

CONTEXTUALIZED PHET SIMULATION AS AN INSTRUCTIONAL MATERIAL IN TEACHING ELECTRICITY

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ABSTRACT

This study utilized a quasi-experimental and descriptive-correlation research design to evaluate the effectiveness of a contextualized PHET simulation for teaching electricity to 52 Grade 8 students at Caridad National High School. Participants were divided into a control group that received traditional instruction and an experimental group that engaged in the simulation. Pre-tests and post-tests were administered to assess learning outcomes, while an adapted 15-item survey evaluated the experimental group's perceptions of the simulation's efficacy. Results demonstrated a significant increase in post-test scores for the experimental group, indicating an enhanced understanding of electrical concepts. Additionally, a strong positive correlation was identified between students' perceptions and their post-test scores, implying that higher engagement with the PHET simulation positively influenced academic performance. These findings underscore the potential of interactive simulations to enhance instructional effectiveness in STEM education and reinforce the importance of favorable student perceptions as a crucial element of learning success. Consequently, the use of the developed contextualized PHET simulation is highly recommended.

Keywords: Contextualized, PHET Simulation, Control Group, Experimental Group, Caridad National High School

1. INTRODUCTION

In education, the pursuit of scientific knowledge is more than a subject in a curriculum; it is the gateway to fostering critical thinking, problem-solving, and curiosity-driven learning (Perkins et al., 2020). To empower the next generation of thinkers and innovators, it is essential to equip them with theoretical knowledge and practical skills that enable them to explore the natural world in a hands-on and engaging manner (Guy & Lownes, 2019). The implementation of interactive and technology-driven tools in the classroom can be a transformative approach to achieving this goal (Vries & May 2019).

Moreover, The Caraga Regional Memorandum No. 0035, s. 2024, identifies earthing and grounding as one of the least learned competencies among students, underscoring the need for improved instruction on these topics. This issue became even more critical after a tragic incident at Caridad National High School, where a student was severely injured due to improper grounding of electrical equipment during a school event. To address these gaps in understanding and enhance safety, the incorporation of PhET simulations into teaching practices offers a dynamic and interactive solution. PhET simulations allow students to visualize the flow of electrical currents, the effects of grounding, and the dangers of improper earthing in a controlled virtual environment. This approach bridges the gap between theoretical knowledge and practical application, ensuring students gain a deeper understanding of electrical grounding principles while minimizing exposure to physical risks, thereby promoting safer practices in handling electrical systems.

2. METHODOLOGY

Research Design

This study used a quasi-experimental and descriptive-correlation research design to assess the effectiveness of a contextualized PHET Simulation in teaching electricity. Participants were assigned to a control group using traditional instruction and an experimental group using the simulation. Both groups completed pre-tests and post-tests to compare learning outcomes. The experimental group answered a validated 15-item survey to measure their perceptions of the instructional material's efficacy.

Research Participants

The participants of the study were 52 Grade 8 students from Caridad National High School, selected using a combination of purposive and stratified sampling methods. Purposive sampling was employed to specifically target students based on their performance in science, while stratified sampling ensured that each group—control and experimental—contained an equal mix of high- and low-performing students. This approach ensured a balanced comparison between the two groups for evaluating the effectiveness of the contextualized PHET Simulation.

Research Instrument

The research instrument for this study included a 20-item multiple-choice questionnaire on electricity to assess students' knowledge and understanding of the subject matter. A 4 A's lesson plan (Activity, Analysis, Abstraction, and

Application) was utilized to guide the instructional process, ensuring a structured approach to teaching. To evaluate students' perceptions of the contextualized PHET Simulation's effectiveness, the experimental group completed an adapted 15-item survey questionnaire. This survey was designed to capture responses based on a 4-point Likert scale, measuring the level of agreement with statements regarding the instructional material's impact on their learning experiences.

Data Gathering Procedure

This study involved several systematic steps to ensure the reliability and validity of the findings. Initially, a permission letter was addressed to the school principal of Caridad National High School to conduct the study, allowing access to the Grade 8 students. Informed consent was then obtained from all participants and their guardians prior to participation. The 20-item multiple-choice questionnaire on electricity was administered to both the control and experimental groups as a pre-test before the intervention to establish baseline knowledge. Following the instructional period, which utilized the 4 A's lesson plan for the experimental group, both groups completed a post-test to evaluate changes in learning outcomes. Subsequently, only the experimental group was asked to complete a validated 15-item survey questionnaire designed on a 4-point Likert scale, to assess their level of agreement regarding the effectiveness of the contextualized PHET Simulation. Additionally, experts were consulted to validate the survey questionnaire, ensuring its relevance and accuracy. Data were then collected, organized, and analyzed to derive insights into the educational impact of the instructional methods employed.

Data Analysis

Frequency counts and percentages were used to summarize the pre-test and post-test scores of the students, providing an overview of performance trends. The mean and standard deviation were calculated to analyze the perceptions of the students based on their responses to the validated survey questionnaire. A t-test was employed to determine the significant difference between the pre-test and post-test scores, allowing for an assessment of learning gains attributable to the instructional methods. Additionally, Pearson's correlation coefficient was utilized to assess the significant correlation between the students' perceptions and their post-test scores, providing further insights into the relationship between their attitudes towards the instructional material and their academic performance.

3. RESULT AND DISCUSSION



Figure 1: Mechanics of the Application

The PHET Simulation app for Earthing and Grounding is an interactive tool designed to demonstrate the concept of electrical circuits in different grounded and ungrounded states as shown in figure 1. The process starts with opening the application and selecting one of three scenarios: a bulb circuit, a washing machine circuit, or a household circuit. For each scenario, the user begins by clicking the "eye" button to visualize the flow of electric charge in the circuit when grounded. In the bulb circuit, users can cut wires using the "scissors" button to observe changes in the current flow and switch to non-grounded states with the green arrow for comparison. Similarly, in the washing machine circuit, users interact by clicking the boy to simulate the impact of touching an appliance under grounded conditions and toggling between grounded and non-grounded states to observe safety differences. The household circuit enables users to click on various appliances and observe how earthing ensures safe current flow. This step-by-step approach allows users to explore the significance of grounding and its effects on circuit behavior visually and interactively.

The advantage of this simulation lies in its ability to make abstract concepts tangible, enhancing users' understanding of earthing and grounding. According to Choi and Ghim (2022), simulations provide dynamic visualizations that promote active learning and deepen comprehension of scientific concepts. By allowing users to switch between grounded and non-grounded scenarios, the app demonstrates the practical importance of grounding in ensuring electrical safety, particularly in household and industrial circuits. This aligns with the findings of Lopez et al. (2021), who highlighted those interactive simulations significantly improve learners' conceptual understanding by offering an experiential approach to physics education. The PHET app, thus, not only simplifies complex electrical phenomena but also bridges theoretical knowledge with real-world application, making it an effective educational tool.

Table 2: Significant Difference between the Pretest and Posttest Results

	T-test	df	p	Mean difference	Decision	Verbal Interpretation
Contextualized PHET Pretest vs. Posttest	23.2	25.0	.001	12.1	Reject H ₀	Significant
Lecture-Based Pretest vs. Posttest	15.2	25.0	.001	10.7	Reject H ₀	Significant

The results from Table 2 indicate a significant difference in the pretest and posttest scores for both the contextualized PHET and lecture-based groups, as evidenced by a T-test yielding p-values of .001 for both instructional approaches. For the contextualized PHET group, the mean difference of 12.1 suggests a dramatic improvement in students' understanding of the subject matter, while the lecture-based group also demonstrated a considerable gain with a mean difference of 10.7. The rejection of the null hypothesis (H₀) in both cases highlights that the instructional methods employed led to meaningful enhancements in students' knowledge and comprehension of electricity concepts. This significant improvement in learning outcomes aligns with the existing literature that supports active learning strategies, as these approaches have been found to facilitate deeper conceptual understanding and promote greater engagement among students (Freeman et al., 2020). While both teaching methodologies led to substantial improvements, the larger mean difference observed in the contextualized PHET group could further imply that the integration of interactive simulations fosters a more effective learning environment that promotes higher-order thinking skills. This suggests that educators should consider incorporating more interactive and contextualized learning experiences into curricula to maximize student achievement and better prepare them for applying their knowledge in real-world scenarios. These findings contribute to a growing body of evidence advocating for the adoption of innovative teaching strategies that significantly enhance student learning outcomes.

Table 3: Students' Perception on the Effectiveness of Contextualized PHET Simulation

Statement	Mean	SD	VI	QD
1. I find that the contextualized PHET simulation enhances my understanding of earthing and grounding concepts.	3.35	0.69	SA	VE
2. I feel more engaged in learning about series and parallel circuits when using the PHET simulation.	3.38	0.70	SA	VE
3. I believe the PHET simulation provides a realistic representation of electrical circuits.	3.42	0.76	SA	VE
4. I enjoy utilizing the PHET simulation to explore concepts related to electrical safety.	3.31	0.62	SA	VE
5. I am able to visualize the flow of electricity in circuits better through the PHET simulation.	3.31	0.74	SA	VE
6. I find the interactive elements of the PHET simulation useful in understanding circuit connections.	3.42	0.64	SA	VE
7. I feel that the PHET simulation allows me to experiment with circuits at my own pace.	3.38	0.75	SA	VE
8. I believe that using the PHET simulation has improved my ability to analyze circuits effectively.	3.38	0.70	SA	VE
9. I find that the PHET simulation enhances my retention of knowledge about earthing and grounding.	3.42	0.64	SA	VE
10. I believe the context provided in the PHET simulation makes learning about electrical concepts more relevant.	3.31	0.74	SA	VE

1. I feel more confident in my understanding of series and parallel circuits after using the PHET simulation.	3.31	0.74	SA	VE
I find it easy to understand complex electrical concepts through the PHET simulation.	3.42	0.70	SA	VE
I appreciate the feedback provided by the PHET simulation during circuit experiments.	3.46	0.65	SA	VE
14. I believe that the contextualized PHET simulation supports collaborative learning among my peers.	3.12	0.71	A	E
5. I feel motivated to learn more about electricity and circuits after using the PHET simulation.	3.38	0.75	SA	VE
Overall	3.36	0.70	SA	VE

	Scale	Verbal Interpretation	Qualitative Description
Legend	1 – 1.75	Strongly Disagree (SD)	Not Effective (NE)
	1.76 – 2.5	Disagree (DA)	Less Effective (LE)
	2.51 – 3.25	Agree (A)	Effective (E)
	3.26 – 4.00	Strongly Agree (SA)	Very Effective (VE)

The student's perceptions of the effectiveness of the developed contextualized PHET simulation in electricity provide valuable insights into its educational impact, emphasizing its role in enhancing learning experiences. Overall, the mean score of 3.36 reflects a favorable response, categorizing the simulation as "Strongly Agree" (SA) and "Very Effective" (VE) in promoting understanding of electrical concepts. Notably, the statement with the highest mean (3.46) pertains to the appreciation of feedback provided by the PHET simulation during circuit experiments, underscoring the importance of immediate feedback in the learning process. Hattie & Timperley (2019) support this result which highlights that timely feedback can significantly enhance student motivation and comprehension. Conversely, the statement with the lowest mean (3.12) regarding the simulation's support for collaborative learning among peers indicates a potential area for improvement in facilitating group interactions. This finding suggests that while the simulation effectively promotes individual understanding, it may not fully leverage social learning opportunities, as collaborative activities have been shown to deepen understanding and foster a supportive learning environment (Johnson & Johnson, 2019).

Participants also indicated a strong perception that the simulation improved their understanding of concepts such as earthing and grounding (3.35) and engagement in learning about series and parallel circuits (3.38), further supporting the effectiveness of interactive simulations in providing a deeper and more meaningful educational experience (Chiu, 2018). These insights imply that integrating such simulators in curricula can enhance students' conceptual grasp of complex topics. However, to maximize the efficacy of the PHET simulations, educators may need to incorporate structured collaborative elements alongside the individual explorations facilitated by the simulation. The positive perceptions highlight the potential of contextualized simulations as transformative tools in STEM education, driving not only content comprehension but also student engagement and motivation.

Table 4: Significant Correlation between the Students' Perception and Their Scores

Factors linked to	Pearson r	p-value	Decision on HO	VI
Students' Perception to the Pretest Scores	0.44	0.35	Accept Ho	Not Significant
Students' Perception to the Posttest Scores	0.78*	0.01*	Reject Ho	Significant
Overall	0.61*	0.01*	Reject Ho	Significant

*Correlation is significant at the 0.01 level

The findings indicate a nuanced relationship between perception and academic performance. Notably, the Pearson correlation coefficient for students' perception concerning pretest scores is 0.44 with a p-value of 0.35, leading to the acceptance of the null hypothesis (Ho) and indicating no significant correlation. This outcome suggests that students' perceptions prior to engaging with the simulation did not substantially influence their initial understanding of electrical concepts, which may be attributed to a lack of previous exposure to the content or inherent challenges in measuring perception before the learning experience.

In contrast, the correlation between students' perception and posttest scores yields a significantly stronger relationship, with a Pearson r of 0.78 and a p -value of 0.01. As the null hypothesis is rejected, this indicates a robust positive correlation between the students' perception of the PHET simulation's effectiveness and their posttest performance. This finding suggests that students who perceive the simulation as effective are more likely to achieve higher scores, which aligns with educational research emphasizing the importance of student engagement and positive perceptions in fostering academic success (Bryson & Hand, 2019). Essentially, it highlights that an enriching learning environment, as perceived by students, can have a substantial impact on their understanding and retention of complex concepts.

Furthermore, the overall correlation of 0.61 with a p -value of 0.01 further supports the significance of the relationship between perception and performance, indicating that students' overall perceptions of the simulation positively contribute to their learning outcomes. Higher scores on the posttests correlate with favorable perceptions, suggesting that positive engagement with the simulation not only enhances understanding but also fosters a more positive learning environment. These findings carry vital implications for instructional design. Enhancing student perceptions through targeted simulations could lead to improved learning outcomes, underscoring the necessity for educators to focus on the quality of learning experiences. This data underscores the critical interplay between students' perceptions of educational tools and their performance, advocating for methodologies that actively consider and cultivate favorable perceptions within learning environments.

4. CONCLUSION

The significant improvement in learning outcomes, as demonstrated by pretest and posttest results, along with the strong correlation between students' perceptions and posttest scores, underscores the effectiveness of the contextualized PHET simulation. Positive engagement with the simulation not only enhances understanding of electrical concepts but also suggests that fostering favorable perceptions can lead to improved academic performance in STEM education.

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