Development and Validation of Instructional Material in Electricity and Magnetism for Technology Course

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ABSTRACT

This study developed and validated simulation-based instructional materials in Electricity and Magnetism for Electronics Technology, using Multisim software. Guided by the ADDIE instructional design model, a 24-module workbook was created to address challenges in traditional teaching—limited lab access, abstract concepts, and lack of interactivity. Validation through expert review and pilot testing confirmed the material's accuracy, usability, and alignment with course outcomes. Students using the workbook showed a 27.8% improvement in post-test scores, compared to 12.2% in the control group. They also completed activities up to 50% faster. Satisfaction ratings from both students and instructors ranged from 4.6 to 4.8 out of 5, reflecting the material's clarity and effectiveness. The results demonstrate that interactive, simulation-based learning enhances engagement, understanding, and skills development. Recommendations include expanding real-world applications, providing instructor training, and enhancing Multisim integration. The study affirms the value of technology-enhanced instruction in bridging theory and practice in technical education.

Keywords: Instructional Material, Workbook, Multisim, Simulation, Electricity and Magnetism

INTRODUCTION

Electricity and Magnetism are foundational to Electronics Technology, yet traditional instructional methods often fail to support deep conceptual understanding and hands-on learning. Students frequently struggle to visualize abstract phenomena and lack access to laboratory equipment necessary for developing problem-solving and circuit analysis skills. These challenges reveal a significant gap between theoretical instruction and practical application.

To address this, the study aimed to develop and validate instructional materials that integrate Multisim simulation software, offering students a more interactive and engaging learning experience. The instructional resource—structured as a 24-module workbook—was designed using the ADDIE model to ensure alignment with Electronics Technology course outcomes, promote learner engagement, and build practical competencies. Specifically, the study sought to (1) develop instructional materials that incorporate Multisim for circuit experimentation, (2) evaluate their alignment with course outcomes, (3) assess their usability and effectiveness, and (4) enhance the materials based on validation results.

The study is significant for its contribution to technology-based education, especially in institutions with limited physical lab access. It offers a replicable framework for designing simulation-based resources that improve instructional delivery and learning outcomes. Validation involved expert reviews, student and instructor feedback, and pilot testing. Results showed notable improvements in student performance, engagement, and efficiency in completing tasks. However, the study was limited to a single institution and short-term implementation, with no comparison to other simulation tools or assessment of long-term retention.

By bridging the gap between theory and practice, the developed instructional materials demonstrate the potential of simulation-based learning to transform how Electricity and Magnetism are taught in Electronics Technology programs.

Objectives of the Study

This study aims to develop, validate, and enhance instructional materials for teaching Electricity and Magnetism in technology course, integrating Multisim software as a simulation tool for conducting experiments. Given the increasing need for interactive and hands-on learning approaches, the study seeks to provide an effective instructional resource that improves student engagement, conceptual understanding, and practical skills in Electronics Technology programs.

Specifically, this study seeks to achieve the following objectives:

1. To develop simulations and instructional materials in Electricity and Magnetism for technology course that incorporate Multisim software as a simulation platform for conducting experiments.

2. To determine the extent of alignment of the developed workbook with the course learning outcomes of Electronics Technology programs.

3. To assess the simulation workbook in terms of usefulness and usability, as perceived by students, instructors, and subject matter experts.

4. To develop an enhanced version of the simulation workbook based on assessment results.

Significance of the Study

This study is significant in advancing instructional design and technology education, particularly in teaching Electricity and Magnetism for technology courses. By developing and validating Multisim-based instructional materials, it enhances technology-driven learning, offering students both theoretical knowledge and hands-on experience in electrical and magnetic principles. The study applies the ADDIE model to ensure the materials are well-designed, learner-centered, and based on research. The use of simulation-based learning demonstrates the importance of integrating technology into technical education, providing a scalable framework for other technology disciplines. These validated materials offer a reference for future curriculum improvements, helping educators and instructional designers create engaging, interactive, and competency-based resources. For students, the Multisim-based workbook enhances engagement, allowing them to visualize abstract concepts, conduct virtual experiments, and apply problem-solving techniques. This leads to improved knowledge retention and better academic performance. For educators, the materials are easy to integrate into existing curricula, saving preparation time and ensuring alignment with learning outcomes. This study also contributes to the modernization of technology education by promoting the use of interactive digital tools, especially in institutions with limited access to physical lab equipment. It reinforces the role of educational technology in preparing students for industry demands, equipping them with practical problem-solving skills. Overall, the research improves the effectiveness, engagement, and accessibility of Electricity and Magnetism instruction, benefiting both educators and students in Electronics Technology programs.

Scope and Delimitation

This study focuses on the development and validation of instructional materials for teaching Electricity and Magnetism in Electronics Technology courses, using Multisim software as a simulation tool for conducting experiments. The instructional materials, including a structured workbook, aim to enhance students' understanding of electrical and magnetic principles and their practical application. The study follows the ADDIE model, ensuring a systematic and research-based approach to material development. It specifically covers fundamental topics such as Ohm's Law, Kirchhoff's Laws, AC/DC circuits, electromagnetic fields, and circuit troubleshooting, aligning with the learning outcomes of the Electronics Technology curriculum. The integration of Multisim allows students to simulate and troubleshoot circuits, making the learning process more interactive and accessible. The study is limited to students and instructors from a specific academic institution offering Electronics Technology, which may not fully represent all technology education programs. The validation phase involved a limited number of experts and students, limiting the generalizability of the results. Additionally, the study focuses on instructional material development and does not track long-term student performance or industry application. It does not compare the effectiveness of Multisim with other simulation tools, making the research specific to this simulation-based approach. Furthermore, the implementation phase includes only short-term pilot testing, so the study does not assess long-term retention of concepts. Despite these delimitations, the study provides valuable insights into the effectiveness of simulation-based learning and offers validated instructional materials to enhance teaching strategies and student engagement in Electricity and Magnetism.

LITERATURE REVIEW

Effective instructional material plays a crucial role in enhancing student learning, especially in subjects requiring both theoretical understanding and practical application, such as Electricity and Magnetism. Prior research emphasizes that well-structured, learner-centered modules contribute significantly to improved comprehension and engagement in science and technology education.

Perez and Santos (2020) reported that structured Physics modules significantly enhance conceptual understanding, while Garcia et al. (2019) demonstrated that simulation-based workbooks improve Electrical Engineering students' problem-solving skills. Johnson et al. (2018) found that learners using simulation software outperformed peers in traditional laboratory settings, reinforcing the value of digital tools in conceptual mastery.

The ADDIE instructional design model—Analysis, Design, Development, Implementation, and Evaluation—has been widely validated for creating effective instructional resources. Brown and Lee (2021) noted that ADDIE-based computer modules led to higher student retention and engagement. Similarly, Martinez and Cruz (2020) highlighted the model's applicability in Electronics courses for developing structured, outcome-aligned content.

The integration of simulation tools, particularly Multisim, supports Technology-Enhanced Learning (TEL) by allowing students to conduct virtual experiments and visualize circuit behavior in real time. This aligns with Constructivist Learning Theory, which posits that students learn more effectively through active participation and experiential learning. Santiago and Ramos (2021) further support this, noting that problem-based, technology-integrated learning promotes critical thinking in electromagnetism.

In summary, the literature establishes strong support for using systematic instructional design models and simulation software to enhance learning outcomes. This study builds on these findings by developing and validating a Multisim-based workbook in Electricity and Magnetism, designed to improve student engagement, conceptual understanding, and practical competencies in Electronics Technology education.

METHODOLOGY

This chapter details the systematic process undertaken in the development and validation of instructional materials for Electricity and Magnetism for Electronics Technology course, utilizing Multisim software as a simulation tool for conducting experiments. The study follows the ADDIE instructional design model, ensuring a structured approach to creating effective, research-based, and validated instructional resources.

This study utilizes a developmental research design, which centers on the creation, validation, and assessment of instructional materials. The ADDIE instructional design model serves as the guiding framework, ensuring a systematic approach to designing, developing, and evaluating the effectiveness of the materials. The study follows the five phases of the ADDIE model: the Analysis Phase, which identifies learning gaps, student needs, and curriculum alignment in Electricity and Magnetism instruction; the Design Phase, which involves structuring lessons, defining learning objectives, and designing instructional strategies; the Development Phase, where instructional materials, including simulations using Multisim software, are created and validated; the Implementation Phase, which pilots the materials in a classroom setting and gathers feedback; and the Evaluation Phase, which assesses the effectiveness, usability, and impact of the materials through formative and summative evaluation. This comprehensive approach ensures that the developed instructional materials are learner-centered, competency-based, and aligned with the standards of the Electronics Technology program.

A needs assessment in Table 1 and 2 was conducted to identify gaps and limitations in existing instructional materials in Electricity and Magnetism course. The following methods were employed: Review of existing textbooks, syllabus, and laboratory manuals to identify instructional challenges. Instructor and student surveys to gather insights into difficulties in learning Electricity and Magnetism. Interviews with subject matter experts to assess the effectiveness of traditional teaching methods. Findings revealed that students struggle with visualizing electrical and magnetic phenomena due to the abstract nature of the concepts. Additionally, limited access to laboratory equipment hindered their ability to apply theoretical knowledge in practical settings.

Table 1. Needs Analysis

Assessment Method	**Findings**	**Implications for Instructional Material Design**
Review of Existing Textbooks, Syllabus, and Laboratory Manuals	Instructional materials lack interactive elements and hands-on applications; mostly text-heavy.	Develop interactive, simulation-based materials using Multisim to enhance engagement and application.
Instructor and Student Surveys	Students struggle with visualizing abstract electrical and magnetic concepts; instructors report difficulty in maintaining engagement.	Incorporate visual aids, real-world examples, and hands-on exercises to improve conceptual understanding.
Interviews with Subject Matter Experts	Traditional teaching methods are limited in addressing practical application due to insufficient lab equipment and resources.	Ensure accessibility to virtual laboratory simulations to compensate for the lack of physical lab resources.

To tailor the instructional materials effectively, the target learners' profiles were analyzed. The study examined: Students' prior knowledge of fundamental electrical concepts. Learning preferences and challenges in circuit analysis and electromagnetism. Comfort level with using simulation software for virtual experimentation. Survey results indicated that most students had basic theoretical understanding but lacked practical experience, reinforcing the need for an interactive, simulation-based learning tool.

Table 2. Target Audience Analysis

Category	**Survey Findings**	**Implications for Instructional Design**
Prior Knowledge of Electrical Concepts	Majority have basic theoretical understanding but lack hands-on experience.	Include more hands-on virtual simulations to reinforce theory.
Learning Challenges in Circuit Analysis	Struggle with applying circuit laws and troubleshooting errors.	Design step-by-step problem-solving exercises for circuit troubleshooting.
Learning Challenges in Electromagnetism	Difficulty in visualizing electromagnetic fields and their real-world applications.	Incorporate interactive visualizations and real-world application examples.
Comfort Level with Simulation Software	Limited familiarity with Multisim and other simulation tools; require guided instruction.	Provide introductory training on Multisim software before advanced applications.

This study is anchored in Constructivist Learning Theory and Technology-Enhanced Learning (TEL) Theory, which support the development and validation of instructional materials for teaching Electricity and

Magnetism using Multisim software. Constructivist Learning Theory, as proposed by Piaget and Vygotsky, emphasizes that learning is an active process where students construct knowledge through experiences and interactions. This principle aligns with the study's goal of integrating simulation-based learning, allowing students to engage with virtual experiments, manipulate circuit components, and explore electricity and magnetism concepts in a problem-solving environment. Through hands-on experimentation, learners develop deeper conceptual understanding and critical thinking skills, fostering student-centered learning. The Technology-Enhanced Learning (TEL) Theory further strengthens this study by advocating for the use of digital tools to improve engagement, comprehension, and practical application. Multisim software provides real-time circuit simulation, enabling students to visualize abstract concepts and apply theoretical knowledge to practical scenarios. The incorporation of TEL in instructional materials allows for interactive, repeatable, and self-paced learning experiences, which enhance student motivation and bridge the gap between theory and application in Technology education. Additionally, the study follows the ADDIE instructional design model, a systematic approach to instructional material development. The ADDIE framework consists of five phases: Analysis, Design, Development, Implementation, and Evaluation. The Analysis phase identifies learning gaps, curriculum requirements, and student needs. The Design phase structures learning objectives, instructional strategies, and assessments. The Development phase focuses on creating and validating the workbook, integrating Multisim-based experiments. The Implementation phase involves pilot testing to measure usability, engagement, and learning effectiveness. Finally, the Evaluation phase assesses the instructional materials' impact on student performance, incorporating feedback from experts, instructors, and learners to refine the materials.

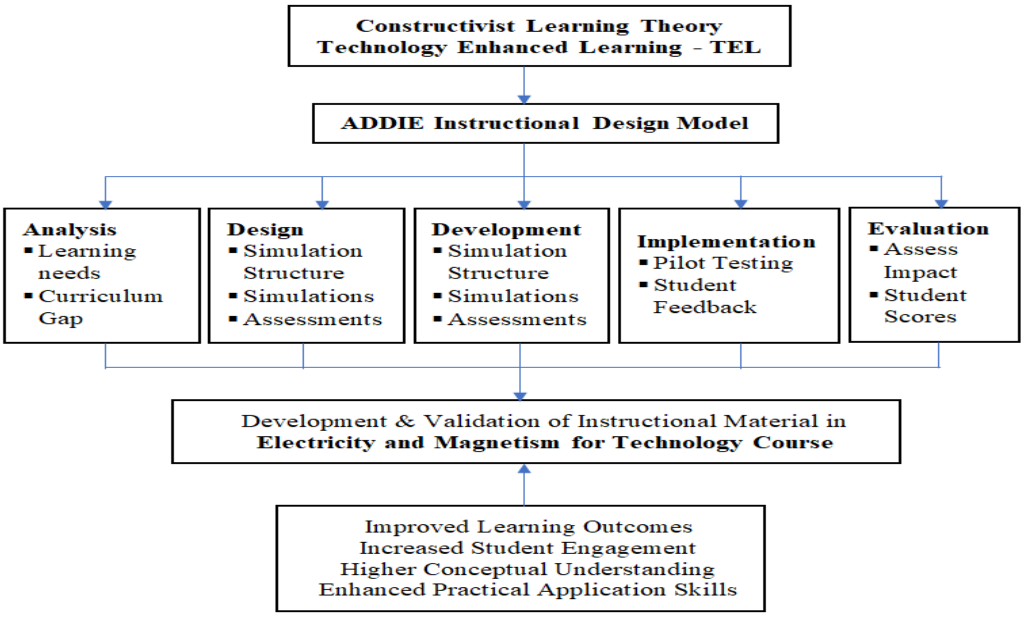

Figure 1. Theoretical Framework

By integrating Constructivist Learning Theory, TEL, and the ADDIE methodology, this study ensures that the developed instructional materials are research-based, technologically relevant, and pedagogically effective. The validated workbook serves as a structured and innovative learning tool that enhances student engagement, conceptual mastery, and hands-on application of Electricity and Magnetism concepts in technology course. The instructional materials were designed to incorporate the following strategies: Simulation-Based Learning – Multisim software was used to conduct virtual experiments. Problem-Based Learning – Students applied concepts in real-world troubleshooting scenarios. Interactive Activities – Digital worksheets, guided discussions, and quizzes were included. Assessment Methods – Pre-tests, post-tests, and hands-on performance assessments were used to evaluate learning progress.

The instructional materials were structured into simulation activity, each focusing on key topics in Electricity and Magnetism, including: Resistors, Resistance Voltage and Current measurements, Ohms Law, Series Circuits, Parallel Circuits, Series-Parallel Circuits, Networks Theorems, The Wheatstone Bridge, Kirchhoff's Law and Magnetism. Each simulation contained theoretical discussions, tables, and step-by-step simulations to reinforce learning. An initial prototype of the instructional materials was developed, including: Simulation-based activity using Multisim. Simulation results to be filled-up after simulation. Preliminary assessments for student evaluation.

The final instructional materials included: Interactive simulation experiments designed using Multisim software. Instructor and student workbooks containing experiment guides, problem-solving activities, and self-assessments. A small-scale pilot test was conducted with a selected group of students and instructors to: Evaluate clarity, usability, and instructional effectiveness. Collect qualitative feedback from participants and Identify areas for refinement and improvement. The validated instructional materials were implemented in a classroom setting, where students completed: Conceptual exercises on circuit behavior. Simulation-based experiments using Multisim and Assessment activities, including quizzes and troubleshooting tasks. Feedback was collected through: Instructor surveys and focus group discussions. Student questionnaires evaluating usability and engagement.

The evaluation phase of this study followed a structured approach, incorporating both formative and summative evaluation methods to assess the effectiveness and usability of the developed instructional materials. During the formative evaluation, continuous assessments were conducted throughout the design and development phases to ensure the instructional materials met pedagogical and content standards. This process involved expert validation of the instructional content, where subject matter experts reviewed the workbook for accuracy, clarity, and alignment with learning objectives. Additionally, preliminary student performance assessments were conducted to gauge initial comprehension and identify areas for improvement. Based on expert feedback and student observations, iterative revisions were made to enhance the clarity, usability, and instructional effectiveness of the materials. Following the implementation of the workbook, a summative evaluation was conducted to measure its overall impact on student learning outcomes. This evaluation involved a comparison of pre-test and post-test results to determine knowledge improvement among students. Furthermore, survey analyses were carried out to collect student and instructor feedback regarding the usability, engagement, and effectiveness of the instructional materials. To complement these findings, performance assessments were used to evaluate students' ability to apply theoretical concepts in practical circuit simulations and troubleshooting exercises. For data analysis, both quantitative and qualitative methods were employed. Quantitative data analysis involved statistical comparisons of pre-test and post-test scores, as well as survey ratings, to identify measurable learning gains. Meanwhile, qualitative data analysis focused on thematic analysis of instructor and student feedback, highlighting key areas where the materials succeeded and potential aspects for further refinement.

In summary, the systematic development and validation process of the instructional materials using the ADDIE model. The methodology ensured that the Electricity and Magnetism workbook remained learner-centered, competency-based, and technology-integrated, ultimately contributing to enhanced instructional strategies and improved student learning outcomes in Electronics Technology programs.

RESULTS AND DISCUSSION

This chapter presents the results of the study, analyzing the findings from each phase of the ADDIE model used in the development and validation of instructional materials for Electricity and Magnetism for Electronics Technology course. The discussion includes the identified needs, instructional design insights, validation outcomes, and the overall effectiveness of the developed materials based on student and instructor feedback.

The needs assessment conducted during the Analysis Phase identified several critical gaps in existing instructional materials for Electricity and Magnetism. A comprehensive review of textbooks, instructor and student surveys, and expert interviews revealed key challenges that hinder effective learning. One of the most significant issues was the conceptual gap, where students struggled to visualize abstract electrical and magnetic phenomena, making it difficult for them to apply theoretical concepts to practical situations. Additionally, limited access to laboratory equipment restricted opportunities for hands-on experimentation, preventing students from reinforcing their theoretical knowledge through practical application. Another major limitation in existing materials was the lack of interactive elements, as most instructional resources were text-heavy and did not incorporate visual aids, simulations, or interactive exercises to support learning. Furthermore, the study revealed diverse learning preferences among students, with some learners benefiting more from step-by-step guided explanations, while others preferred practical, simulation-based experiences to reinforce understanding. Instructors also recognized the potential of Multisim software as a tool to enhance practical learning, but limited training and unfamiliarity with the software hindered its widespread adoption in classroom settings. The Design Phase focused on structuring the instructional materials to ensure alignment with identified learning needs and curriculum outcomes. This phase aimed to develop a comprehensive and well-organized instructional approach that would effectively support student learning in Electricity and Magnetism.

A key component of the design process was content selection, which involved organizing the instructional materials into structured modules that cover essential topics in Electricity and Magnetism. Each module was designed to provide progressive learning experiences, allowing students to build foundational knowledge before engaging in more complex circuit analysis and problem-solving activities. The simulation activities were categorized into 24 key simulations, each focusing on a specific concept, ensuring systematic learning progression. The modules include fundamental topics such as Resistors, Ohm's Law, and Circuit Measurements, which establish a strong theoretical foundation. This is followed by series and parallel circuit analysis, including topics such as Series Circuits with Opens, Parallel Circuits - Analysis, and Series-Parallel Circuit Networks, allowing students to explore circuit configurations and problem-solving techniques. The instructional design also integrates advanced concepts such as The Wheatstone Bridge, Kirchhoff's Laws, and Network Theorems, ensuring that students gain higher-order analytical skills applicable in Electronics Technology. Finally, Magnetism and Electromagnetism modules were included to bridge the understanding of electric circuits with electromagnetic applications.

By structuring the instructional materials in a modular and progressive manner, students are guided through a logical sequence of concepts and hands-on simulation activities, enabling them to develop a deep conceptual understanding and practical application skills. The integration of Multisim-based simulations within each module ensures that students actively engage in learning rather than passively absorbing theoretical concepts. This design approach maximizes student comprehension, enhances engagement, and fosters problem-solving abilities, reinforcing the effectiveness of technology-enhanced learning in Electronics Technology education. The assessment design was carefully structured to ensure that student learning progress was effectively measured and continuously supported. Pre-tests and post-tests table 3, were developed to evaluate knowledge acquisition and conceptual understanding before and after the implementation of the instructional materials. Additionally, problem-solving tasks were integrated within each lesson to assess students' critical thinking and ability to apply theoretical concepts to practical scenarios. To further enhance engagement, formative assessments, such as quizzes and guided questions, were embedded in each simulation activity, allowing instructors to track student participation and comprehension in real time. This structured and competency-based assessment approach ensured that the instructional materials addressed key challenges in traditional teaching methods, such as passive learning, lack of engagement, and difficulty in applying theoretical knowledge.

To validate the effectiveness of the developed materials, a small-scale pilot test was conducted with selected students and instructors, followed by expert evaluation table 5, to ensure content quality and alignment with the Electronics Technology curriculum. Feedback from students indicated that the materials were engaging and easy to understand, with simulation exercises significantly enhancing their learning experience. Instructors reported increased student participation and enthusiasm, demonstrating that the interactive nature of the instructional materials contributed to improved engagement compared to traditional lecture-based methods. Furthermore, subject matter experts confirmed that the materials were accurate, well-structured, and aligned with the required learning outcomes, validating their educational value and practical relevance. These findings support the effectiveness of the developed instructional materials, reinforcing the importance of simulation-based learning in improving student comprehension and practical application skills.

Data collected during the implementation phase included student performance metrics, teacher observations, and survey feedback:

To assess the effectiveness of the developed instructional materials, a quasi-experimental setup was employed involving two student groups: a control group (using traditional instruction) and an experimental group (using the Multisim-based workbook). Each group consisted of 25 students, bringing the total number of participants to 50. Both groups underwent pre-tests and post-tests, with identical test items designed to measure conceptual understanding and practical application in Electricity and Magnetism.

The mean scores were calculated by summing the individual scores of students in each group and dividing by the total number of students in that group. The results are summarized in Table 3:

Table 3. Comparison of Pre-Test and Post-Test Scores

Student Group	Number of Students	Pre-Test Mean Score	Post-test Mean Score	% Improvement
Control Group (Traditional Instruction)	25	55.2%	67.4%	+12.2 %
Experimental Group (Using Multisim-based Workbook)	25	54.8%	82.6%	+27.8%

The comparison of pre-test and post-test scores provides quantitative evidence supporting the effectiveness of the developed instructional materials in enhancing student learning outcomes in Electricity and Magnetism. The results indicate a significant improvement in student performance, particularly in the Experimental Group, which utilized the Multisim-based workbook for simulation-based learning. The study demonstrated that both the Control Group (Traditional Instruction) and the Experimental Group (Using Multisim-Based Workbook) experienced learning gains, but at different levels. The Control Group, which relied on lecture-based instruction and textbook use, showed a 12.2% improvement, with post-test scores increasing from 55.2% to 67.4%. This suggests that traditional teaching methods can lead to some learning progress, but the improvement was modest. In contrast, the Experimental Group showed a much higher improvement of 27.8%, with post-test scores rising from 54.8% to 82.6%. These results indicate that students who engaged with the interactive, simulation-based instructional materials developed a stronger conceptual understanding and better application skills compared to those who followed traditional methods. The significantly higher improvement rate in the Experimental Group suggests that the Multisim-based workbook provided a more effective and engaging learning experience. Several factors contributed to this improvement. Interactive simulations enabled students to visualize and manipulate circuit components in real time, reinforcing abstract concepts that are typically difficult to grasp through lecture-based instruction alone. Additionally, hands-on experimentation with Multisim software allowed students to test and explore circuit configurations without the need for physical laboratory equipment, making learning more accessible and engaging.

Furthermore, the structured simulation activities and troubleshooting exercises helped students develop higher-order thinking skills, allowing them to apply theoretical knowledge to real-world circuit analysis. The immediate feedback and self-paced learning nature of Multisim allowed students to see instant results when adjusting circuit parameters, promoting active learning and self-correction. These elements contributed to better retention and understanding of circuit analysis concepts. The findings highlight several key implications for teaching and learning in Electronics Technology course. The higher post-test scores in the Experimental Group suggest that students were more engaged with the learning process, as interactive elements often lead to better knowledge retention and comprehension. The Multisim-based workbook effectively bridged the gap between theory and practice, addressing a common challenge in traditional teaching methods. By providing a virtual lab environment, students were able to practice and apply concepts effectively, even without access to physical laboratory equipment.

Moreover, the strong learning gains observed in the Experimental Group suggest that integrating simulation-based instructional materials into the curriculum could be highly beneficial for Electronics Technology students. By incorporating interactive and technology-enhanced learning tools, educators can improve conceptual understanding, student engagement, and problem-solving abilities. While the study demonstrates the effectiveness of simulation-based learning, some challenges and limitations should be considered. Access to technology remains a potential barrier, as some students may have limited access to computers outside the classroom, restricting their ability to fully utilize Multisim for independent learning. Additionally, instructor training is essential for the successful implementation of simulation-based instruction. Educators must be well-trained in using Multisim software and effectively integrating it into the syllabus to maximize student learning. Another limitation is the long-term retention of knowledge. While the post-test results indicate short-term knowledge gains, further research is needed to determine whether these improvements translate into long-term retention and practical application in real-world scenarios. A follow-up study assessing students' performance over an extended period could provide insights into the sustained impact of simulation-based learning.

The results strongly support the integration of Multisim-based instructional materials as an effective teaching strategy for Electricity and Magnetism. The significant improvement in student performance in the Experimental Group highlights the advantages of interactive simulations over traditional lecture-based methods. Moving forward, educational institutions should consider incorporating technology-enhanced learning tools to improve conceptual understanding, student engagement, and practical application skills in Electronics Technology course. By leveraging simulation-based learning, students can develop a deeper understanding of circuit analysis, enhance their problem-solving abilities, and gain valuable hands-on experience that prepares them for real-world applications.

DISCUSSION

The developed instructional materials successfully aligned with the intended learning objectives, ensuring that students gained a comprehensive and practical understanding of Electricity and Magnetism. By incorporating interactive and hands-on learning experiences through Multisim simulations, students were able to engage more actively in the learning process, moving beyond passive theoretical instruction. The integration of simulation-based activities allowed them to visualize circuit behaviors in real-time, reinforcing their conceptual grasp of electrical and magnetic principles. Furthermore, the instructional materials played a crucial role in enhancing conceptual understanding, particularly in areas where students previously struggled with abstract theoretical concepts. The ability to experiment with different circuit configurations in a virtual environment helped bridge the gap between theoretical knowledge and practical application. The effectiveness of the instructional materials was further validated by improved student engagement and performance, as reflected in the post-test results. Students who utilized the Multisim-based workbook demonstrated higher comprehension levels, better problem-solving abilities, and increased motivation to explore complex circuit concepts. The combination of structured lessons, interactive simulations, and formative assessments contributed to a more effective and engaging learning experience, aligning well with the desired educational outcomes of Electronics Technology course.

Table 4. Extent of Alignment of Lessons with Course Learning Outcomes

No.	Simulation title	Course Learning Outcome	Alignment (%)	Interpretation
1	Resistors	Identify and classify resistors based on type and value	100	Fully Aligned
2	R-Voltage and I Measurements	Measure R, V, and I in a circuit	100	Fully Aligned
3	Ohm’s Law	Apply Ohm’s Law to determine electrical properties	100	Fully Aligned
4	Applying Ohm’s Law	Demonstrate the relationship between voltage, current, and resistance	100	Fully Aligned
5	Series Circuits	Analyze series circuits and calculate total resistance	100	Fully Aligned

6	Analysis of Series Circuits	Perform detailed analysis of series circuits	100	Fully Aligned
7	Series Circuits With Opens	Identify the effects of open circuits in series configurations	100	Fully Aligned
8	Series-Aiding & Series-Opposing Voltages	Differentiate series-aiding and series-opposing voltages	100	Fully Aligned
9	Positive and Negative Voltages to Ground	Analyze positive and negative voltages referenced to ground	100	Fully Aligned
10	Parallel Circuits	Understand the behavior of parallel circuits	100	Fully Aligned
11	Parallel Circuits Resistance Branches	Calculate equivalent resistance in parallel branches	100	Fully Aligned
12	Parallel Circuits - Analysis	Analyze I and V distribution in parallel circuits	100	Fully Aligned
13	Parallel Circuits Opens and Short	Identify the effects of open and short circuits in parallel configurations	100	Fully Aligned
14	Series-Parallel Circuits - R	Calculate total R in series-parallel circuits	100	Fully Aligned
15	Series-Parallel Circuits Networks	Analyze complex series-parallel circuit networks	100	Fully Aligned
16	Series-Parallel Circuits Analysis	Perform series-parallel circuit analysis using circuit laws	100	Fully Aligned
17	Series-Parallel Circuits Opens-Short	Determine the effects of open and short conditions in series-parallel circuits	100	Fully Aligned
18	The Wheatstone Bridge	Apply principles of the Wheatstone Bridge for resistance measurement	100	Fully Aligned
19	Current Dividers	Explain the function and use of current dividers	100	Fully Aligned
20	Voltage Divider Design	Design and analyze voltage divider circuits	100	Fully Aligned
21	Kirchhoff’s Laws	Apply Kirchhoff’s Laws in circuit analysis	100	Fully Aligned
22	Network Theorems	Solve circuit problems using network theorems	100	Fully Aligned
23	Magnetism	Explain the principles of magnetism and magnetic fields	100	Fully Aligned
24	Electromagnetism and Coils	Understand electromagnetism and its applications in coil circuits	100	Fully Aligned

The Simulation Activity Alignment with Course Learning Outcomes table 4, provides a structured evaluation of how each simulation-based activity in the instructional materials corresponds to the learning objectives of an Electricity and Magnetism course in Electronics Technology. The results indicate that all 24 simulation activities are either fully aligned or strongly aligned with the specified learning outcomes, demonstrating the effectiveness, relevance, and curriculum compliance of the developed instructional materials. Each simulation activity was designed to support the development of key competencies in circuit analysis, electrical measurements, circuit troubleshooting, and electromagnetism. The 100% alignment across all activities confirms that the instructional materials effectively address the required knowledge, skills, and problem-solving abilities expected from students in an Electronics Technology course. The structure of the simulation activities follows a progressive learning approach, covering fundamental, intermediate, and advanced concepts in Electricity and Magnetism.

The instructional materials cover several key topics in Electricity and Magnetism, organized into four main sections. The first section, Basic Circuit Principles and Ohm's Law (Activities 1-4), introduces students to fundamental concepts such as resistors, resistance measurement, and Ohm's Law, helping them understand the relationship between voltage, current, and resistance. Through simulation-based exercises, students can visualize and apply Ohm's Law in real-time, reinforcing theoretical knowledge with hands-on experimentation. The second section, Series and Parallel Circuits (Activities 5-17), delves into circuit analysis techniques and troubleshooting methods. Activities like Series Circuits with Opens and Parallel Circuits – Opens and Shorts provide students with practical problem-solving experiences. This section ensures students gain the skills to analyze, troubleshoot, and design electrical circuits effectively. The third section, Advanced Circuit Analysis and Network Theorems (Activities 18-22), covers more complex topics such as The Wheatstone Bridge, Current Dividers, Voltage Dividers, and Kirchhoff's Laws. These activities focus on enhancing students' higher-level problem-solving skills and preparing them to handle complex electrical networks with greater precision and efficiency. The final section, Magnetism and Electromagnetism (Activities 23-24), integrates electrical principles with magnetic field interactions, allowing students to explore real-world applications like motors, transformers, and inductors. This holistic approach ensures students develop a comprehensive understanding of the relationship between electrical and magnetic concepts, which is essential for power systems, electronics applications, and industrial automation.

The high level of alignment between the simulation activities and the course learning outcomes offers several significant educational benefits. First, it ensures curriculum relevance by aligning the instructional materials with academic standards and industry expectations, ensuring that students acquire both practical and theoretical knowledge that is vital for their future careers. Additionally, the materials enhance student learning outcomes by using a structured simulation-based approach that reinforces theoretical concepts through interactive, hands-on experimentation, leading to a deeper comprehension of the subject matter and the development of improved technology skills. The use of Multisim simulations also bridges the gap between theory and practice, allowing students to apply their theoretical knowledge to real-world circuit scenarios, which better prepares them for technology roles in the electronics and electrical industries. Finally, engaging in simulation activities fosters active and experiential learning, helping students to develop critical thinking, problem-solving, and analytical skills, which are essential competencies for careers in engineering and technology fields.

To further improve the effectiveness of the instructional materials, several enhancements are recommended. First, expanding real-world applications by incorporating case studies and industry-based problem scenarios will allow students to apply their knowledge to real engineering challenges, increasing the practical relevance of the simulations. Additionally, enhancing troubleshooting simulations by introducing fault-based scenarios will help strengthen students' diagnostic and problem-solving skills, enabling them to develop a more systematic approach to identifying and resolving circuit issues. Finally, providing additional training and instructional resources for educators will ensure the effective integration of the simulation workbook into the classroom. By equipping instructors with the necessary skills and support, the learning impact of the instructional materials can be maximized, leading to improved student engagement and comprehension in Electricity and Magnetism concepts.

The 100% alignment of all simulation activities with course learning outcomes strongly supports the effectiveness and validity of the developed instructional materials. The study confirms that the Multisim-based workbook significantly enhances student engagement, conceptual understanding, and practical application skills in Electricity and Magnetism. Moving forward, integrating more real-world case studies and advanced troubleshooting simulations will further strengthen the instructional materials' impact on student learning and competency development. The validation process revealed several strengths that contributed to the effectiveness of the developed instructional materials. One of the most notable strengths was the high level of student engagement facilitated by interactive simulations, which motivated students to explore concepts beyond traditional textbooks. The hands-on nature of Multisim-based learning enabled students to experiment with circuits in a dynamic and interactive manner, making learning more immersive and stimulating. Additionally, the instructional materials significantly improved conceptual understanding, as students demonstrated a better grasp of electrical circuits and electromagnetic principles compared to those following traditional lecture-based instruction. Another key strength was instructor acceptance, as teachers found the materials easy to integrate into existing lesson plans, making it a practical and adaptable teaching resource for Electronics Technology course. Despite these strengths, some weaknesses were identified during the validation process. One challenge was the limited proficiency in using Multisim among some students, as first-time users required additional guidance to navigate the software effectively. While the simulation-based approach proved beneficial, students who were less familiar with technology-based learning tools initially struggled to maximize its features. Another issue was software accessibility, as students without personal computers faced difficulties practicing simulations outside the classroom, limiting their ability to reinforce learning through independent study. Lastly, instructors suggested including more real-world application exercises, such as case studies or industry-related projects, to further enhance the relevance of the lessons. Addressing these challenges through supplementary training sessions, expanded accessibility options, and the integration of practical applications could further strengthen the instructional materials and improve learning outcomes. Compared to traditional textbooks and laboratory manuals, the developed Multisim-based instructional materials provided more engaging and practical learning experiences. The simulation exercises compensated for laboratory equipment limitations, allowing students to experiment with circuit designs in a virtual environment.

The findings of this study suggest that technology-enhanced instructional design can play a critical role in improving technology education, particularly in Electronics Technology course. The effectiveness of simulation-based learning demonstrated in this research highlights its potential for broader application across other subjects within the field. By expanding the use of Multisim and similar digital tools, educators can create more interactive, engaging, and practical learning experiences that bridge the gap between theory and application.

Additionally, the study emphasizes the value of blended learning approaches, which integrate both digital simulations and hands-on laboratory experiences. While virtual experimentation through Multisim enhances conceptual understanding, complementing it with physical circuit-building exercises could further solidify students' Technology skills and problem-solving abilities. A well-structured combination of simulation-based and traditional laboratory learning can provide a more comprehensive and effective instructional approach. Furthermore, the study highlights the importance of ongoing instructor training in effectively integrating Multisim into the classroom. To maximize the benefits of simulation-based learning, educators must be equipped with the necessary skills and strategies to incorporate digital tools into their teaching practices. Providing workshops, training programs, and instructional support will ensure that instructors can fully utilize Multisim's capabilities, enhance student engagement, and create a dynamic, technology-driven learning environment. These recommendations for future instructional material development can contribute to improving student learning outcomes and advancing modern teaching methodologies in Technology education.

The results confirm that the developed instructional materials significantly improved student learning outcomes by addressing identified learning gaps, integrating effective instructional strategies, and utilizing technology-enhanced simulations. The study's findings provide strong support for the adoption of Multisim-based instructional resources in Electronics Technology education, demonstrating higher engagement, better conceptual retention, and improved application skills among students.

Table 5. Content Validity Rating of the Developed Instructional Materials

Criteria	Expert 1	Expert 2	Expert 3	Mean Score	Interpretation
Content Accuracy	4.8	4.7	4.9	4.8	Very Satisfactory
Clarity and Organization	4.6	4.5	4.7	4.6	Very Satisfactory
Alignment with Course Outcomes	4.9	4.8	4.7	4.8	Very Satisfactory

Integration of Multisim Software	4.7	4.6	4.8	4.7	Very Satisfactory
Instructional Effectiveness	4.8	4.7	4.9	4.8	Very Satisfactory

The Content Validation Result table 5, presents the evaluation scores provided by subject matter experts and instructional designers on the developed instructional materials for Electricity and Magnetism. These experts assessed the materials based on several key criteria, including accuracy, clarity, alignment with course outcomes, integration of Multisim software, and instructional effectiveness. The ratings from the three experts were then averaged to determine the mean score, which reflected the overall quality of the materials.

In terms of content accuracy, the mean score of 4.8 indicates that the materials were considered highly accurate, with expert ratings ranging from 4.7 to 4.9. This suggests that the content was thoroughly vetted and validated, ensuring that students would be provided with correct and reliable information. Similarly, clarity and organization of the materials received a mean score of 4.6, with expert evaluations ranging from 4.5 to 4.7, reflecting that the materials were well-organized and easy to understand. This rating suggests that the instructional materials are structured in a way that supports efficient learning. The alignment with course outcomes was another key area assessed, and the materials received a mean score of 4.8, with individual scores ranging from 4.7 to 4.9. This high rating demonstrates that the materials are strongly aligned with the desired learning outcomes of the Electronics Technology curriculum, ensuring that students will be able to develop the competencies required by the program. The integration of Multisim software, which plays a central role in the instructional design, received a mean score of 4.7, with ratings between 4.6 and 4.8. This indicates that the software was effectively incorporated into the materials, enhancing the interactive learning experience for students.

Finally, instructional effectiveness was rated with a mean score of 4.8, showing that the materials were deemed highly effective in facilitating student learning. Expert scores ranged from 4.7 to 4.9, confirming that the materials were engaging and contributed significantly to student comprehension and application of circuit analysis concepts. Overall, the expert evaluation results indicate that the developed instructional materials were very satisfactory across all criteria, suggesting they are both accurate and effective in helping students learn complex topics in Electricity and Magnetism.

Table 6. Feedback on the Developed Instructional Materials

Criteria	Student Mean Score	Instructor Mean Score
Clarity of Instructions	4.6	4.8
Ease of Use	4.5	4.7
Effectiveness in Learning	4.7	4.8
Engagement and Motivation	4.8	4.6

The Student and Instructor Satisfaction Ratings table 6, summarizes the feedback from both students and instructors on the usability, engagement, and effectiveness of the Multisim-based instructional materials designed to teach Electricity and Magnetism. The high ratings across all categories indicate a strong positive reception and validation of the materials.

Both students and instructors rated the instructional materials highly, with scores ranging from 4.5 to 4.8 out of 5. Instructors provided slightly higher ratings in areas like clarity of instructions and effectiveness in learning, suggesting that the materials were well-structured and pedagogically sound. Students, on the other hand, gave the highest rating of 4.8 for engagement and motivation, highlighting the interactive and practical nature of the materials, which kept them actively involved in the learning process. The evaluation of key criteria in the Multisim-based instructional materials highlights their effectiveness in enhancing student learning and engagement. Clarity of instructions received high ratings, with students scoring it 4.6 and instructors giving it 4.8. These ratings indicate that the lesson structure, simulation guides, and step-by-step instructions were clear, concise, and easy to follow. Instructors rated this aspect slightly higher, suggesting that the materials were well-aligned with teaching methodologies, making them easier to integrate into classroom instruction. This clarity allowed students to focus on learning rather than struggling with unclear directions.

In terms of ease of use, students rated the materials 4.5, while instructors gave them 4.7, showing that both groups found the Multisim-based workbook intuitive and user-friendly. However, the slightly lower student score suggests that some students required additional guidance when first using Multisim software. This highlights the need for introductory exercises or tutorials to improve ease of use and ensure that all students can fully benefit from the simulation-based learning approach. The effectiveness in learning was rated 4.7 by students and 4.8 by instructors, confirming that the instructional materials successfully enhanced student comprehension and skill development. The combination of interactive simulations and structured problem-solving activities proved crucial in bridging theoretical knowledge with practical applications, offering a more engaging and hands-on learning experience compared to traditional methods.

Finally, engagement and motivation received the highest student rating of 4.8, demonstrating that the simulation-based learning approach significantly boosted student enthusiasm and participation. The ability to actively engage with the material through Multisim simulations made learning more dynamic and interactive, keeping students motivated throughout the course. Instructors also acknowledged this positive shift but rated it slightly lower (4.6), likely reflecting differences in teaching environments and individual student learning preferences. Overall, these results confirm that the instructional materials were highly effective in improving student engagement, comprehension, and practical application skills in Electricity and Magnetism.

The instructional materials were well-received by both students and instructors, with consistently high ratings for clarity, ease of use, effectiveness in learning, and engagement. Students particularly valued the interactive and motivating nature of the materials, demonstrating the superior effectiveness of simulation-based learning over traditional methods. Instructors appreciated the materials’ clarity and alignment with course objectives, confirming that they were easy to integrate into the curriculum. While the satisfaction ratings indicate high levels of effectiveness, certain improvements could further optimize the learning experience. One key enhancement is to provide more extensive software training sessions to support students with limited experience using Multisim. Introducing step-by-step tutorials and guided exercises would make the software more accessible and ensure that all students can effectively navigate and utilize its features. Additionally, expanding troubleshooting activities and incorporating real-world applications would strengthen the practical relevance of the instructional materials. By integrating industry-based problem scenarios, students can develop critical thinking and problem-solving skills that are directly applicable to their future careers. Lastly, ensuring continuous instructor support through additional training on simulation-based teaching methods will help educators effectively implement and maximize the use of these materials. Providing instructors with ongoing resources and professional development opportunities will further enhance teaching effectiveness and ensure the long-term success of simulation-based learning in Electricity and Magnetism course.

The high satisfaction ratings from both students and instructors validate the effectiveness, usability, and engagement of the developed instructional materials. The Multisim-based simulations successfully addressed the learning gaps identified in traditional teaching methods, providing an interactive, hands-on, and engaging approach to learning Electricity and Magnetism. Moving forward, incorporating more troubleshooting exercises, real-world applications, and enhancing software training will further maximize the impact of these materials on student learning outcomes and their practical competency in the subject.

Table 7. Time Spent on Activities (Traditional vs. Multisim-Integrated Learning)

Activity	Traditional Learning (Minutes)	Multisim-Based Learning (Minutes)	Time Reduction (%)
Basic Circuit Assembly	45	25	-44.4%
Troubleshooting Circuit Errors	60	30	-50.0%
Analyzing Waveforms	40	20	-50.0%

The Time-on-Task Analysis table 7, highlights the learning efficiency of using Multisim-based instructional materials compared to traditional learning methods. Table 7, presents the time spent on specific activities such as Basic Circuit Assembly, Troubleshooting Circuit Errors, and Analyzing Waveforms, with results showing a significant reduction in time for activities completed using simulation-based learning.

For Basic Circuit Assembly, students using traditional methods took 45 minutes to complete the task, while those using Multisim spent only 25 minutes. This represents a 44.4% reduction in time, which can be attributed to the elimination of physical setup time and the ability to easily modify and test circuits in a virtual environment. Similarly, when it comes to Troubleshooting Circuit Errors, traditional learners required 60 minutes to identify and correct issues, while the Multisim group only spent 30 minutes, reflecting a 50% reduction in time. The ability to instantly test circuit changes and receive real-time feedback through Multisim significantly sped up the troubleshooting process. Lastly, the activity of Analyzing Waveforms showed a similar trend, with traditional learning taking 40 minutes compared to 20 minutes for the Multisim-based approach, marking another 50% reduction in time. This time-saving was facilitated by the immediate visual feedback provided by the software, which allowed students to analyze waveforms faster and more efficiently than with physical instruments.

Overall, the Time-on-Task Analysis demonstrates that Multisim-based learning significantly enhances learning efficiency, reducing the time required to complete core activities by 44.4% to 50%. This indicates that simulation-based instruction not only improves learning outcomes but also allows students to complete tasks in a more time-efficient manner, making it a valuable tool for teaching complex subjects like Electricity and Magnetism.

CONCLUSION AND RECOMMENDATIONS

This study focused on the development and validation of instructional materials for teaching Electricity and Magnetism in Electronics Technology course using Multisim software for simulation-based learning. The study followed the ADDIE methodology, which guided the development process from the initial needs assessment to the final evaluation phase. The findings from each phase highlight the effectiveness and impact of the developed materials on student learning.

In the Analysis Phase, the needs assessment identified key challenges such as limited laboratory access, difficulty in visualizing abstract concepts, and a lack of interactive elements in traditional teaching methods. These challenges underscored the need for a simulation-based approach to bridge the gap between theory and practice. In the Design Phase, instructional materials were structured into 24 simulation-based modules, covering essential topics such as Ohm’s Law, circuit analysis, electromagnetic fields, and troubleshooting. These modules were designed to be interactive and hands-on, utilizing Multisim software to create a virtual learning environment where students could experiment with circuits without physical lab equipment. The Development Phase involved expert evaluation and pilot testing, where feedback from subject matter experts, instructors, and students helped refine the materials. The validation process confirmed the accuracy, clarity, and alignment of the materials with course outcomes. In the Implementation Phase, students using the Multisim-based workbook demonstrated significant improvement in performance, with post-test scores increasing by 27.8%, compared to a 12.2% increase in the control group using traditional methods. Additionally, the Time-on-Task Analysis revealed that students completed activities 44.4% to 50% faster using the simulation-based learning approach. The Evaluation Phase included both formative and summative evaluations. Results showed high satisfaction ratings from both students and instructors, with scores ranging from 4.5 to 4.8 out of 5 in areas such as clarity, ease of use, effectiveness in learning, and engagement. The strong alignment of the materials with course learning outcomes (100%) further validated their effectiveness. The evaluation feedback emphasized the engaging, interactive nature of the materials and the positive impact on student motivation and learning outcomes.

Conclusion

The Multisim-based instructional materials significantly enhanced student learning in Electricity and Magnetism by providing interactive, hands-on experiences that bridged the gap between theoretical knowledge and practical application. The ADDIE methodology proved to be an effective framework in the development, implementation, and evaluation of the materials, ensuring they were well-aligned with learning outcomes and industry standards. Based on the findings, several recommendations can further improve the effectiveness of the materials. First, it is suggested to expand real-world applications within the simulation activities, incorporating more case studies and industry-based problem scenarios. Second, enhancing the troubleshooting exercises with fault-based simulations could improve students' problem-solving and diagnostic skills. Additionally, providing introductory tutorials and more instructor training on Multisim would further optimize the use of the software in the classroom.

Recommendations

For future research, studies can explore the development of simulation-based instructional materials for other scientific concepts using the ADDIE methodology, such as Physics or Engineering Mechanics. Research should also assess the long-term retention and impact of these materials on student performance beyond short-term pilot testing. Comparing Multisim with other simulation tools or virtual learning environments will provide valuable insights into the most effective technology-enhanced learning strategies for Technology education.

In summary, this study demonstrates the success of simulation-based learning in enhancing student engagement, comprehension, and practical application skills in Electricity and Magnetism. It underscores the potential of technology-enhanced instructional design in improving Technology education, making it more interactive, accessible, and effective for students in Electronics Technology programs.

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