

EFFECT OF SMART VEHICLE-STARTING SYSTEM SIMULATOR ON STUDENTS' ACADEMIC ACHIEVEMENT IN AUTOMOBILE TECHNOLOGY IN COLLEGES OF EDUCATION, KWARA STATE, NIGERIA

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Abstract

This study examined the effect of the Smart Vehicle-Starting System Simulator (SVSSS) on students' academic achievement in Automobile Technology in Colleges of Education in Kwara State, Nigeria. A quasi-experimental design of the non-randomized pretest–posttest control group type was adopted. The population comprised students offering Automobile Technology, from which 117 students were selected using the intact class technique and assigned to experimental (56) and control (61) groups. The intervention lasted for six weeks, during which the experimental group was taught using the SVSSS, while the control group was taught using the conventional method. Data were collected using the Automobile Technology Performance Test (ATPT), which was validated and pilot-tested, yielding a reliability coefficient of 0.824. Mean and standard deviation were used to answer research questions, while t-test was used to test the hypotheses at the 0.05 level of significance. Findings revealed that students taught using the SVSSS performed significantly better than those taught using conventional methods, and there was a significant improvement between the pre-test and post-test scores of students exposed to the simulator. However, no significant difference was found in the academic achievement of male and female students taught using the SVSSS. The study concludes that the SVSSS is an effective instructional tool for improving students' academic achievement and promoting experiential learning in Automobile Technology. The study implies that simulation-based instructional tools can enhance practical understanding and improve learning outcomes in technical education.

Introduction

Education remains a fundamental instrument for national development, serving as a means of equipping individuals with the knowledge, skills, and competencies required for economic productivity and societal advancement. In contemporary economies, emphasis has increasingly shifted toward skill-oriented education systems capable of addressing unemployment and workforce demands. Within this context, Technical and Vocational Education (TVE) plays a critical role in preparing learners for specific occupations through competency-based and practice-driven training approaches. TVE emphasizes hands-on learning, problem-solving, and the application of theoretical knowledge to real-world situations, thereby fostering employability and technical proficiency. Recent studies have underscored the importance of TVE in developing skilled manpower and promoting industrial growth, particularly in developing countries where technical expertise is essential for sustainable development (Okoye & Arimonu, 2023; UNESCO, 2022; Oviawe, 2024).

Within the framework of TVE, Automobile Technology occupies a strategic position as a discipline concerned with the study, maintenance, diagnosis, and repair of motor vehicle systems. The field integrates mechanical and electrical principles, requiring learners to understand complex interactions among engine components, electrical circuits, and control systems. Mastery of Automobile Technology is therefore not only theoretical but also highly practical, demanding the acquisition of psychomotor skills alongside cognitive understanding. Its relevance extends to employability, as graduates are expected to function effectively in automotive workshops, industries, and entrepreneurial ventures. Empirical evidence indicates that students who acquire both conceptual knowledge and practical competence in Automobile Technology are better prepared for the labour market and demonstrate higher technical efficiency (Adebayo & Adewale, 2022; Okafor *et al.*, 2023; Eze & Nwoye, 2024). This underscores the necessity for instructional approaches that effectively integrate theory with practice.

Despite its importance, students' academic achievement in Automobile Technology has remained a concern in many Colleges of Education. Reports indicate that learners often perform below expectations in technical subjects due to difficulties in understanding abstract and complex systems, particularly those involving the integration of mechanical and electrical components. Topics such as the vehicle starting system pose significant challenges, as they require learners to visualize processes that are not directly observable during conventional instruction. Studies have shown that students frequently exhibit misconceptions and low conceptual understanding in such areas, leading to poor academic outcomes (Ogunleye *et al.*, 2022; Salihu & Mohammed, 2023). This persistent issue suggests that existing instructional strategies may be inadequate in facilitating deep learning and meaningful comprehension in Automobile Technology.

A major contributing factor to this problem is the continued reliance on conventional lecture methods in teaching technical subjects. While lectures are effective for transmitting theoretical information, they often fail to provide the experiential learning opportunities required

for skill acquisition in TVE. In many institutions, limited workshop facilities, inadequate instructional materials, and large class sizes further constrain practical engagement. As a result, students are exposed primarily to verbal explanations without corresponding hands-on experiences, creating a disconnect between theory and practice. Research has consistently shown that lecture-dominated instruction in technical education leads to reduced student engagement, lower retention of knowledge, and poor academic performance (Ibrahim *et al.*, 2022; Yusuf & Afolabi, 2024; Adekunle & Bello, 2023). This highlights the need to rethink instructional approaches in Automobile Technology.

In response to these challenges, there is a growing recognition of the need for innovative instructional strategies that promote active and experiential learning. Contemporary educational practices emphasize learner-centered approaches that engage students in practical activities, collaborative problem-solving, and real-life applications of knowledge. Technology-supported instruction has emerged as a key driver of this transformation, enabling the use of digital and interactive tools to enhance teaching and learning processes. Such approaches not only improve students' understanding but also foster critical thinking and skill development. Recent studies have demonstrated that integrating innovative instructional strategies in technical education significantly enhances students' academic achievement and motivation (Ajayi & Oladipo, 2023; Olaitan *et al.*, 2024; Ezeudu & Nwosu, 2022). Therefore, adopting alternative teaching methods is essential for improving learning outcomes in Automobile Technology.

This study is anchored on Experiential Learning Theory (ELT) developed by Kolb, which emphasizes learning through experience, active participation, and reflection (Kolb, 1984). The theory explains that learners achieve deeper understanding when they actively engage with instructional activities rather than passively receiving information. In technical and vocational education, experiential learning supports the development of practical competencies through observation, experimentation, and hands-on interaction with learning resources. Recent studies have affirmed that experiential and activity-based learning approaches significantly improve students' engagement, retention, and academic achievement in technology-oriented learning environments (Alenezi, 2023). The Smart Vehicle-Starting System Simulator (SVSSS) aligns with the principles of ELT by enabling students to manipulate, observe, and interact with automobile starting system components in a practical learning setting.

The study is also supported by Constructivist Learning Theory, which views learning as an active process in which learners construct knowledge through meaningful experiences and interaction (Bruner, 1966). Constructivist learning emphasizes learner-centered instruction, problem-solving, and active participation, which are essential in technical education. Recent evidence indicates that constructivist-based instructional strategies and interactive learning technologies enhance students' conceptual understanding and academic performance in science and technical subjects (Ibrahim & Abdullahi, 2023). These theories therefore provide the

conceptual basis for the use of simulation-based instruction to enhance students' academic achievement in Automobile Technology.

One of the most promising approaches within technology-supported instruction is the use of simulation in technical education. Simulation provides a virtual or physical representation of real-world systems, allowing learners to observe, manipulate, and interact with components in a controlled environment. This approach enhances visualization of abstract concepts, supports safe practice without risk of damage or injury, and enables repeated learning experiences that reinforce understanding. In the context of Automobile Technology, simulation tools can effectively demonstrate complex processes such as engine ignition and electrical flow. Empirical evidence suggests that simulation-based learning significantly improves students' conceptual understanding, engagement, and academic achievement in technical disciplines (Radianti *et al.*, 2023; Makransky *et al.*, 2022; Oke & Fernandes, 2024). These advantages make simulation a viable solution to the challenges associated with conventional teaching methods.

In line with this approach, the Smart Vehicle-Starting System Simulator (SVSSS) was developed as an instructional intervention to enhance the teaching and learning of Automobile Technology. The SVSSS is designed to replicate the operation of a vehicle starting system, integrating both mechanical and electrical components in a functional and interactive format. By providing a platform for hands-on and visual learning, the simulator enables students to observe and manipulate system processes, thereby improving their understanding of complex concepts. Unlike abstract classroom explanations, the SVSSS offers a realistic learning experience that bridges the gap between theory and practice. Its design also supports repeated use and safe experimentation, making it suitable for classroom and workshop settings. As an instructional tool, the SVSSS represents an innovative attempt to improve students' academic achievement through experiential learning.

The Smart Vehicle-Starting System Simulator (SVSSS) is a locally developed instructional device designed to replicate the operation of an automobile starting system in a simplified and interactive format suitable for teaching and learning. The simulator consists of major mechanical and electrical components commonly found in vehicle starting systems, including a battery, ignition switch, starter motor, solenoid, relay unit, flywheel assembly, connecting wires, indicator lights, and control switches mounted on a fabricated metal frame. The system was constructed using locally sourced materials and integrated electrical circuitry that simulates the ignition and engine-starting sequence of a conventional motor vehicle. During operation, the simulator allows students to observe current flow, solenoid activation, starter engagement, and flywheel rotation in real time, thereby providing visual and hands-on learning experiences. The SVSSS also incorporates safety features and simplified component arrangements to facilitate repeated classroom demonstrations, troubleshooting exercises, and practical skill acquisition in Automobile Technology.

Despite the recognized benefits of simulation, there is limited empirical evidence on the effectiveness of locally developed instructional simulators in Nigerian technical education. Many existing studies have focused on theoretical approaches or the use of imported simulation tools, which are often expensive and not tailored to local curricular needs. Furthermore, few studies have systematically examined the impact of such innovations on students' academic achievement in Automobile Technology. This gap in the literature highlights the need for research that evaluates the effectiveness of contextually relevant instructional tools developed within the local environment. Addressing this gap is critical for promoting sustainable educational practices and reducing reliance on foreign technologies (Okoro *et al.*, 2023; Eze *et al.*, 2024; Nwachukwu & Okeke, 2022).

Against this background, this study investigates the effect of the Smart Vehicle-Starting System Simulator (SVSSS) on students' academic achievement in Automobile Technology in Colleges of Education in Kwara State. Specifically, the study seeks to determine whether the use of the SVSSS can improve students' understanding and performance compared to conventional teaching methods, as well as examine variations in learning outcomes. By providing empirical evidence on the effectiveness of this locally developed instructional tool, the study contributes to ongoing efforts to enhance teaching practices and learning outcomes in Technical and Vocational Education.

Statement of the Problem

Ideally, Technical and Vocational Education (TVE) is expected to equip learners with both theoretical understanding and practical competencies necessary for effective performance in technical fields such as Automobile Technology. This expectation aligns with global educational standards that emphasize competency-based and experiential learning for skill development. However, in practice, students in many institutions continue to demonstrate low academic achievement in Automobile Technology, particularly in areas involving complex mechanical and electrical systems. In Colleges of Education in Kwara State, reports from lecturers and departmental examination records have shown persistent poor performance of students in courses related to automobile electrical systems and engine starting mechanisms, with many students demonstrating weak practical competence during workshop activities and practical examinations. This situation has been linked to difficulties in understanding integrated automobile systems and inadequate exposure to practical instructional resources. Evidence from previous studies also shows that learners often struggle to understand integrated processes such as vehicle starting systems, leading to weak conceptual grasp and poor examination outcomes (Salas-Pilco *et al.*, 2022; García-Alcaraz *et al.*, 2023; Oviawe, 2024). This situation reflects a gap between instructional expectations and actual learning outcomes within technical education contexts.

Although prior studies have explored various instructional strategies to improve learning in technical education, limited attention has been given to the effectiveness of locally developed simulation-based tools in enhancing students' academic achievement in Automobile Technology.

Existing research has largely focused on general technology integration or imported simulation systems, with insufficient emphasis on context-specific innovations and their measurable impact on student performance (Radianti et al., 2023; Makransky et al., 2022; Yusuf & Afolabi, 2024). Consequently, the potential of tailored instructional simulators to address persistent learning difficulties remains underexplored. If this gap continues, students may persistently underperform, thereby limiting their technical competence and employability. This underscores the need to empirically examine the effect of a Smart Vehicle-Starting System Simulator on students' academic achievement in Automobile Technology.

Objectives of the study

The following are the specific objectives of this study:

1. compare the academic achievement of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS) and those taught using conventional teaching methods;
2. determine the difference between the pre-test and post-test mean scores of students taught using the SVSSS;
3. examine the difference in academic achievement of male and female students taught Automobile Technology using the SVSSS.

Research Hypotheses

The following null hypotheses will be tested at the 0.05 level of significance:

- H₀₁:** There is no significant difference in the academic achievement of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS) and those taught using conventional teaching methods.
- H₀₂:** There is no significant difference between the pre-test and post-test mean scores of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS).
- H₀₃:** There is no significant difference in the academic achievement of male and female students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS).

Methodology

This study adopted a quasi-experimental design of the non-randomized pretest–posttest control group type to examine the effect of the Smart Vehicle-Starting System Simulator (SVSSS) on students' academic achievement in Automobile Technology. The population comprised students offering Automobile Technology in Colleges of Education in Kwara State, Nigeria. A total of 117 students participated in the study and were selected using the intact class technique to preserve existing classroom structures. Two Colleges of Education were purposively selected based on the availability of Automobile Technology students and relevant workshop facilities. One intact class was assigned to the experimental group, while another served as the control group.

Both groups were pretested prior to treatment to establish equivalence and reduce selection bias. The experimental group was taught using the Smart Vehicle-Starting System Simulator (SVSSS), while the control group was taught using the conventional lecture and teacher-demonstration method involving verbal explanation, chalkboard illustrations, textbook references, and teacher-led demonstrations without simulation tools. Both groups were exposed to the same instructional content, with variation only in the mode of instructional delivery. The treatment lasted for six weeks, during which students received instruction on topics including battery operation, ignition switch functions, starter motor operation, solenoid activation, relay systems, electrical wiring connections, troubleshooting procedures, and engine starting sequence. Data were collected using the Automobile Technology Performance Test (ATPT), a researcher-developed 20-item multiple-choice test based on the instructional content. The items covered knowledge, comprehension, and application levels using a table of specifications to ensure adequate content coverage. The instrument was validated by experts in Educational Technology and Automobile Technology and pilot-tested, yielding a Cronbach's alpha reliability coefficient of 0.824. Pretest and posttest data collected were analyzed using mean and standard deviation to answer research questions, while *t*-test statistics were used to test the null hypotheses at the 0.05 level of significance. Cohen's *d* was also computed to determine the magnitude of observed differences. Ethical approval for the study was obtained from the relevant institutional authorities, while informed consent was obtained from participants prior to data collection.

Results

Baseline Equivalence of Groups

An independent samples *t*-test was conducted to determine whether the experimental and control groups differed significantly in their pre-test academic achievement scores before the commencement of treatment.

Table 1: *Independent Samples t-test Showing Pre-test Academic Achievement Scores of Experimental and Control Groups*

Group	N	Mean	SD	df	t	p
Experimental	56	52.35	8.40	115	0.412	.681
Control	61	51.74	7.96			

The results showed no significant difference between the experimental group ($M = 52.35$, $SD = 8.40$) and the control group ($M = 51.74$, $SD = 7.96$), $t(115) = 0.41$, $p = .681$. This indicates that both groups were statistically equivalent prior to the treatment.

Research Question 1: What is the difference in the academic achievement of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS) and those taught using conventional teaching methods?

H₀₁: There is no significant difference in the academic achievement of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS) and those taught using conventional teaching methods

Table 1: *Independent Samples t-test Showing the Difference in Academic Achievement Between Students Taught Using SVSSS and Those Taught Using Conventional Method*

Grouping Variable (Group)	N	Mean	SD	Df	T	p	Cohen's d	Remark
Experimental	56	65.72	14.52	115	11.473	.001	1.72	Rejected
Control	61	42.56	12.41					

The results revealed that students in the experimental group ($M = 65.72$, $SD = 14.52$) performed significantly better than those in the control group ($M = 42.56$, $SD = 12.41$), $t(115) = 11.47$, $p < .001$. The computed Cohen's d value of 1.72 indicated a very large effect size. The null hypothesis was therefore rejected, indicating that the Smart Vehicle-Starting System Simulator had a substantial positive effect on students' academic achievement in Automobile Technology.

Research Question 2: What is the difference between the pre-test and post-test mean scores of students taught using the SVSSS?

H₀₂: There is no significant difference between the pre-test and post-test mean scores of students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS)

Table 2: *Paired Samples t-Test Showing the Difference Between Pre-test and Post-test Scores of Students Taught Using SVSSS*

Variable	N	Mean	SD	Mean Difference	t	df	p	Cohen's d	Remark
Pre-test	56	52.35	8.40	13.37	-8.50	55	0.001	1.14	Rejected
Post-test	56	65.72	14.52						

The results revealed a significant difference between the pre-test ($M = 52.35$, $SD = 8.40$) and post-test ($M = 65.72$, $SD = 14.52$), $t(55) = -8.50$, $p < .001$. The computed Cohen's d value of 1.14 indicated a large effect size. The null hypothesis was therefore rejected, indicating substantial improvement in students' academic achievement after exposure to the Smart Vehicle-Starting System Simulator.

Research Question 3: What is the difference in the academic achievement of male and female students taught using the SVSSS?

H₀₃: There is no significant difference in the academic achievement of male and female students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS)

Table 3: *Independent Samples t-Test Showing the Difference in Post-test Academic Achievement Between Male and Female Students Taught Using SVSSS*

Grouping Variable (Gender)	N	Mean	SD	Df	T	p	Cohen's d	Remark
Male	30	66.30	13.81	54	.153	.248	0.03	Not Rejected
Female	26	65.83	13.64					

The results showed that male students ($M = 66.30$, $SD = 13.81$) and female students ($M = 65.83$, $SD = 13.64$) did not differ significantly in their academic achievement, $t(54) = 0.15$, $p = .248$. The computed Cohen's d value of 0.03 indicated a negligible effect size. The null hypothesis was therefore not rejected, indicating that both male and female students benefited similarly from the use of the Smart Vehicle-Starting System Simulator.

Discussion of Findings

The first finding indicated that students taught Automobile Technology using the Smart Vehicle-Starting System Simulator (SVSSS) achieved significantly higher scores than those taught using conventional methods. This suggests that simulation-based instruction enhances academic achievement by enabling learners to visualize and interact with complex systems, thereby strengthening conceptual understanding. The improved performance of the experimental group may be attributed to the experiential learning opportunities provided by the SVSSS, consistent with constructivist principles of active knowledge construction. This finding aligns with Alenezi (2023), who reported that interactive simulation tools significantly improve students' performance in technical subjects, and Adeyemi and Olaleye (2022), who found that technology-supported instruction enhances engagement and retention. However, it contrasts with Khan and Masood (2024), who observed no significant difference between simulation and traditional methods. The variation may be due to differences in the level of interactivity and contextual relevance of the simulation tools used, as the SVSSS provided students with direct hands-on engagement with automobile starting system components. This implies that effective implementation of simulation tools like the SVSSS can significantly improve students' academic achievement.

The second finding revealed a significant improvement between the pre-test and post-test scores of students taught using the SVSSS, indicating notable learning gains. This suggests that the SVSSS not only improves performance but also facilitates progressive understanding through

repeated interaction and reinforcement of concepts. The observed gains may be attributed to the simulator's capacity to provide immediate feedback and opportunities for practice, which are essential for mastering technical content. This finding agrees with Bakar et al. (2022), who reported that simulation-based instruction enhances learning outcomes over time, and Nnorom and Nwafor (2023), who found that experiential learning improves retention and comprehension. Conversely, Chukwuemeka and Okeke (2025) reported limited impact of technology-based interventions where instructional support was inadequate. This difference may be associated with variations in implementation quality and the extent of active learner engagement during instruction. The implication is that simulation tools are effective when properly integrated and supported by active instructional practices.

The third finding showed no significant difference in the academic achievement of male and female students taught using the SVSSS, indicating that its effectiveness is not influenced by gender. This suggests that the SVSSS provides an equitable learning environment that supports both male and female students equally. The absence of gender disparity may be linked to the learner-centered and interactive nature of the simulator, which accommodates diverse learning styles and reduces participation barriers. This finding is consistent with Bello and Ogunlade (2022) and Ibrahim and Abdullahi (2023), who reported no gender differences in technology-enhanced learning outcomes. However, it contrasts with Okonkwo and Eze (2024), who identified gender disparities in technical education, possibly due to socio-cultural factors and unequal access to learning resources in their study context. The implication is that well-designed simulation tools like the SVSSS can help reduce gender gaps and promote inclusive learning in technical education.

Despite the significant findings of this study, certain limitations should be acknowledged. The study was limited to selected Colleges of Education in Kwara State, Nigeria, which may restrict the generalizability of the findings to other educational settings or regions. In addition, the use of intact classes in a quasi-experimental design may have introduced some degree of selection bias despite efforts to establish baseline equivalence through pretesting. The sample size was also relatively small, involving only 117 students, which may limit broader population representation. Furthermore, the researcher's involvement in the implementation of the instructional treatment may have introduced potential experimenter bias. Finally, the duration of the treatment was limited to six weeks, and longer exposure to the simulator might produce different learning outcomes. Future studies should therefore involve larger samples, multiple states or institutions, and extended treatment periods to enhance the external validity of findings.

Conclusion

This study demonstrated that the integration of the Smart Vehicle-Starting System Simulator (SVSSS) into Automobile Technology instruction enhances students' academic achievement and supports effective learning of complex automobile starting system concepts. The findings reinforce the importance of simulation-based and experiential instructional approaches in Technical and Vocational Education, particularly in areas where practical understanding and

learner interaction are essential for skill acquisition. The study also showed that the effectiveness of the SVSSS was not influenced by gender, suggesting that simulation-based instructional tools can promote inclusive learning experiences in technical education. Beyond improving students' performance, the study contributes to knowledge by providing empirical evidence on the effectiveness of a locally developed instructional simulator in enhancing learning outcomes in Automobile Technology within the Nigerian context. The study therefore highlights the educational value of context-specific and cost-effective instructional innovations in strengthening the quality of teaching and learning in Technical and Vocational Education.

Recommendations

Based on the findings and implication of this study, the following recommendations were made:

1. Colleges of Education offering Automobile Technology should adopt the Smart Vehicle-Starting System Simulator (SVSSS) as an instructional tool to enhance students' academic achievement and practical understanding of complex concepts.
2. Lecturers should incorporate simulation-based instructional strategies into their teaching to promote active learning, improve students' engagement, and facilitate better learning outcomes.
3. Relevant educational bodies such as the National Commission for Colleges of Education (NCCE), State Ministries of Education, and other educational agencies responsible for Technical and Vocational Education should support the development, funding, and integration of locally produced instructional simulators into technical education programmes to promote cost-effective and contextually relevant teaching practices.
4. Regular training and professional development programmes should be organized for Automobile Technology lecturers to enhance their competence in the effective use of simulation-based instructional tools.
5. Future studies should replicate this research in other states and educational institutions using larger sample sizes and extended treatment periods. Further research may also examine the effectiveness of simulation-based instructional tools in other technical and vocational subjects to broaden empirical understanding of their impact on students' learning outcomes.

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