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Research Article

Utilization and Evaluation of Virtual Reality and Simulations in Teaching-Learning Direct Current Circuits

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Abstract

This study evaluates the effectiveness of integrating Virtual Reality (VR) and simulation in teaching direct current (DC) circuits. VR and simulation provide interactive spaces for students to learn, manipulate components, and conduct experiments, thereby enhancing motivation and engagement. The study employs a quasi-experimental design with control and experimental groups. The participants were assessed through pretests and posttests. Pretest results of both groups reveals no significant difference which suggests similar baseline abilities and level of knowledge in relation to DC circuits. The pretest and posttest results showed a significant difference which suggest that after the intervention, both groups showed a significant improvement in their knowledge of Direct Current Circuits. However, posttest results also showed a marked improvement of the experimental group using VR and simulation compared to the control group, supporting the effectiveness of integrating VR and simulation in teaching DC circuits. This suggests that VR and simulation can be valuable resources in instructional delivery, facilitating a deeper understanding and mastery of electrical concepts.

Keywords: Virtual Reality, Physics Education, Teaching-Learning, Effectiveness, Circuits

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INTRODUCTION

Direct current is essential in teaching electricity and magnetism. However, learning this branch of Physics requires learners to have a profound knowledge about the fundamentals of physics. Students find Physics difficult because they must contend with different representations such as experiments, formulas and calculations, graphs, and conceptual explanations at the same time (Ornek et al.,2008). According to PISA, although students express interest in science topics and recognize that science plays an important role in the world, their performances are not excellent, and greatly depend on how science is taught in their schools (Bigozzi et al., 2018). Hussain et al. (2011) stated that teaching of Physics suffers due to limited resources, equipment, and latest physics books. Technology has become an integral aspect of education, driving major changes in the way learning is approached, communicated, and understood (Kalyani, Dr. L. K.,2024). Learning management systems (LMSs) and digital learning materials offer the possibility to improve traditional classroom environments, thus making learning environments more effective (Garrison & Anderson, 2003). Virtual reality is a technology that has been well-received, being successfully applied in the field of education (Radiantia et al., 2019).

For many years, laboratory activities have been regarded as an important and almost sacred part of science education. Laboratory experiences have been purported to promote central science education goals including the enhancement of students' understanding of concepts in science and its applications; scientific practical skills and problem-solving abilities; scientific ‘habits of mind’; understanding of how science and scientists work; interest and motivation (Hofstein & Mamlok-Naaman, 2007). Major benefits of this activity-based learning are that it makes the subject matter more comprehensible, minimizes forgetting, and is more likely to lead to transfer of knowledge and acquire favorable attitudes toward a particular subject and toward learning in general (Aladejana & Aderibigbe, 2007). In this time where digital materials have been integrated in teaching, many online digital tools such as virtual reality and simulations can be used.

The use of virtual reality in education has enabled the possibility of representing abstract concepts and virtually manipulating them, providing a suitable platform for understanding mathematical concepts and their relationship with the physical world (Campos et al., 2022). The use of VR is to increase the intrinsic motivation of students, and refer to a narrow range of factors such as constructivist pedagogy, collaboration, and gamification in the design of their experiences (Banfield, J., & Wilkerson, B.,2014). According to Marougkas, A., et al. (2023), learners can interact with their peers and the virtual environment, making the experience more active. It can additionally offer students a personalized learning experience by allowing them to explore the virtual world at their own pace and in the way they prefer. Students can improve their comprehension of the subject matter by using VR technology to deliver personalized feedback (Alnafiei et al.,2024).

VR is widely used in many fields because it is realistic, low cost, easy to implement, repeatable, and not bound by time and space (Guan et al., 2022). Moreover, it gives reality experiences that can be used to create even more exciting, engaging, and realistic learning setups to conduct experiments and work with simulations (Mikropoulos, T. A., & Natsis, A., 2010). Through this, VR can help improve the learning experiences of students, as well the teacher to facilitate and manipulate the device. However, there are some challenges in using VR. Scaverelli et al. (2017), as cited in Van Der Meer et al., (2023) presented that accessibility should be considered a primary concern and they recommend exploring the interplay and connectivity between virtual environments (VEs) and the real world, as doing so could reveal new learning theories that innovate VRCL. According to Zheng et al. (2020), as cited in Van Der Meer et al., (2023), research should focus on pedagogical strategies involving VRCL, including how to apply VR to educational settings involving collaboration. They propose a focus on finding a balance between using VRCL to recreate (or simulate) existing (“real”) situations and creating new situations that would normally be impossible, considering that prior work has primarily been centered on the former and as such misses out on VR's potential to do the latter. Overall, results show that virtual laboratories seem to be as effective as or more effective than physical ones for acquiring conceptual knowledge (Bailenson et al., 2008).

The main goal of the study is to determine the effectiveness of VR and simulation in teaching-learning Direct Current Circuits in Senior High School. With the continuous advancement of technology, it is highly probable that VR will become an essential component of the education system, offering students a potent means to amplify their learning (Marougkas et al., S2023). As time goes by, the development of technology becomes more advanced, thus it needs to be utilized and integrated into the teaching-learning process. It is very crucial for teachers in science to master and integrate the purpose of technology. The use of VR helps both teachers and students to engage and incorporate digital and physical environments.

RESEARCH METHOD

Research Design

This study employed a quasi-experimental research design to evaluate the impact of Virtual Reality (VR) and simulation-based learning on students' understanding of Direct Current (DC) Circuits. The research involved two groups: a control group and an experimental group. The control group learned about DC circuits through traditional teaching methods, including class lectures, textbook-based instruction, and problem-solving exercises. On the other hand, the experimental group received instruction integrating VR and simulation tools, providing an interactive learning experience designed to enhance conceptual understanding and engagement.

To evaluate the effectiveness of VR and simulation interventions, a pretest-posttest approach was utilized. Before the instruction, a pretest was administered to both groups to establish their baseline knowledge. Following the instructional intervention, a posttest was given to measure the learning gained by the students in each group. The collected data were subjected to statistical analysis to determine the impact of VR and simulation on student learning outcomes. Descriptive statistics were used to summarize the results. At the same time, inferential statistical tests such as t-tests and Analysis of Variance (ANOVA) were applied to evaluate significant differences in performance between the two groups. Additionally, qualitative feedback from students in the experimental group was gathered to assess their engagement levels and perceived effectiveness of VR and simulation-based learning. This mixed-method approach ensured a comprehensive evaluation of the instructional intervention, contributing valuable insights into the role of emerging technologies in STEM education.

Research Target/Subject

The subjects of this study consisted of Grade 8, with a particular focus on the physics of the Grade 8 science curriculum. The intact group sampling method was employed to maintain the natural classroom setting while ensuring a structured and unbiased selection process. To enhance the reliability of the findings, the composition of each group was randomized to distribute potential variations in academic abilities evenly.

Furthermore, the assignment of students to either the experimental or control group was conducted through a random selection process to ensure comparability between the two groups. This randomization assumed that both groups were equal in terms of academic performance before the intervention. By implementing this approach, the study aimed to minimize selection bias and enhance the validity of its conclusions regarding the effectiveness of VR and simulation in learning Direct Current Circuits.

Research Procedure

Written informed consent was obtained from all study participants. A pretest was administered to both the control and experimental groups. The teacher then delivered instruction on Direct Current Circuits, using traditional teaching methods for the control group and VR and simulation-based instruction for the experimental group. Following the intervention, a posttest was conducted to evaluate learning gains. The collected data were then analyzed and interpreted.

Instruments, and Data Collection Techniques

The study utilized validated pretest and posttest questionnaires to assess students' knowledge before and after the instructional intervention involving Virtual Reality and Simulations. These instruments were adapted and validated to ensure reliability and accuracy in measuring student learning outcomes.

Data Analysis Technique

To ensure the accuracy of statistical interpretation, Shapiro-Wilk's Normality Test and Levene's Homogeneity of Variances Test were conducted to determine whether the data followed a parametric or non-parametric distribution. Since the results indicated that the data were non-parametric, the Mann-Whitney U Test was employed to assess whether there was a significant difference between the control and experimental groups.

RESULTS AND DISCUSSION

The results of this study provide valuable insights into the effectiveness of virtual reality (VR) and simulation-based interventions in teaching Direct Current Circuits to Senior High School students. This section presents a detailed analysis of the data gathered from the pretest and posttest assessments of both the control and experimental groups. The statistical tests applied Normality Testing, Homogeneity of Variances Testing, and Mann-Whitney U Test revealed significant differences in the posttest scores, highlighting the impact of VR and simulation on students' conceptual understanding of electricity and magnetism. In this section, we will discuss the findings in relation to existing literature and explore the implications of these results for the future integration of technology in science education. Additionally, we will address the potential challenges and benefits of incorporating VR and simulation into the classroom to enhance students' learning experiences and academic outcomes.

The pretest and posttest of the subjects was subjected to Shapiro-Wilk's Normality test. The pretest of the control group and experimental group resulted in a p-value of .024, while the posttest of both groups resulted in a p-value of .005. Both results are less than the significance level ($\alpha = 0.05$). The low p-values suggest that the data does not follow a normal distribution which indicates a violation of the normality assumption. This is consistent with previous studies showing that non-parametric tests are needed when normality is violated (Field, 2013).

Table 1. Normality Test Results

Normality Test (Shapiro-Wilk)	p-value
Pretest	0.024
Posttest	0.005

Then, the pretest and posttest scores of the subjects was subjected to Levene's Homogeneity of Variances Test. The pretest of both groups resulted in a p-value of .377, while the posttest of both groups resulted in a p-value of .103. Both scores are greater than the significance level ($\alpha = 0.05$). These results suggest that the assumption of equal variances is met for both the pretest and posttest scores. According to Levene's test, the homogeneity of variances is not violated. These implies that variance is similar across both groups (Levene, 1960).

Table 2. Homogeneity of Variances Test Results

Homogeneity of Variances Test (Levene's)	p-value
Pretest	0.377
Posttest	0.103

Afterwards, the pretest and posttest scores of the subjects were subjected to Mann-Whitney U Test. The pretest scores of both groups have a Mann-Whitney U score of 305.00 and a p-value of .097, which is greater than the significance level ($\alpha = 0.05$). This implies that the subjects in both groups before the intervention have no significant differences in their knowledge. It suggests that they are of the same ability level. According to Willson & Putnam (2024), the similarity in pretest scores is crucial for evaluating the effectiveness of interventions like VR and simulation. This is because it ensures that any posttest differences can be attributed to the intervention rather than pre-existing differences between the groups.

Table 3. Mann-whitney u test results of pretest scores

	Mann-Whitney U	p
Pretest	305.00	0.097

The pretest and posttest results in the Mann-Whitney U Test is compared. The pretest scores of the subjects have a Mann-Whitney U score of 305.00 and a p-value of 0.097 which is greater than the significance level ($\alpha = 0.05$). This suggests that the pretest scores of the subjects have no significant differences, suggesting that the subjects are of the same ability and level of knowledge. The posttest scores of the subjects have a Mann-Whitney U score of 86.50 and a p-value of <0.001 which is less than the significance level ($\alpha = 0.05$). This suggests that after the intervention, both groups showed a significant improvement in their knowledge of Direct Current Circuits.

Table 4. Mann-whitney u test score for pretest and posttest scores

	Mann-Whitney U	p
Pretest	305.00	0.097
Posttest	86.50	<0.001

The posttest scores of the subjected which was subjected to Mann-Whitney U Test had a Mann-Whitney U score of 86.50 and a p-value of <0.001 which is less than the significance level ($\alpha = 0.05$). A low p-value indicates that the null hypothesis should be rejected. Also, the low p-value implies that there is a significant difference in the posttest scores of the experimental and control group. This suggests that after the intervention, the experimental group that received VR and simulation-based teaching showed a significant improvement in their knowledge of Direct Current Circuits compared to the control group. Studies have demonstrated that VR-based interventions can significantly enhance conceptual understanding and engagement in science education (Mikropoulos & Natsis, 2011).

Table 5. Mann-whitney u test score for posttest scores

	Mann-Whitney U	p
Posttest	86.50	<0.001

After the scores of the experimental and control group were subjected to different test and data were analyzed, the hypothesis is accepted: there is significant difference in the integration of VR and simulation in teaching-learning Direct Current Circuits in Senior High School. Therefore, it is concluded that the integration of VR and simulation in teaching-learning Direct Current Circuits is effective. These findings align with those of previous studies that suggest that virtual laboratory simulations are more effective than traditional learning methods (Bailenson et al., 2008).

Virtual laboratory simulations have been proven to be more effective than traditional lab methods. A literature review found that integrating simulations improves students' and pre-service teachers' conceptual understanding of science, as simulations provide learners with opportunities to grasp difficult concepts experimentally (Bailenson et al., 2008). In teaching modern physics, interactive simulations have been successful in improving students' creative problem-solving and critical thinking skills (Candido et al.,2022).

Moreover, studies have shown that alternative teaching methods in electricity and magnetism, such as VR and simulation, can greatly aid in delivering learning to science students. VR laboratories have been found to help students understand complex concepts in electricity and magnetism (Rendon et al.,2022). Additionally, VR technology has proven to be effective in various educational fields, including software engineering, where students using VR achieved 12% better results on average (Akbulut et al., 2018). These findings support the use of VR in science education to enhance learning outcomes.

Studies also suggest that VR and simulation laboratories can be as effective as, or better than, hands-on activities. VR allows students to visualize and understand the mechanisms behind experiments, which is particularly beneficial in abstract subjects like electricity and magnetism (Rendon et al.,2022). Furthermore, VR has been shown to improve nursing students' knowledge in healthcare education (Chen et al., 2020), and simulation-based learning has been found to be effective for medical students learning clinical skills (Ziv et al.,2003).

The findings from the statistical analyses of the data provide strong evidence for the effectiveness of virtual reality (VR) and simulation-based interventions in teaching Direct Current Circuits. The results from the Normality and Homogeneity of Variances Tests indicate that the data was non-parametric, which led to the use of the Mann-Whitney U test to analyze the differences between the control and experimental groups. The significant difference in posttest scores ($p < 0.001$) between the groups suggests that the experimental group, which was exposed to VR and simulation-based teaching, demonstrated a notable improvement in their understanding of Direct Current Circuits. This improvement can be attributed to the immersive and interactive nature of VR, which has been shown to facilitate deeper learning and engagement with complex scientific concepts (Mayer, 2009).

The findings align with previous research that highlights the advantages of VR and simulation in enhancing science education. Virtual laboratories allow students to visualize and manipulate abstract concepts that are often challenging to understand through traditional teaching methods. As demonstrated by Mikropoulos and Natsis (2011), VR-based learning experiences enable students to interact with scientific phenomena in ways that enhance their conceptual understanding. Additionally, studies have shown that VR and simulations can improve students' problem-solving skills, critical thinking abilities, and overall academic performance (Bailenson et al., 2008). Given these advantages, it is clear that VR and simulations can play a pivotal role in modernizing science education, making learning more engaging, accessible, and effective (Mercado et al., 2024).

However, despite the demonstrated effectiveness of VR and simulation-based teaching, their integration into the classroom remains limited in many educational settings. The results of this study suggest that while VR has the potential to revolutionize science education, further efforts are needed to ensure its widespread adoption. Barriers such as cost, access to technology, and teacher training may hinder the full integration of VR in schools. As noted by studies in various fields (Chen et al.,2020), the successful application of VR in education requires careful planning, adequate resources, and ongoing support for educators. Therefore, future research should focus on overcoming these barriers and exploring the long-term effects of VR-based learning on student achievement and motivation.

In conclusion, VR and simulations are now replacing traditional lab practices. Although the effectiveness of these methods has been well-documented, they are still rarely used in science classrooms. This study recommends further integration of VR and simulation into science teaching to enhance student engagement and learning outcomes.

CONCLUSION

The study used a quasi-experimental design involving pretest and post-test measurements to evaluate the effectiveness of VR and simulation. The goal was to see if virtual reality (VR) and simulation helped students learn better than normal teaching styles. The results showed that students who learned with VR and simulation did much better at understanding electric circuits compared to those who learned the old way. VR and simulation allowed for interactive and engaging learning. Students could see concepts that are hard to picture and play with them virtually. These findings suggest that using VR and simulation in physics classes can help students understand, stay motivated, and have a better overall experience learning the subject. This shows that technology tools like VR have the pote-ntial to make science education more effective, especially for complex topics like electricity and magnetism.

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AUTHOR CONTRIBUTIONS

Kashmera A. Sinolinding: Conceptualization; Project administration.
John Paul Arca:Validation; Writing - review and editing.
Christine Mae Dionela: Conceptualization.
April Joy Lamput: Data curation: In-vestigation.
Jessel James Paez: Data curation; Investigation.
Rustria Apellanes: Formal analysis; Methodology.
April Joy Lamputi: Writing - original draft.
Yvonne Bedano: Supervision; Validation.
Roevela Ren Sales: Other contribution; Resources;
Justine C. Mercado: Visuali-zation; Writing - original draft.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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