THE INFLUENCE OF COMPUTER-BASED SIMULATION IN TEACHING DIRECT CURRENT CIRCUITS ON IMPROVING STUDENTS' ACADEMIC ACHIEVEMENT AND ATTITUDES

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ABSTRACT

This study investigates the influence of computer-based simulations on students' academic achievement and attitudes toward learning Direct Current (DC) circuits in physics. A quasi-experimental design was employed, involving 40 secondary school students divided into an experimental group (20 students) and a control group (20 students). The experimental group was taught using computer-based simulations, while the control group received traditional instruction. Pre- and post-tests were administered to measure academic achievement, and attitude surveys were conducted to assess students' motivation, interest, and confidence. The results revealed a statistically significant improvement in the experimental group's post-test scores ($M = 78.60$, $SD = 12.63$) compared to the control group ($M = 68.80$, $SD = 11.24$), with $t(19) = 2.421$, $p < 0.05$. Additionally, the experimental group reported significantly higher attitude scores ($M = 3.67$, $SD = 0.49$) than the control group ($M = 3.38$, $SD = 0.64$), with $t(19) = 2.179$, $p < 0.05$. Feedback from students in the experimental group highlighted the engaging and interactive nature of simulations, which helped them visualize abstract concepts and build confidence in performing electrical experiments. These findings underscore computer-based simulations' effectiveness in enhancing academic performance and attitudes toward learning physics. The study recommends the integration of simulations into physics education to foster deeper conceptual understanding, improve problem-solving skills, and create a more engaging learning environment. Future research should explore the long-term impact of simulations on students' academic trajectories and investigate strategies for scaling their implementation in diverse educational contexts.

Keywords: *Academic achievement, attitudes, computer simulation, electric current circuits, secondary school student.*

INTRODUCTION

Physics, a cornerstone of the natural sciences, is often perceived as one of the most challenging subjects due to its abstract concepts. Many students find physics problem-solving difficult, especially when dealing with formulas and equations, often perceiving the subject as a set of facts to memorize rather than an area to explore. Teaching and learning DC circuits pose significant challenges at the secondary school level that impede students' conceptual understanding and engagement with the topic. These challenges arise from the abstract nature of DC circuit concepts, limitations in instructional methods, and gaps in resources or teacher preparation. DC circuits involve principles such as voltage, current, resistance, and their relationships, which are often difficult for students to visualize or comprehend.

Misconceptions are prevalent in natural sciences, including various physics concepts (Suprapto, 2020). One of the most commonly misunderstood topics in physics is the concept of direct current electricity. Research indicates that misconceptions about direct current rank just behind those related to mechanics (Zulvita, 2017).

Traditional teacher-centered approaches, such as lectures, question-and-answer sessions, assignments, and discussions, often rely solely on blackboards as the primary teaching tool. This method, commonly called conventional learning, tends to limit student engagement and participation in the learning process (Wahyu et al., 2017). This challenge arises because direct current is an abstract concept, making it difficult for students and future physics educators to grasp (Yunita, 2017). These misunderstandings often stem from errors in conceptual relationships, such as the connection between current and voltage or the differences between series and parallel circuits (Stolzenberger et al., 2022). Several factors contribute to these misconceptions, including students' everyday experiences, common misunderstandings across cultures, instructional approaches, textbooks, and an overreliance on informal language (Zainuddin et al., 2020). These misconceptions are persistent and can be reinforced by inadequate instructional methods. Moreover, traditional "chalk-and-talk" or lecture-based teaching methods often dominate the classroom, focusing on the theoretical aspects of DC circuits. These methods present the subject as a series of formulas and calculations, leaving little room for interactive or practical learning. Without hands-on experimentation, students struggle to link theoretical knowledge to real-world observations (Taber, 2011). Practical experiments are crucial in understanding DC circuits, yet their implementation is often limited in secondary schools, particularly in developing countries. Many schools lack laboratory resources such as functional circuit components, multi-meters, and power supplies. This scarcity of practical experience deprives students of opportunities to test and refine their understanding through experimentation (Nivalainen et al., 2010). Teachers' insufficient content knowledge and lack of effective pedagogical strategies exacerbate the challenge. Teachers may focus excessively on solving circuit problems mathematically without emphasizing the underlying concepts. Moreover, many teachers lack training in modern teaching aids, such as computer simulations, which could help simplify complex ideas (Asikainen & Hirvonen, 2010). Traditional teaching approaches, such as lecture-based methods, have been criticized for presenting science as a collection of disjointed facts, lacking creativity and innovation. Addressing these challenges requires equipping secondary students with a strong foundation in physics, enabling them to apply this knowledge in further studies, daily life, or research (Mbonyiryivuze et al., 2021).

It is crucial to understand teachers' perspectives and beliefs about the role of practical work in the teaching and learning of physics at the secondary level to address these challenges. Practical work has the potential to make physics concepts more tangible and relatable, thereby enhancing students' understanding and interest. However, despite its importance, only a limited number of studies have explored the role of practical work in science education, particularly in developing countries. Research has identified key barriers to effective physics education, including teachers' insufficient subject knowledge and pedagogical skills. Well-designed teacher education programs that enhance subject knowledge and teaching strategies are essential for overcoming these obstacles. Teachers play a critical role in shaping educational practices and outcomes, as their beliefs and practical knowledge directly influence how they teach and interact with students (Borliboune et al., 2022). Mustofa and Hidayah (2020) emphasized that educators should go beyond teaching factual knowledge and focus on enhancing students' abilities, such as creative thinking.

In addition, there is a need for physics teachers to improve their teaching by incorporating computer simulations into their instruction. Computer simulations have been shown to significantly improve students' achievement in understanding electric current circuits. Simulations provide a visual and interactive platform for students to explore and experiment with circuit components and behaviors, enhancing their conceptual understanding and problem-solving skills. Electric current circuits involve abstract principles like voltage, current, and resistance, which can be challenging for students to grasp. Computer simulations, such as those provided by PhET Interactive Simulations, allow students to visualize these concepts dynamically.

Over the past few decades, the integration of technology in education, including games, virtual reality, and computer simulations, has significantly advanced (Makransky et al., 2019). Simulations, in particular, have proven effective in enhancing teaching methods and promoting active student involvement. They help students grasp scientific concepts more easily by providing visual and interactive representations of complex information (Manunure et al., 2019). Additionally, simulations foster critical skills such as problem-solving, innovation, and creativity (Vlachopoulos & Makri, 2017). As a result, simulations play a crucial role in modern teaching and learning practices. The functionality of simulations enables learners to interact virtually with phenomena that are too dangerous to explore in real-time and to solve complex problems (Krajcik & Mun, 2014). Recent research emphasizes using technology, such as simulations, in learning environments where learners develop knowledge and skills through inquiry-based learning. In addition, this study aims to improve students' learning achievement and attitudes toward learning electric current circuits by using computer simulations. Using computer simulations in teaching electric current circuits is significant as it enhances students' learning experiences by addressing conceptual challenges, fostering engagement, and improving practical understanding. This approach benefits teachers and learners, making learning more effective and accessible.

Objective of the Study

The main objective of this study is to explore the influence of computer-based simulation teaching on students' learning outcomes and attitudes towards DC circuits. Specifically, the study aims to:

1. Assess the impact of computer-based simulations on students' academic performance in understanding direct current circuits compared to traditional teaching methods.
2. Analyze changes in students' attitudes, including interest, engagement, perceived relevance, and self-efficacy towards learning direct current circuits following instruction using simulation-based tools.
3. Identify potential benefits and challenges associated with integrating computer simulations in teaching DC circuits within the physics curriculum.

Research Hypotheses

Based on the objectives of the study, the following hypotheses were formulated:

1. Hypothesis 1 (H1): Students who are taught DC circuits using computer-based simulations will demonstrate significantly higher academic performance compared to students who are taught using traditional instructional methods.
2. Hypothesis 2 (H2): The use of computer-based simulations in teaching DC circuits will result in a more positive change in students' attitudes towards learning this topic compared to traditional teaching methods.

LITERATURE REVIEW

The use of computer-based simulations in science education, particularly in physics, has been widely researched and recognized for its potential to enhance teaching effectiveness and student engagement. This literature review examines existing studies on integrating simulations in educational settings, particularly focusing on teaching DC circuits, and discusses the theoretical underpinnings, benefits, and challenges associated with simulation-based learning.

Computer-Based Simulations in Education

Computer-based simulations have gained widespread popularity as an educational instructional tool due to their ability to create dynamic and interactive learning environments that enhance understanding of complex concepts. These simulations enable students to visualize abstract phenomena, manipulate variables, and observe real-time outcomes, offering a more engaging and meaningful learning experience than traditional teaching methods. This section examines the key benefits, challenges, and applications of computer-based simulations in education, particularly focusing on their role in science and technology learning. Computer-based simulations provide an interactive and visual approach to learning that surpasses traditional instruction by allowing students to explore and experiment within virtual environments. Sari et al. (2019) discovered that computer-based laboratory and virtual applications positively influenced students' attitudes. Their research highlighted that simulations enable students to visualize complex phenomena, manipulate variables, and receive immediate feedback, which enhances conceptual understanding and improves knowledge retention. In the context of physics education, simulations make abstract concepts more accessible, engaging students through interactive and immersive learning experiences. The definition of computer simulation varies across literature, with some definitions offering complementary perspectives. In scientific disciplines, computers have been utilized early on due to their computational capabilities. The speed of computers allows for rapid hypothesis testing, enabling researchers to simulate theoretical outcomes and assess their validity quickly, thereby accelerating the development of scientific theories. This approach involves advancing the understanding of real-world phenomena by proposing digital models and comparing simulation results with real-world observations (Chekour, 2018). Educators emphasize the importance of integrating simulations to facilitate learners' cognitive tasks and enhance the quality of education, particularly in physical sciences like electricity.

Simulations simplify real-world systems, making them easier to study (Arnold & Wade, 2017). Additionally, simulations are flexible and adaptable to different learning styles (Perez & Poole, 2019). In some cases, simulations serve as a "unique" didactic tool to address challenges posed by time-consuming, hazardous, or costly experiments. Simulations also enable virtual experiments, allowing students to interact with simulation software (Shih & Kuo, 2021). Research has shown that simulations can significantly enhance students' academic achievement (Marczynski et al., 2022). Furthermore, simulations can complement laboratory experiments by reducing the time required for lab sessions and supporting student reasoning through model-based learning (Develaki, 2017). By combining simulations with hands-on laboratory work, educators can create a more efficient and effective learning experience, bridging the gap between theory and practice.

Academic Benefits of Simulations

Numerous studies have highlighted the positive effects of simulation-based learning on student achievement. When integrated into teaching, simulations encourage students to engage in scientific inquiry, fostering active knowledge construction and deeper understanding (Çelik, 2022). Inquiry-based activities, such as designing experiments, testing hypotheses, collecting and analyzing data, and drawing conclusions (Pedaste et al., 2015), help students develop essential science process skills (Çelik, 2022). Computer simulations' dynamic and interactive nature facilitates these exploratory scientific activities, making learning more engaging and effective. In contrast, conventional instruction often relies on passive learning methods, such as rote memorization of information delivered by teachers (Golder, 2018) or textbook reading. Traditional approaches like lecturing and direct instruction are misaligned with constructivist learning theory and are ineffective in helping students grasp complex and abstract physics concepts meaningfully. Beyond improving academic performance, simulation-based teaching significantly influences students' attitudes toward learning. Positive attitudes, such as increased motivation, interest, and perceived relevance of the subject, are strongly linked to better educational outcomes. Simulations are widely used not only in education but also in various fields requiring practical application, including military training, industry, aerospace, engineering, and healthcare. They are also actively employed in natural sciences (e.g., physics, chemistry, biology), social sciences (e.g., geography), and other disciplines like mathematics and language education. As a next-generation technology, simulations have quickly gained attention in education, from primary to higher levels, due to their unique features. Research has shown that simulations improve student success and performance (Abdel-Maksoud, 2019), fostering a lasting positive attitude toward science by encouraging curiosity and engagement with challenging material.

Integrating computer-based simulations in education not only boosts academic achievement but also plays a crucial role in shaping students' attitudes toward learning, particularly in subjects like physics and engineering. Simulations create an engaging and dynamic learning environment that influences students' perceptions, motivation, and interest in the subject matter. This section explores how computer-based simulations impact student attitudes, focusing on their ability to enhance engagement, build confidence, and improve perceptions of subjects like DC circuits. One of the most significant advantages of simulations is that they provide a safe, non-threatening environment for students to explore complex concepts. In traditional classrooms, students may feel anxious about making mistakes in front of peers or instructors, which can negatively affect their attitude toward the subject. Simulations allow students to experiment with circuits and test different configurations without the risk of damaging equipment or causing harm. The researchers also examined the impact of teaching chemical kinetics using computer simulations on students' academic achievement than conventional instruction. Substantial research has shown that technology-based instructional methods, such as computer simulations, lead to greater academic achievement than traditional teaching approaches (Savelsbergh et al., 2016). Although the study indicates that integrating technology into science education enhances academic performance, it also reveals variations in the effect sizes of these interventions.

Student Attitudes towards Physics

Perspective plays a crucial role in shaping human behavior and guiding daily efforts. According to Haber (1975), perspective is a framework that organizes our understanding of the world. As intellectual beings, humans strive to master their environment, and perspective provides the cognitive structure needed to navigate social interactions and meet fundamental needs. For students, perspective is particularly important as it directly influences their academic success and learning outcomes. A positive outlook on learning can significantly enhance students' academic progress, as highlighted by Veloo et al. (2015), who emphasized that students with a positive attitude toward learning are likelier to achieve better results. Physics, a field closely tied to everyday phenomena, is often perceived as challenging. This perception can create barriers for students, making it difficult to pursue higher education in science and technology (Guido, 2018). Students with a positive perspective on physics tend to perform better than those with a negative attitude. Positive attitudes toward science learning, including physics, foster deeper understanding, greater success, and more meaningful knowledge acquisition. Veloo et al. (2015) further noted that students with positive attitudes and strong learning motivation are likelier to improve their academic performance. Conversely, negative attitudes toward physics can hinder current and future learning, leading to reduced confidence, poor performance, and difficulties in solving physics problems (Olasimbo, 2012). Students with negative attitudes toward physics often extend these feelings to their physics teachers, further complicating the learning process (Guido, 2018). A positive perspective on physics is strongly associated with a favorable attitude toward science, sustained motivation, and a lasting interest in the subject. Students who exhibit scientific behavior tend to gain the most from their learning experiences. Abiasen and Reyes (2021) explored science teachers' perceptions of integrating computer simulation into their classrooms. Their findings revealed a favorable perception among teachers, highlighting the potential of computer simulation to transform the learning environment significantly. The study demonstrated that when computer simulation is effectively incorporated into teaching practices, it positively influences learners' knowledge, skills, and attitudes. This integration motivates teachers to adopt more innovative and effective teaching methods, though the study also emphasized the need to enhance teachers' technological, pedagogical, and content knowledge (TPACK) for optimal implementation.

Previous Studies

Research on electric current circuits is an essential component of physics and engineering education, as understanding these concepts is fundamental to students' grasp of electrical systems and their applications. Over the years, numerous studies have explored the teaching and learning of electric circuits, particularly in terms of student comprehension, challenges faced by learners, and the effectiveness of various teaching methods, including traditional and modern techniques like computer-based simulations. Below is an overview of key studies on electric current circuits, highlighting various approaches, findings, and pedagogical implications. Studies have also examined the role of visual representations and simulations in improving students' understanding of electric circuits. Recently, a study by Mhamed et al. (2021) aimed to investigate the impact of computer simulations on students' performance in learning physical science, specifically focusing on Ohm's Law in electricity. The findings revealed that the experimental group outperformed the control group in the posttest, demonstrating the effectiveness of computer simulations in enhancing student performance. Based on the results, the study recommends incorporating simulation software into teaching practices to improve middle school students' academic performance in physical science. Another study by Daniel and Juma (2023) investigated the perceptions of teachers and students on the use of computer simulations for teaching and learning Ohm's Law in physics at secondary schools. The results revealed strong positive perceptions among teachers and students, with computer simulations praised for enhancing student interaction and improving the overall learning experience. The study concluded that computer simulations are effective for teaching Ohm's Law and recommended its integration into classrooms, promoting gender equity in science education and utilizing visual aids to enrich teaching and learning outcomes. Moreover, a study by Abdul et al. (2024) compared the effectiveness of traditional teaching methods and simulation-based learning in improving students' performance. The findings revealed that simulation-based learning, particularly using the Cisco Packet Tracer Simulator, was more effective than traditional methods. Students in the experimental group gained practical networking knowledge, including understanding switches, routers, cables, and data transmission between computers. The study recommends that teachers integrate simulation tools into their teaching practices to enhance student understanding. It also advises school management to adopt ICT tools for better learning outcomes and urges policymakers to establish ICT labs and incorporate ICT into the curriculum. Overall, the study concludes that simulation is more efficient than traditional methods for teaching elementary-level students, offering significant potential to improve the education system.

Furthermore, a study by Daniel et al. (2024) addressed the persistent challenge of poor student performance in physics, particularly in Tanzania, where the subject's complexity often hinders understanding. The study compared the effectiveness of computer simulations with traditional teaching methods in improving students' grasp of Ohm's Law to tackle this issue. The study highlights the potential of computer simulations as an innovative teaching tool to improve physics education and recommends their integration into teaching practices to boost student performance and comprehension.

METHODOLOGY

This section outlines the research design, participants, data collection instruments, procedures, and data analysis methods used to investigate the influence of computer-based simulation teaching on students' academic achievement and attitudes regarding DC circuits.

Research Design

The study employed a quasi-experimental design with a pretest-posttest control group model. This approach allowed for a comparison between two groups of students: an experimental group exposed to computer-based simulations and a control group taught using traditional instructional methods. Using a pretest and posttest for both groups enabled the measurement of changes in students' academic performance and attitudes.

Participants

The study involved 40 high school students enrolled in physics courses. The participants were randomly assigned to the experimental group (20 students) or the control group (20 students). The sample was balanced for gender and academic background to ensure the comparability of groups.

Data Collection Instruments

The data collection involved two primary instruments:

1. Academic Achievement Test

A standardized test was developed to assess students' knowledge and understanding of direct current circuits. The test included multiple-choice and short-answer questions covering fundamental concepts such as Ohm's Law, circuit components, series and parallel circuits, and electrical current flow. The test was administered as a pretest and posttest to both groups to measure students' academic performance changes.

2. Attitude Survey
A validated Likert-scale survey assessed students' attitudes towards learning DC circuits. The survey measured dimensions such as interest in the subject, perceived relevance, engagement, and self-efficacy. The survey was administered to both groups before and after the intervention period.

Procedure
The study was conducted over a four-week period and followed these steps:

1. Pretest Administration
Both groups completed the academic achievement test and the attitude survey prior to the intervention.

2. Instructional Intervention

Experimental Group: Students in the experimental group received instruction using computer-based simulations. The simulations allowed students to build and manipulate virtual DC circuits, observe current and voltage changes, and test hypotheses in a safe and interactive environment.

Control Group: Students in the control group were taught using traditional instructional methods, which included textbook explanations, teacher-led lectures, and static diagrams of DC circuits. No computer simulations were used.

The instructional content and duration were the same for both groups to ensure comparability.

3. Posttest Administration
After the four-week intervention, both groups completed the academic achievement test and the attitude survey again.

Data Analysis
Quantitative data from the pretest and posttest scores were analyzed using statistical methods:

Descriptive Statistics: Mean scores, standard deviations, and score distributions were calculated to summarize students' performance and attitudes.

Inferential Statistics: A paired samples t-test was used to compare pretest and posttest scores within each group, while an independent samples t-test compared the posttest scores between the experimental and control groups.

Attitude Analysis: Students' changing attitudes were analyzed using a paired samples t-test to assess differences post-intervention between the two groups.

RESULTS

Results of the Pre-Test and Post-Test
The implementation of the experimental teaching method and the traditional teaching method yielded pre-test and post-test results, as shown in Table 1 below:

Table 1. *Pre-Test and Post-Test Results of the Experimental Group and the Control Group*

Group	Pre-test	Post-test
Experimental	37.75	78.60
Control	36.85	68.80

From Table 1, it is evident that the average pre-test scores of the experimental and control groups were relatively close, with averages of 37.75 and 36.85, respectively. The average post-test score of the experimental group was higher than that of the control group, with scores of 78.60 and 68.80, respectively.

Table 2. *T-test Analysis Results for Pre-Test and Post-Test Scores of the Experimental and Control Group*

Group	Analyze	N	Mean	SD	df	t	p
Experimental	Pre-test	20	37.75	11.93	19	17.509	0.000
	Post-test	20	78.60	12.63			
Control	Pre-test	20	36.85	11.12	19	21.251	0.000
	Post-test	20	68.80	11.24			

According to Table 2, the average pre-test score of the experimental group was $M = 37.75$ ($SD = 11.93$), and the mean post-test score was $M = 78.60$ ($SD = 12.63$). This indicates a statistically significant difference between the pre- and post-test scores in the experimental group, $t(19) = 17.509$, $p < 0.05$. Similarly, in the control group, the mean pre-test score was $M = 36.85$ ($SD = 11.12$), and the mean post-test score was $M = 68.80$ ($SD = 11.24$), also showing a statistically significant difference between pre- and post-test scores, $t(19) = 21.251$, $p < 0.05$. These results suggest that both groups showed improvement over time, but the experimental group, which utilized computer-based simulations, demonstrated a greater increase in academic achievement than the control group.

Table 3. *T-test Analysis Results for Pre-Test and Post-Test Scores between the Experimental and Control Group*

Analyze	Group	N	Mean	SD	df	t	p
Pre-test	Experimental	20	37.75	11.93	19	0.237	0.815
	Control	20	36.85	11.12			
Post-test	Experimental	20	78.60	12.63	19	2.421	0.026
	Control	20	68.80	11.24			

According to Table 3, the mean pre-test score of the experimental group was $M = 37.75$ ($SD = 11.93$), and that of the control group was $M = 36.85$ ($SD = 11.12$). This indicates no statistically significant difference between the two groups before the intervention, $t(19) = 0.237$, $p > 0.05$. However, after the intervention, the mean post-test score of the experimental group was $M = 78.60$ ($SD = 12.63$), while the control group's mean post-test score was $M = 68.80$ ($SD = 11.24$). This shows a statistically significant difference between the two groups after the intervention, $t(19) = 2.421$, $p < 0.05$. These results suggest that while both groups were comparable at the start of the study, the experimental group, which utilized computer-based simulations, achieved significantly higher post-test scores compared to the control group, highlighting the effectiveness of the intervention.

Students' attitudes

The results section will present the findings from the attitude surveys, highlighting the differences between the experimental and control groups.

Table 4. *T-test Results Comparing Student Attitudes in the Experimental Group and Control Group*

Group	N	Mean	SD	df	t	p
Experimental	20	3.67	0.49	19	2.179	0.042
Control	20	3.38	0.64			

According to Table 4, the mean attitude score of students in the experimental group was $M = 3.67$ ($SD = 0.49$), while the mean score for the control group was $M = 3.38$ ($SD = 0.64$). This indicates that the experimental group had a significantly higher attitude score than the control group, with a statistically significant difference between the two groups, $t(19) = 2.179$, $p < 0.05$. These results suggest that computer-based simulations not only improved academic achievement but also positively influenced students' attitudes toward learning, fostering greater motivation, interest, and confidence in the subject matter.

Students' Feedback

Feedback from the experimental group indicates that using computer simulations makes learning more engaging. Students reported that they appreciated the ability to observe electrical circuit behavior and conduct simulations without the limitations of missing physical components. Feedback from this group included:

> *"I saw how changing the resistance affected the flow of electric current in the circuit."*
> *"I enjoy using computer simulations because it makes the material easier to understand and much more comprehensible."*
> *"I was afraid to work with live electricity, but this teaching method helped me feel more confident about performing electrical experiments."*

Additionally, feedback from the control group emphasized the need for traditional teaching methods to incorporate more opportunities for student participation and input.

Comments from this group included:

> *"The teacher thoroughly explained the issues that students didn't understand."*
> *"When students couldn't find the answer themselves, the teacher wrote the answers on the board."*

DISCUSSION

The findings of this study provide strong evidence that the use of computer-based simulations in teaching DC circuits enhances students' academic achievement and positively influences their attitudes towards learning. The results from the pre-test and post-test comparisons indicate a significant improvement in the experimental group's performance compared to the control group, reinforcing the effectiveness of simulations as a pedagogical tool.

The statistically significant difference in post-test scores between the experimental and control groups underscores the impact of simulation-based learning on academic performance. Students in the experimental group who engaged with interactive simulations demonstrated higher comprehension and retention of DC circuit concepts. This aligns with previous studies (Çelik, 2022; Marczynski et al., 2022) that emphasize the role of simulations in facilitating active learning, hypothesis testing, and immediate feedback, which contribute to deeper understanding and better academic outcomes. Moreover, the ability of students to manipulate variables and visualize abstract electrical phenomena within a simulated environment likely contributed to their improved performance. Studies by Guzman et al. (2011) and Mhamed et al. (2021) corroborate these findings, showing that simulations enable students to observe real-time effects of parameter changes in circuit configurations, reinforcing theoretical knowledge through experiential learning.

Beyond academic achievement, the study revealed that students in the experimental group exhibited significantly more positive attitudes toward learning physics than those in the control group. The increased engagement, motivation, and confidence associated with interactive simulations align with findings from previous research (Abdel-Maksoud, 2019; Daniel & Juma, 2023). The safe, non-threatening environment provided by simulations allowed students to experiment freely without fear of failure, fostering a growth mindset and curiosity-driven learning. Traditional instructional methods, while effective in conveying fundamental concepts, often rely on passive learning strategies such as lectures and textbook-based instruction. The results suggest that these methods may not be as effective in sustaining student interest and engagement, a conclusion also drawn by Golder (2018) and Savelsbergh et al. (2016). The significant difference in attitude scores between the experimental and control groups highlights the role of interactive technology in shaping student perceptions and enthusiasm toward complex physics topics.

The results of this study support the integration of computer-based simulations into physics curricula to enhance student learning experiences. Given that both experimental and control groups demonstrated improvement, it is evident that traditional instruction still has educational value. However, the superior gains in the experimental group suggest that supplementing conventional teaching with simulations can lead to more significant academic and attitudinal benefits. Educators should consider leveraging simulations as a complementary tool, particularly for topics involving abstract or complex concepts, such as electric circuits. Simulations effectively bridge theory and practice, allowing students to develop a more intuitive understanding of physical principles. Moreover, integrating simulations in classroom instruction could address logistical and financial constraints associated with physical laboratory experiments, as highlighted by Shih and Kuo (2021).

CONCLUSION

This study highlights the significant potential of computer-based simulations as an effective tool for enhancing academic achievement and attitudes toward learning in physics education, particularly in teaching DC circuits. The findings demonstrate that students who engaged with simulations outperformed their peers in traditional learning environments, achieving higher post-test scores and exhibiting more positive attitudes toward the subject. These results align with existing literature, which emphasizes the ability of simulations to improve conceptual understanding, problem-solving skills, and overall engagement in science education. The interactive and visual nature of simulations allows students to explore abstract concepts, such as current flow, voltage, and resistance, dynamically and engagingly. This approach not only deepens students' understanding but also fosters curiosity, confidence, and motivation, as evidenced by the experimental group's higher attitude scores. By providing a safe and non-threatening environment for experimentation, simulations reduce anxiety and encourage students to approach challenging topics with greater enthusiasm. Moreover, the study underscores the importance of addressing students' perspectives and attitudes toward physics, which are often shaped by the perceived difficulty of the subject. By integrating simulations into the curriculum, educators can create a more inclusive and supportive learning environment that promotes positive attitudes and sustained interest in science. This is particularly crucial in overcoming the barriers that hinder students' academic progress and future engagement in STEM fields.

However, implementing simulations successfully in education requires addressing challenges such as teacher training, access to technology, and alignment with curriculum objectives. Educators should have the skills and resources to effectively integrate simulations into their teaching practices, while schools and policymakers must prioritize investments in technological infrastructure and professional development programs. Computer-based simulations represent a powerful and transformative tool for modern physics education. By enhancing academic achievement and attitudes toward learning, simulations can be pivotal in fostering a deeper understanding of complex concepts and preparing students for success in an increasingly technology-driven world. Future research should explore the long-term impact of simulations on students' academic trajectories and investigate strategies for scaling their implementation across diverse educational contexts. Policymakers, educators, and stakeholders must work collaboratively to harness the full potential of simulations, ensuring that all students have access to innovative and effective learning opportunities.

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