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DEVELOPMENT AND EXPERT VALIDATION OF A SMART VEHICLE-STARTING SYSTEM SIMULATOR FOR TEACHING AUTOMOBILE TECHNOLOGY IN COLLEGES OF EDUCATION

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Abstract

This study developed and validated a Smart Vehicle-Starting System Simulator (SVSSS) for teaching Automobile Technology in Colleges of Education (Technical) in Kwara State, Nigeria. A descriptive research and development (R&D) design was adopted, involving interdisciplinary expert validation. The population comprised professionals in mechanical engineering, electrical/electronic engineering, and educational technology, from which twenty-one experts were purposively selected, including seven mechanical engineers, seven electrical/electronic engineers, and seven educational technology specialists. Data were collected using three researcher-designed instruments: the Mechanical Engineers' Rating Scale (MERS), Electrical/Electronic Engineers' Rating Scale (EERS), and Educational Technology Experts' Rating Scale (ETERS). The instruments were validated by subject experts and pilot-tested, yielding reliability coefficients of 0.751, 0.742, and 0.842, respectively. Findings indicated high levels of expert validation across all domains: mechanical engineers affirmed the simulator's structural integrity, durability, and mechanical efficiency; electrical/electronic engineers confirmed its electrical safety and functional reliability; and educational technology specialists validated its usability and instructional relevance. The study concludes that the SVSSS is a technically sound and pedagogically effective instructional tool capable of enhancing experiential learning and bridging the gap between theory and practice in Automobile Technology. It is recommended that Colleges of Education adopt the simulator for instructional use and that educational stakeholders support the development of locally produced instructional technologies to promote sustainable and cost-effective technical education.

Keywords: Smart Vehicle-Starting System Simulator, Automobile Technology, Expert Validation, Instructional Simulator, Technical and Vocational Education

Introduction

Education is widely recognized as a fundamental driver of individual empowerment and national development, serving as a cornerstone for economic growth, social cohesion, and technological advancement. Through the acquisition of knowledge, skills, values, and attitudes, education enhances human capital and prepares individuals to participate meaningfully in the workforce and civic life. Contemporary global agendas, particularly the United Nations Sustainable Development Goal 4, emphasize inclusive and equitable quality education as essential for sustainable development. Recent scholarship underscores the role of education in fostering innovation, productivity, and societal transformation, especially in developing economies where skilled human resources are critical for national competitiveness (UNESCO, 2023; World Bank, 2023; Oketch, 2022). Consequently, strengthening educational systems remains central to achieving long-term socio-economic progress.

In the context of rapid technological change and evolving labour market demands, there is an increasing global emphasis on education systems that prioritize the development of practical and employable skills. Modern economies require graduates who possess not only theoretical knowledge but also competencies such as problem-solving, creativity, critical thinking, and technical expertise. Skill-oriented education bridges the gap between academic learning and workplace expectations, thereby enhancing employability and productivity. Recent studies highlight that aligning educational outcomes with industry needs is essential for addressing youth unemployment and ensuring sustainable economic development (International Labour Organization [ILO], 2023; OECD, 2023; World Economic Forum, 2024). This shift toward competency-based education underscores the necessity of integrating hands-on and experiential learning into educational programmes.

Technical and Vocational Education (TVE) has emerged as a strategic component of national education systems aimed at equipping individuals with occupational skills relevant to industry and entrepreneurship. TVE plays a vital role in fostering economic diversification, reducing unemployment, and promoting self-reliance by preparing a skilled workforce capable of meeting labour market demands. In Nigeria, Colleges of Education (Technical) are pivotal institutions responsible for training technical teachers and middle-level manpower required for technological advancement. Recent policy and research reports affirm that strengthening TVE is essential for achieving sustainable development and industrial growth in developing countries (Federal Republic of Nigeria, 2023; UNESCO-UNEVOC, 2022; Okoye & Arimonu, 2023). Therefore, enhancing the quality and effectiveness of TVE programmes remains a critical priority.

Within the framework of Technical and Vocational Education, Automobile Technology represents a crucial specialization that addresses the maintenance, diagnosis, and operation of motor vehicle systems. The programme prepares future technical educators and skilled technicians with competencies in both mechanical and electrical aspects of automotive engineering. As the global automotive industry increasingly integrates advanced electrical and electronic technologies, a comprehensive understanding of foundational systems, particularly the vehicle starting system, becomes indispensable. The starting system serves as a gateway to engine operation and embodies the integration of mechanical motion and electrical control, making it a fundamental concept in automobile training (Akinwale & Ojo, 2022; Oviawe, 2023). Mastery of such systems is therefore essential for effective technical instruction and professional competence.

Effective learning in technical disciplines is inherently dependent on experiential and hands-on engagement, which enables learners to connect theoretical concepts with real-world applications. Educational theories such as constructivism and Kolb's experiential learning theory emphasize that knowledge is constructed through active participation and reflection on practical experiences. Hands-on activities enhance skill acquisition, retention, learner confidence, and problem-solving abilities, all of which are essential for technical competence. Recent empirical studies have demonstrated that simulation-based and practice-oriented instructional approaches significantly improve students' understanding and performance in technical and vocational education settings (Makransky & Petersen, 2022; Yusuf & Afolabi, 2024). Consequently, integrating experiential learning strategies is vital for achieving meaningful outcomes in Automobile Technology education. Despite the recognized importance of practical engagement, the teaching of Automobile Technology in many Colleges of Education remains predominantly lecture-based, limiting students' opportunities for hands-on experience. Several challenges contribute to this situation, including

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inadequate workshop facilities, scarcity of instructional equipment, high costs associated with procuring and maintaining real automobile components, and safety concerns related to the use of operational vehicle systems. Additionally, the complex internal processes of mechanical and electrical components are often difficult for students to visualize through theoretical instruction alone. These constraints hinder the effective integration of theory and practice, resulting in suboptimal learning outcomes and reduced skill competence among graduates (Oviawe & Uwameiye, 2022; Okolie et al., 2023; Nwankwo, 2024). Addressing these limitations is essential for improving the quality of technical education.

Instructional simulators have emerged as innovative tools capable of addressing the limitations associated with conventional teaching methods in technical education. By replicating real-life systems within a controlled and safe environment, simulators enable learners to observe, manipulate, and practice complex processes without the risks or costs associated with actual equipment. Simulation-based learning supports competency-based and student-centered pedagogies, enhances conceptual understanding, and promotes active engagement. Recent research indicates that the use of simulators significantly improves learners' cognitive and psychomotor skills, particularly in engineering and vocational disciplines (Radianti et al., 2023; Oke & Fernandes, 2024). Therefore, the integration of instructional simulators represents a viable strategy for enhancing the effectiveness of Automobile Technology education.

The development of instructional materials using locally sourced resources is increasingly recognized as a sustainable approach to improving educational quality, particularly in developing countries. Locally produced simulators reduce dependence on expensive imported equipment, ensure contextual relevance to the curriculum, and promote indigenous technological innovation. Such initiatives also support national policies aimed at technological self-reliance and capacity building. In the Nigerian context, the emphasis on local content development aligns with broader educational and industrial objectives, enabling institutions to provide cost-effective and accessible training tools (Federal Republic of Nigeria, 2023; Okoye & Arimonu, 2023; Adebayo & Adewale, 2022). Consequently, the design and production of locally developed instructional simulators hold significant potential for strengthening Technical and Vocational Education.

For instructional hardware to be considered effective and suitable for educational use, rigorous interdisciplinary validation is essential. Mechanical engineers are required to assess the structural integrity, durability, and mechanical efficiency of the system, while electrical and electronic engineers evaluate the safety, functionality, and reliability of its electrical components. In addition, educational technology experts examine the usability, pedagogical relevance, and alignment of the simulator with curriculum objectives. Such comprehensive validation ensures that the instructional tool meets both technical and educational standards, thereby enhancing its credibility and adoption potential. Recent studies emphasize that interdisciplinary collaboration in the evaluation of educational technologies significantly improves their effectiveness and sustainability (Nworgu & Ugwuanyi, 2023; Oke & Fernandes, 2024). This holistic approach is therefore indispensable in the development of instructional simulators.

Despite the growing recognition of simulation-based learning and the need for locally developed instructional materials, there remains a paucity of validated automobile starting system simulators tailored to the context of Colleges of Education in Nigeria. Existing studies have largely focused on the effectiveness of simulations without adequately addressing the systematic development and interdisciplinary validation of such instructional hardware. Furthermore, limited research has employed structured instructional design frameworks, such as the ADDIE model, to guide the

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development process. This gap underscores the necessity for a comprehensive study that not only develops a contextually relevant simulator but also rigorously validates its mechanical, electrical, and pedagogical attributes. Addressing this gap provides a strong justification for the present study and contributes to the advancement of technical education.

Statement of the Problem

The effectiveness of Technical and Vocational Education (TVE) in preparing competent technical teachers and skilled graduates depends largely on the availability of practical and experiential learning opportunities. However, in many Colleges of Education (Technical) in Nigeria, the teaching of Automobile Technology remains predominantly theoretical, limiting students' acquisition of essential hands-on competencies. This limitation is particularly evident in the instruction of the vehicle starting system, a fundamental component that integrates mechanical and electrical principles necessary for engine operation. Empirical evidence indicates that inadequate workshop facilities and limited access to functional instructional equipment significantly hinder skill acquisition and students' readiness for professional practice (Okolie et al., 2022; Oviawe & Uwameiye, 2023). Consequently, the gap between theoretical instruction and practical competence continues to undermine the objectives of TVE.

Although simulation-based instructional tools offer viable alternatives for enhancing practical learning, their development and application within Nigerian technical education remain limited. Many available simulators are imported, costly, and often misaligned with local curricular and infrastructural realities. Moreover, there is a paucity of studies focusing on the systematic development and interdisciplinary expert validation of locally produced instructional hardware for Automobile Technology in Colleges of Education. Existing research has largely emphasized learning outcomes without adequately addressing the technical integrity and pedagogical usability of such innovations (Okoye et al., 2024; Nworgu & Ugwuanyi, 2023). This gap necessitates the development and rigorous expert validation of a contextually relevant Smart Vehicle-Starting System Simulator to enhance the teaching and learning of Automobile Technology and ensure its technical and instructional suitability.

Objectives of the study

The following are the specific objectives of this study:

1) describe the development process of the Smart Vehicle-Starting System Simulator using the ADDIE instructional design model and locally sourced materials.
2) examine the mechanical engineers' evaluation of the structural design, durability, and mechanical efficiency of the developed simulator.
3) determine the electrical/electronic engineers' validation of the safety, functionality, and reliability of the simulator's electrical and electronic components.
4) assess the Educational Technology specialists' validation of the usability, instructional relevance, and alignment of the simulator with the Automobile Technology curriculum in Colleges of Education.

Research Questions

What processes were involved in the development of the Smart Vehicle-Starting System Simulator for teaching Automobile Technology in Colleges of Education?

How do mechanical engineers evaluate the structural design, durability, and mechanical efficiency of the developed Smart Vehicle-Starting System Simulator?

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What are the electrical/electronic engineers' validations of the safety, functionality, and reliability of the electrical and electronic components of the developed simulator?

How do Educational Technology specialists validate the usability and instructional relevance of the Smart Vehicle-Starting System Simulator for teaching Automobile Technology in Colleges of Education?

Methodology

This study adopted a descriptive research and development (R&D) design to facilitate the systematic design and expert validation of a Smart Vehicle-Starting System Simulator (SVSSS) for teaching Automobile Technology in Colleges of Education (Technical) in Kwara State, Nigeria. The population comprised professionals with expertise in mechanical engineering, electrical/electronic engineering, and educational technology. Using a purposive sampling technique, twenty-one (21) experts were selected, including seven mechanical engineers, seven electrical/electronic engineers, and seven educational technology specialists, based on their academic qualifications and professional experience in evaluating technical and instructional systems. Data were collected using three researcher-developed instruments: the Mechanical Engineers' Rating Scale (MERS), assessing structural design, durability, and mechanical efficiency; the Electrical/Electronic Engineers' Rating Scale (EERS), evaluating electrical safety, circuit integrity, and functional reliability; and the Educational Technology Experts' Rating Scale (ETERS), examining usability and instructional relevance. Each instrument employed a five-point Likert scale ranging from 5 (Excellent) to 1 (Poor). Face and content validity were established by independent experts from the Departments of Mechanical Engineering, Electrical/Electronic Engineering, and Educational Technology at the University of Ilorin. Reliability was determined using Cronbach's alpha, yielding coefficients of 0.751 (MERS), 0.742 (EERS), and 0.842 (ETERS), indicating acceptable internal consistency. Following ethical approval and informed consent, the simulator was demonstrated to the experts, who subsequently completed the rating scales. Data were analyzed using descriptive statistics, mean and standard deviation, with a benchmark mean of 3.50 adopted as the decision rule for item acceptance.

Results

Analysis of Research Questions

Research Question 1: What processes were involved in the development of the Smart Vehicle-Starting System Simulator for teaching Automobile Technology in Colleges of Education?

The development of the Smart Vehicle-Starting System Simulator (SVSSS) followed a systematic process grounded in engineering design and instructional technology principles. The process comprised four key stages: conceptualization, design, construction, and expert validation. During the conceptualization stage, an instructional gap was identified in the teaching of automobile starting systems, particularly students' difficulty in visualizing the interaction between mechanical and electrical components. The design stage involved the preparation of detailed mechanical and electrical schematics and the selection of locally sourced materials to ensure cost-effectiveness and sustainability. In the construction stage, essential components such as the battery, ignition switch, starter motor, solenoid, flywheel, and control circuitry were assembled into a functional prototype with clearly labeled parts to enhance instructional clarity and safety. The final stage involved interdisciplinary expert validation by mechanical engineers, electrical/electronic engineers, and educational technology specialists, whose evaluations confirmed the simulator's structural integrity, electrical safety, and instructional relevance. Overall, the development process resulted

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in a reliable and pedagogically effective instructional tool suitable for teaching Automobile Technology in Colleges of Education.

Research Question 2: How do mechanical engineers evaluate the structural design, durability, and mechanical efficiency of the developed Smart Vehicle-Starting System Simulator?

Table 1: Mean Ratings of Mechanical Engineers on the Structural Design, Durability, and Mechanical Efficiency of the Developed Smart Vehicle-Starting System Simulator

Item	Mean	Std. D
The mechanical components of the system are robust and durable.	4.20	0.84
The system is designed to minimize wear and tear on moving parts.	4.00	1.41
The flywheel connection is precise and operates without misalignment.	4.20	0.83
The system exhibits smooth engagement and disengagement of the flywheel.	4.00	1.23
The solenoid mechanism demonstrates high reliability under varying conditions.	3.80	0.84
The system's mechanical design adheres to industry standards.	3.80	0.84
The system components are easily accessible for maintenance and repair.	4.20	0.45
The design effectively minimizes heat generation during operation.	4.20	0.84
The starting system demonstrates consistent performance under varying loads.	4.00	1.41
The materials used in the system construction are appropriate for its intended purpose.	4.20	0.84
Average Mean	4.06	

Key: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent
Bench mark = 3.50

A benchmark mean of 3.50 was established to determine the acceptability of each item. As presented in Table 1, the ten selected items recorded mean ratings ranging from 3.80 to 4.20, indicating that mechanical engineers evaluated all aspects of the developed Smart Vehicle-Starting System Simulator as either "Very Good" or "Excellent." The highest-rated items included the robustness and durability of the mechanical components, the precision of the flywheel connection, the accessibility of system components for maintenance, the effectiveness of heat minimization, and the appropriateness of the construction materials (Items 1, 3, 7, 8, and 10; Mean = 4.20). Conversely, the lowest-rated items were the reliability of the solenoid mechanism and the system's adherence to industry standards (Items 5 and 6; Mean = 3.80), though these values still exceeded the acceptance benchmark. The cluster mean of 4.06 further indicates a high level of agreement among the experts regarding the structural integrity, durability, and mechanical efficiency of the simulator.

Research Question 3: What are the electrical/electronic engineers' validations of the safety, functionality, and reliability of the electrical and electronic components of the developed simulator?

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Table 2: Mean Ratings of Electrical/Electronic Engineers on the Electrical and Electronic Components of the Developed Smart Vehicle-Starting System Simulator

Item	Mean	Std. D
The electrical connections are secure and insulated to prevent short circuits.	4.20	0.44
The wiring and circuitry are compliant with automotive electrical standards.	4.40	0.54
The battery power is utilized efficiently by the system.	3.80	0.83
The solenoid operates reliably across a range of electrical loads.	3.60	1.14
The starter motor demonstrates efficient conversion of electrical energy into mechanical energy.	4.00	1.00
The system includes adequate protective measures against electrical surges.	4.20	0.83
The ignition switch circuitry is responsive and fault-free.	4.60	0.54
The system demonstrates minimal energy loss during operation.	4.80	0.44
The system's electrical components are durable and designed for long-term use.	4.20	0.83
The overall electrical design ensures user safety and reliability.	4.20	1.09
Average Mean	4.20	

Key: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent
Bench mark = 3.50

Table 2 presents the mean and standard deviation scores of experts' evaluation of the developed smart vehicle-starting system simulator for teaching Automobile Technology. All ten items received mean ratings ranging from 3.60 to 4.80, indicating that electrical and electronic engineers rated all the electrical and electronic components of the developed smart vehicle-starting system simulator as either "Very Good" or "Excellent." The highest-rated item was the system's demonstration of minimal energy loss during operation (Item 8, Mean = 4.80), while the lowest-rated item was the solenoid's reliability across different electrical loads (Item 4, Mean = 3.60). These results suggest that the simulator exhibits strong compliance with automotive electrical standards, efficient energy utilization, and robust design features that ensure safety, durability, and operational reliability, making it suitable for instructional use in Colleges of Education.

Research Question 4: How do Educational Technology specialists validate the usability and instructional relevance of the Smart Vehicle-Starting System Simulator for teaching Automobile Technology in Colleges of Education?

Table 3: Educational Technology Specialists' Ratings of the Usability and Instructional Relevance of the Developed Smart Vehicle-Starting System Simulator

Item	Mean	Std. D
The system is effective in demonstrating the principles of automobile starting systems.	3.60	1.14
The design is suitable for use in a classroom or workshop environment.	4.40	0.89
The system promotes active learning and student engagement.	4.60	0.54
The system's components are clearly labeled for instructional purposes.	3.80	1.30
The system allows students to visualize the working principles effectively.	4.20	0.83
The system includes interactive elements for hands-on learning.	4.20	0.83

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The design enables students to safely handle and operate the system.	3.80	1.30
The system is designed to align with the Nigerian Colleges of Education curriculum.	4.40	0.89
The system provides opportunities for students to test theoretical concepts in practice.	4.40	0.54
The system effectively integrates technology with conventional teaching methods.	4.00	1.41
Average Mean	4.16	

Key: 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent
Bench mark = 3.50

Table 3 presents the mean and standard deviation scores of experts' evaluation of the developed smart vehicle-starting system simulator for teaching automobile technology in Colleges of Education. All ten items recorded mean ratings between 3.60 and 4.60, indicating that Educational Technology specialists rated all aspects of the simulator's usability and instructional relevance as "Very Good" or "Excellent." The highest-rated item was the system's promotion of active learning and student engagement (Item 3, Mean = 4.60), while the lowest-rated item, though still above the benchmark, was the system's effectiveness in demonstrating the principles of automobile starting systems (Item 1, Mean = 3.60). These findings suggest that the developed simulator possesses high usability and strong instructional relevance for effective classroom and workshop integration in Colleges of Education.

Discussion of Findings

The first finding revealed that the Smart Vehicle-Starting System Simulator (SVSSS) was successfully developed through a systematic process integrating engineering design principles with the ADDIE instructional design framework. This demonstrates the feasibility of producing contextually relevant instructional hardware using locally sourced materials to address practical skill gaps in Automobile Technology education. The finding aligns with Branch and Dousay (2022) and Okoye et al. (2024), who noted that the ADDIE model supports the development of pedagogically sound instructional materials. It also supports evidence that locally produced instructional resources enhance sustainability and cost-effectiveness in Nigerian technical education (Adebayo & Adewale, 2022; Okoye & Arimonu, 2023), thereby strengthening experiential learning in Technical and Vocational Education.

The second finding indicated that mechanical engineers rated the simulator highly in terms of structural design, durability, and mechanical efficiency, confirming its compliance with acceptable engineering standards for instructional use. This validation demonstrates the simulator's structural integrity and operational reliability for repeated classroom and workshop demonstrations. The result corroborates Nworgu and Ugwuanyi (2023), who emphasized the importance of expert evaluation in ensuring the technical adequacy of educational innovations, and aligns with Oke and Fernandes (2024), who reported that rigorous expert assessment enhances the credibility and adoption of simulation-based tools. Additionally, the finding supports broader empirical evidence that well-designed simulators effectively replicate real-world mechanical operations and facilitate hands-on learning in technical education (Makransky et al., 2022).

The third finding showed that electrical and electronic engineers provided high ratings for the simulator's electrical safety, energy efficiency, and functional reliability, indicating strong compliance with automotive electrical standards. This suggests that the simulator is safe and dependable for instructional use in teaching complex electrical concepts. The finding is consistent with Radianti et al. (2023), who highlighted the effectiveness of simulation technologies in enhancing understanding of complex systems, and with Oke and Fernandes (2024), who emphasized that technical reliability and safety are critical for the successful adoption of simulation-based instructional tools. These results further underscore the value of interdisciplinary validation in ensuring the technical soundness of educational technologies.

The fourth finding revealed that Educational Technology specialists rated the simulator highly in terms of usability and instructional relevance, indicating its effectiveness in promoting active learning, visualization of concepts, and alignment with curriculum objectives. This confirms the pedagogical soundness of the SVSSS and its capacity to enhance student engagement and experiential learning in Automobile Technology. The finding supports Makransky et al. (2022), who demonstrated that simulation-based environments improve learner engagement and conceptual understanding, and aligns with Yusuf and Afolabi (2024), who found that instructional simulators enhance mastery of technical concepts. It also reinforces the importance of locally developed instructional materials in addressing contextual educational needs (Adebayo & Adewale, 2022).

Conclusion

In conclusion, this study established that the Smart Vehicle-Starting System Simulator (SVSSS) developed for teaching Automobile Technology in Colleges of Education is both technically sound and pedagogically effective. The systematic development process, grounded in engineering and instructional design principles, produced a reliable and contextually relevant instructional tool using locally sourced materials. Interdisciplinary expert validation confirmed high levels of acceptance across the three domains assessed. Mechanical engineers verified the simulator's structural integrity and durability, electrical/electronic engineers affirmed its safety and functional reliability, and Educational Technology specialists validated its usability and instructional relevance. Collectively, these findings demonstrate that the SVSSS is suitable for instructional use and capable of enhancing experiential learning. The study therefore contributes to Technical and Vocational Education by providing empirical evidence that locally developed simulators can serve as sustainable and cost-effective alternatives to imported training equipment.

Recommendations

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

1) Colleges of Education should integrate the Smart Vehicle-Starting System Simulator into Automobile Technology instruction to enhance practical learning.
2) Government and educational stakeholders should support the development of locally produced instructional simulators.
3) Professional training should be provided for lecturers to ensure effective utilization of the simulator.
4) The National Commission for Colleges of Education (NCCE) should include validated simulators in the minimum standards for Technical and Vocational Education programmes.

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