in the Psychomotor Retention of Students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2140.902 ^a	2	1070.451	225.894	.000
Intercept	808.558	1	808.558	170.628	.000
Pretest	16.163	1	16.163	3.411	.069
Group	2081.146	1	2081.146	439.179	.000*
Error	336.449	71	4.739		
Total	388112.000	74			
Corrected Total	2477.351	73			

a. R Squared = .864 (Adjusted R Squared = .860)

Table 4 presents the results for the test of significant difference between the mean scores of the experimental group and the control group in the psychomotor retention of students in the Basic-Electronics programme in technical college. The result shows an F-value of 439.18 and a p-value of .000 ($p < 0.05$), indicating a statistically significant difference between the two groups. This suggests that students taught using the Intelligent Tutoring System retained psychomotor skills significantly better than those taught using the conventional method. Based on this analysis, the null hypothesis is

rejected, and it is concluded that the Intelligent Tutoring System significantly enhances students' psychomotor retention in the Basic-Electronics programme.

Findings and Discussions

The findings of this study demonstrate that the use of Intelligent Tutoring Systems (ITS) in the Basic-Electronics programme of technical colleges significantly enhanced both cognitive and psychomotor retention among students compared to conventional instructional methods. Students exposed to ITS retained more cognitive content over time, as evidenced by the statistically significant differences in mean retention scores between the experimental and control groups. This suggests that ITS fosters deeper cognitive processing and supports long-term memory formation, largely due to its adaptive features such as individualized feedback, interactive reinforcement, and mastery-based progression. These mechanisms encourage active engagement and repeated practice, which are critical for consolidating knowledge beyond the immediate instructional period.

The results are consistent with earlier studies. Arıcı and Karacı (2018) reported that web-based ITS improved achievement and retention in electronic spreadsheet learning, while Karacı *et al.* (2018) similarly found that ITS promoted long-term retention compared to traditional methods. These findings reinforce the present study by highlighting the role of ITS in sustaining learning gains through self-paced and student-centered approaches. However, other research has nuanced perspectives. Cerezo *et al.* (2020) emphasized ITS's contribution to self-regulated learning among students with learning disabilities, noting that retention outcomes were not always significant, thereby suggesting that learner characteristics and instructional contexts may mediate ITS effectiveness. Schmidt (2022) also observed that ITS improved performance in an online nursing course, but retention gains varied across subgroups, likely due to differences in content complexity and learner engagement.

Beyond cognitive outcomes, this study revealed that ITS also significantly enhanced psychomotor retention. Students taught with ITS retained more psychomotor skills over time than those taught conventionally, with statistical evidence confirming the difference in mean scores between groups. This finding underscores ITS's potential to support practical skill development in technical education, where competence in hands-on tasks is essential for workplace readiness. ITS platforms simulate practical tasks, provide real-time feedback, and engage learners in interactive environments that reinforce procedural skills. Dascalu *et al.* (2022) highlighted the effectiveness of ITS in guiding learners through structured skill-building sequences, while Neagu (2022) demonstrated that ITS frameworks designed for open and interactive environments improved psychomotor capabilities.

Compared to previous studies that primarily focused on cognitive retention and achievement (Aricı & Karacı, 2018; Chien *et al.*, 2008; Çakır, 2019), the present research extends the application of ITS into the psychomotor domain. This contribution is particularly valuable, as limited studies have documented ITS's influence on hands-on skills. The multimodal and interactive nature of ITS, which often integrates visual demonstrations, simulations, and step-by-step guidance, likely explains the enhanced psychomotor retention observed. Such features reduce cognitive overload while facilitating the physical application of learned procedures, thereby strengthening psychomotor memory. Clément *et al.* (2024) further noted that ITS systems incorporating learner choice and adaptive sequencing improve performance by accommodating individual preferences and learning speeds, which may enhance both skill acquisition and retention.

The study confirms the dual role of ITS in supporting cognitive and psychomotor retention within technical education. While prior research has largely emphasised cognitive outcomes, these findings highlight ITS's broader potential in strengthening practical skill development. These positions ITS as a valuable instructional tool for technical and vocational education, where both theoretical understanding and practical competence are critical for preparing students for professional practice.

Conclusion and Recommendations

The study highlighted the evaluation of an ITS aimed at enhancing instructional delivery and learning outcomes in technical colleges. The study showed that students taught using ITS demonstrated significantly higher cognitive and psychomotor retention compared to those taught with the conventional method. These students also retained more cognitive and psychomotor content over time, confirming the system's positive impact on long-term learning outcomes. The significant differences observed between the experimental and control groups in retention provide strong evidence for the effectiveness of ITS in technical education settings. Its ability to support individualised learning, facilitate skill acquisition and promote sustained knowledge retention makes it a valuable innovation in electronics instruction.

The system offers a practical solution for addressing instructional gaps in technical education by supporting individualised learning, reinforcing theoretical understanding, and promoting the acquisition of practical skills. Based on the findings of the study, it is concluded that the Basic-Electronics Intelligent Tutoring System is an effective and reliable instructional tool that enhances both cognitive and psychomotor learning outcomes in technical college students and its integration into the technical education curriculum is strongly justified. Based on the findings of this study, the following recommendations were made:

1. Curriculum developers at National Board for Technical Education should integrate BEITS into the national TVE framework by aligning its content with existing learning objectives through collaboration with subject experts.
2. Science and Technical Boards in the Lagos State, Nigeria should use BEITS for learner revision and retention by embedding its assessments into regular school-based testing programs.
3. Heads of Electrical/Electronics and Maintenance Works Department should adopt BEITS for psychomotor skill development by pairing its virtual simulations with hands-on practical sessions in school workshop.

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