Journal of Science and Education (JSE)
Vol. 2, No. 2, 2022, 88-98

DOI: 10.56003/jse.v2i2.101
ISSN: 2745-5351

PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students

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Received: 12 January 2022 Accepted: 20 March 2022 Published: 31 March 2022

Abstract: By boosting students' thinking and understanding of hard ideas, innovative teaching pedagogies help them better comprehend difficult subjects in Physics. This study aimed to assess the students' conceptual knowledge in electricity and magnetism and their perspectives on the effects of the Phet Simulation Approach in teaching the said concepts. It utilized educational action research design with assessment-tests and a structured-interview guide as the main instruments in gathering the required data. There are 14 science teacher education students whose taking electricity and magnetism as their major subject served as participants. The assessment-test is composed of the traditional assessment test or multiple-choice test composed of 60 questions. The structured-interview guide contains one question, "What are the effects of Phet Simulation Approach in learning Electricity and Magnetism?" The results have revealed that the conceptual knowledge in Electricity and Magnetism improved to very satisfactory after the application of intervention. There is a significant difference in the assessment scores between pre-test and posttest. Six themes emerged from the students' perspectives on the effects of the intervention, including (a) better understanding; (b) learning through visualization; (c) learning became fun; (d) promotes self-facilitation of learning; (e) provides a broader range of options; and (f) grasping the micro-scale concepts. The study concludes that PhET Simulation Approach is an effective teaching strategy in electricity and magnetism. Further, the strategy is positively accepted by the students based on the qualitative data.

Keywords: Phet smulation, electricity and magnetism, science teacher education.

How to cite: Dantic, M.J.P., & Fularon, A.R. (2022). PhET interactive simulation approach in teaching electricity and magnetism among science teacher education students. *Journal of Science and Education (JSE), 2(2): 88-98.* https://doi.org/10.56003/jse.v2i2.101

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INTRODUCTION

According to Rogayan and Dantic (2021), science education is vital for societal progress, particularly in designing and implementing policies and guidelines. The entire pedagogical techniques to which teachers and students were previously used have shifted. Many of our established pedagogies are ineffective, so novel and practicable pedagogies should be explored and implemented (Dantic, 2021).

Bao and Koenig (2019) also emphasized that the new educational standards place a premium on higher-order abilities such as logic, creativity, and open problem-solving. Additionally, they stressed the ongoing evolution of (STEM) disciplines. The constructivist method now in use enhances cognitive challenge and course standards (Chang, 2008).

Physics should be taught in constructivist manner. Because this discipline is critical for comprehending the world in which we live, the world within us, and the world beyond us. Although it is the most fundamental and foundational science, it really is one of the most challenging courses in school.

According to a study, "common sense" concepts are incompatible with sound physics. Regrettably, these erroneous beliefs are ingrained in students' minds and are difficult to escape (Freedman, 2000).

As a result, physics educators should engage students in inquiry, discovery, demonstration, modeling, practical work, laboratory experiences, and other hands-on activities to transmit knowledge about physics. Physicists must understand topics through physical, visual, and mathematical representations and models since physics is a theoretical science (Lamina, 2019). It was discovered by Hou et al. (2021) that practicing and utilizing computer software simulations had assisted in the improvement and advancement of academic performance in physics. The use of PhET Interactive Simulations (sims) in the teaching of physics, including electricity and magnetism, is becoming increasingly popular. Sims can be utilized in various educational situations, including lectures, individual or small group inquiry activities, homework, and laboratory work, among others (Wieman et al., 2010). Using visualization to help students see processes and structures that are otherwise inaccessible to them is particularly effective in educational settings. For Electricity and Magnetism, these laboratory techniques can be made available so that learners can view the details or can perform experiments numerous times utilizing simulation-based activities (Batuyong & Antonio, 2018).

The last decade has seen a lot of research that shows that computer simulations can make training on the learning benefits of computer simulations in science education more effective (Rutten, van Joolingen, & van der Veen, 2012). Students learn like a scientist if they predict what will happen with things in a certain situation, then look into what actually happens in that situation, and then make conclusions about why the thing formed in that way (Van Joolingen, De Jong, & Dimitrakopoulou, 2007).

Thus, using PHET simulations to teach physics, namely electricity and magnetism, may be beneficial. Mbonyiryivuze, Yadal and Amadalo (2019) report that students continue to struggle with electricity and magnetism concepts. There have been proposals for educational approaches based on conceptual change. Misconceptions persist even when well-established instructional strategies are utilized. Perhaps the PHET simulation approach can help eliminate such misconceptions and pave the way for actual learning.

This study aimed to investigate the effects of PHET Interactive Simulation Approach in teaching electricity and magnetism based on the assessment scores and narrative perspectives among BSED Science Students.

Theoretical Framework

Simulation-based education is a form of education or training that aims to "replace or augment real-world experiences with guided encounters" (Gaba, 2004). It is critical to include simulation into the curriculum at this point. Today, simulation enables pupils to acquire new skills and strengthen their ability to reason (Aebersold, 2018).

Constructivism is predicated on the notion that individuals actively construct or create their knowledge and that experiences determine reality as a learner (Western Governor's University, 2020). Constructivism is a pedagogical paradigm that asserts that individuals actively construct or create their individual understanding and that actuality is influenced by the learner's experiences (Elliott et al., 2000). Contrary to traditional education, constructivist learning theory underpins many student-centered teaching methods and practices, whereby knowledge is passively transmitted by teachers to students (McLeod, 2019).

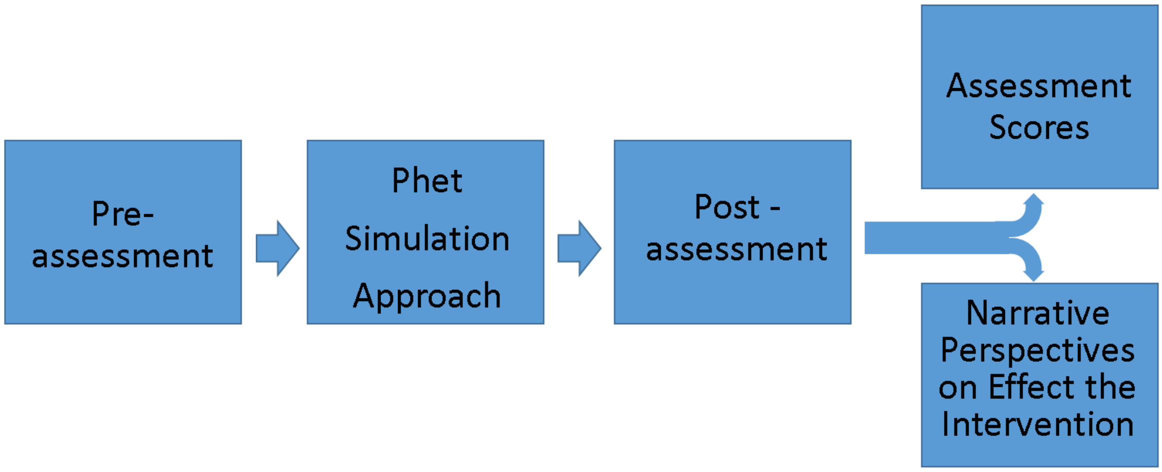

Fig. 1. Theoretical Paradigm of the study

METHOD

The study has utilized educational action research design with assessment tests and a structured interview guide as the main instruments in gathering the required data. The present study assesses the student's conceptual in electricity and magnetism and their perspectives on the effects of Phet Simulation Approach in learning. The study used comprehensive sampling. There are 14 science teacher education students whose taking electricity and magnetism as their major subject that served as participants. The assessment test was validated by three experts, two physics teachers, and a professional education teacher. There are two types of the instrument was used to gather data, these are (a) assessment test and (b) structured interview guide. The assessment test is composed of the traditional assessment test or multiple-choice test composed of 60 questions. The structured interview guide is composed of one question "What are the effects of Phet Simulation Approach in learning Electricity and Magnetism?" The assessment scores in the pre-test and post-test were analyzed through T-test. The study checked if there are significant difference between the test scores. Also, the steps in thematic analysis of Braun and Clark (2019) were employed in identifying, analyzing, and reporting patterns (themes) within the data.

RESULTS AND DISCUSSION

Student's Level of Conceptual Knowledge before the Application of Intervention

The level of conceptual knowledge of science students in Electricity and Magnetism prior to the conduct of Phet Simulation approach was reflected by the result of their Pre-test.

The Pre-test was composed of Sixty (60) items. It was used in gathering information and identifying the strengths and weaknesses of STE students. It was administered to evaluate the level of students' domain of learning. Class scores were described using frequency distribution and percentages.

Table 1 shows the frequency and percentage distribution of the respondents scores in 60 items pre-test given by the researcher. Nine (9) participants, or 64% have fairly satisfactory conceptual knowledge. Five (5) participants or 36% of the class Satisfactory conceptual knowledge. The overall mean score is 24.28, with a standard deviation of 4.33. In summary, before the intervention, most of the students had a fairly satisfactory level of knowledge and still needed improvement.

Table 1. Frequency and Percentage Distribution of Participants' Score in the Pre-test

Scores	Frequency	Percent	Descriptive Rating
13.00 – 24. 00	9	64	Fairly Satisfactory
25.00 – 37. 00	5	36	Satisfactory
Total	**14**	**100**	
Level of Knowledge	SD = 4.33	Mean=24.28	Fairly Satisfactory

According to the study's findings conducted by Balfour and Khonle (2016), misinterpretations persist at higher educational levels, and new knowledge might well be absorbed into old beliefs without a significant shift in conceptual framework.

Student's Level of Conceptual Knowledge after the application of Intervention

The level of conceptual knowledge of STE students in Electricity and Magnetism after the conduct of Visual Arts Approach was reflected by the result of their Post-test. The Post-test was composed of Sixty (60) items. It was used in gathering information and identifying the strengths and weaknesses of SE students. It was administered to evaluate the level of students' domain of learning. Class scores were described using frequency distribution and percentages.

Table 2 shows the frequency and percentage distribution of the participants' scores in 60 items posttest given by the researcher. There are Six (6) participants or 43% considered very satisfactory, and eight (8) participants or 57% of the class, were Outstanding. The overall mean is 48.14 with a standard deviation of 5.04. In summary, after the intervention of strategy, most of the students had very satisfactory level of conceptual knowledge.

Table 2. Frequency and Percentage Distribution of Participants' Score in the Post-test

Scores	Frequency	Percent	Descriptive Rating
37.00 – 48.00	6	43	Very Satisfactory
49.00 – 60.00	8	57	Outstanding
Total	**14**	**100**	
Level Of Competency	**SD= 5.04**	**Mean=48.14**	**Very Satisfactory**

According to the findings of a study conducted by Buxner et al. (2018), educated consumers must have a strong basis in science knowledge as well as the ability to evaluate such knowledge. The concept of transferability and approachability is easier to grasp when one has a well-developed conceptual understanding of Physics. As a result, an individual can utilize the idea in a dynamic, creative, and technically sound manner across various disciplines or features (Dantic, 2021).

Significant Difference in the Student's Level of Analysis before and after the Intervention.

To see the difference in level of knowledge of STE students taking Electricity and Magnetism discipline, pre-test and posttest were compared. Table 3 compares the mean and standard deviation of pre-test and post-test of the group. Based on table 3, the computed t-value is 15.71, significantly higher than the critical two-tail value 2.16 with 13 degrees of freedom. There is enough evidence to reject the null hypothesis. It means there is significant difference in the scores of students in the pre-test and posttest of the participants and in the level of conceptual knowledge of STE students after the application of the intervention.

Table 3. Significant Difference on the T-test of Pre-Test and Post-Test

	Variable 1	*Variable 2*
Mean	24.29	48.14
Variance	20.22	27.36
Observations	14.00	14.00
Pearson Correlation	0.33	
Hypothesized Mean Difference	0.00	
df	13.00	
t Stat	-15.71	
P(T<=t) one-tail	0.00	
t Critical one-tail	1.77	
P(T<=t) two-tail	0.00	
t Critical two-tail	2.16	

It means that the intervention positively affects and had a good response towards the students' achievement based on their pre-test and post-test. The intervention was deemed to be effective in assisting the students in learning using a unique and different mode in learning electricity and magnetism.

Effects of the Phet Simulation Approach Towards Electricity and Magnetism

To have a glimpse of the themes culled from the 14 Science Educations students' narratives, a text table is presented (Table 4) with a narrative discussion.

Theme 1. Better Understanding

Garlick (2014) stated that science literacy is the fundamental knowledge and comprehension of scientific concepts and processes. Working knowledge is required to completely comprehend the ideas in Physics. However, with the use of simulation, pupils' comprehension improves since analysis can be easily confirmed. Like participants (P10 & P05) said "We can understand the concepts in electricity and magnetism much better than just using video or picture." and "Because of accessible simulation, I can do it a lot more which gives me a full understanding." Simulation has long been employed as a teaching technique in the classroom setting, owing to the high degree of engagement and participation that students may create and their ability to replicate real-life situations (Nkhoma et al., 2014). "It made us learn more. We can understand the topic more due to its practicality as a virtual laboratory. Actually, it's much better than the original laboratory, because it has all the tools needed during experiments. P02"

Table 4. Perspectives of Science Education students on the Effects of Phet Simulation Approach

Themes Generated	Significant Sample Statement	Theme Description
Better Understanding	It made us learn more. We can understand the topic more due to its practicality as a virtual laboratory. Actually, it's much better than original laboratory, because it has all the tools needed during experiments. P02	This focuses on how PHET simulation provides much learning with easy understanding.
Learning Through Visualization	Before, I cannot understand electricity and magnetism just by pictures and explanation. But when I visualized it, it became easy to grasp.P05	This discusses the role of visualizations as a form of better learning.
Learning Became Fun	It is really fun to do the experiments on your own. Because of it, I discover much more due to the unlimited trial and errors I do. P14	This pertains to how the utilization of PHET makes learning fun.
Promotes Self-Facilitation in Learning	As a future science educator who should always be curious, it greatly helps me teach electricity and magnetism. With these, I have fully understood the concepts because it shows every detail in every experiment we conducted on our own. P01	This addresses how Phet Simulation promotes self-facilitation through conducting unlimited trials and errors.
Provides a Wider Range of Options	This gives us more opportunities to explore more in electricity and magnetism. Unlike in a traditional laboratory, the tools here are complete, the phenomena have labels. P03	This describes how PHET simulation offers much more to learning.
Grasping the Micro Scale Concepts	Because of PHET, my perspective towards electricity and magnetism widens. Now I know how magnets, capacitors, resistors really do. Because it clearly depicts how charges behave when it contacts with this (magnets, capacitor, resistors etc.). P11	This describes how PHET Simulation assisted in exploring the micro scales of Electricity and Magnetism.

That statement was also justified by another participant (P12), “Without it, we cannot grasp the learning just by doing some calculations and explanation.” The PHET simulation tremendously aided them in learning the ideas. PhET simulations are very helpful in assisting students in making sense of scientific ideas, making sense of real-world events, and engaging in scientific research (Wieman et al., 2010).

Theme 2. Learning Through Visualization

According to Carpenter and Chasteen (2016), PhET simulations provide animated, interactive, and game-like settings that allow scientists to conduct experiments. Learning became more efficient as a result of these interactive animations. A participant (P04) justified, “We can visualize the concept more. I realized that visualization is important in electricity and magnetism. Now, I can grasp the topics.” According to the researchers, building pupils' runnable mental models results in a greater degree of conceptual knowledge (Clement, Zietsman & Monaghan, 2005). Considering this, another person (P05) agreed with its merits for visualization development. They said, "Before, I cannot understand electricity and magnetism just by pictures and explanation. But when I have visualized it, it became easy to grasp." Students who were educated using PhET simulations and YouTube videos performed considerably better on the posttest than students who received neither (Ndihokubwayo, Uwamahoro & Ndayambaje, 2020). As emphasized by participant (P12), "The PHET simulation greatly helps us to visualize the concept in electricity and magnetism."

Theme 3. Learning Became Fun

Several research have demonstrated that playing games may enhance learning results and physiological, cognitive, behavioral and soft and social abilities (University at Bufallo, n.d.) PHETs are a game-like environment that maximizes learning. A notable response was highlighted, "It is really fun to do the experiments on your own. Because of it, I discover much more due to unlimited trial and errors I do." It is said in Thorndike's 'Law of Freedom' that the greatest way to learn anything is to allow yourself to be taught. As a result, people's capacity to grow intellectually rises in direct proportion to their degree of educational autonomy.

A participant (P08) also stated, "This is fun. We can do a lot of simulation due to complete lab kits for experiments." PhET interactive simulations have an overall beneficial influence on students' attitudes and perceptions of learning, according to the findings of Salame and Makki (2021). Because of this, PHET simulations make learning more enjoyable. Cartoon-like visuals and whimsical elements like the option to add a puppy or a dollar note to a circuit in the Circuit Construction Kit simulation make PhET simulations enjoyable and engaging (Science Education Research Center, 2021).

Theme 4. Promotes Self-Facilitation in Learning

Carpenter et al. (2021) believes that student participation and investigation are encouraged via interactive simulations provided by PhET Interactive Simulations. "Opportunities like this, cannot be attained with just traditional laboratory.P07" was one standout answer. Learners are encouraged to investigate and explore on their own. Metacognition and self-reliance are fostered when pupils have options and the ability to evaluate their own development. Additionally, it is critical to provide activities that encourage students to take responsibility for their own learning in order to encourage deeper engagement with the material (Pandolpho, 2018).

Laboratory work has plenty of educational possibilities, but PHET Simulation is more convenient and accessible. "This gives us more opportunity to explore more in electricity and magnetism. Unlike in traditional laboratory, the tools here are complete, the phenomena has labels." one of the participants (P03) said. Well-designed laboratory experiences have been demonstrated to help children build critical-thinking abilities as well as expose them to lab reactions, materials and equipment (American Chemical Society, 2020).

Theme No. 5: Provides a Wider Range of Options

For Rogayan and Dantic (2021), science education should be a catalyst for improvement throughout time by introducing new ideas and approaches to the system. PHET Simulation was praised by one of the participants for its educational value. “This gives us more opportunity to explore more in electricity and magnetism. Unlike in traditional laboratory, the tools here are complete, the phenomena have labels.” Providing learners with direction is all they need to continue their education. Students may improve this ability using an inquiry-driven method when participating in guided-inquiry activities and getting feedback from a PhET interactive simulation (Carpenter, Moore & Perkins, 2015).

Theme 6. Grasping the Micro Scale Concepts

According to Carpenter and Chasteen (2016), PHET Simulation emphasizes connections between real-world phenomena and the underlying science, makes the invisible visible (e.g., atoms, molecules, electrons, photons), and includes visual models that scholars use to assist their thinking, all of which support the learning process and exploration. “We can also see the concept in much clearer detail because it presents even the smallest particle (electric charges) moving and behaving.” said participant (P10). The simplest details have the greatest influence. In other words, studying the micro ideas may aid in comprehending the big principles. Small particles with sizes ranging from one nanometer to tens of microns are widespread in both the natural and manmade worlds (National Research Council (US) Chemical Sciences Roundtable, 2012).

Another response related to it, “When we are conducting experiments using this, we can see the smallest details. It is more indulging to learn. It never gets boring because we can explore the smallest scales more. P09” This result demonstrates unambiguously that visualizing/representing tiny particles has a significant influence on conceptual learning. According to Aerts (2014), further experimental research will need to demonstrate if sharp quantum effects—as they manifest in smaller things—appear to be ontological properties of conventional macroscopic entities. Perhaps studying these quantum notions via PHET simulations can aid students in comprehending more complex scientific topics.

CONCLUSION

The conceptual knowledge in Electricity and Magnetism before the application of intervention of STE students is fairly satisfactory. The conceptual knowledge in Electricity and Magnetism after the application of intervention of STE students is very satisfactory. There is a significant difference between the mean scores of the assessment tests before and after the intervention application.The perspectives of the STE students in the effects of PHET Simulation in learning Electricity and Magnetism, 6 themes have emerged including; (a) better understanding**;** (b) learning through visualization; (c) learning became fun; (d) self-facilitation of learning**;** (e) provides a wider range of options; and (f) grasping the micro-scale concepts.

RECOMMENDATIONS

Establish and expand the conceptual understanding of STE students in Electricity and Magnetism. Increase students' comprehension of electricity and magnetism topics via the use of suitable pedagogical strategies for teaching and evaluation. Employ PHET Simulation as a teaching aid. This will significantly improve students' learning and comprehension, active involvement, and critical thinking. Lastly, investigate other multidisciplinary PHET Simulations that connect to electrical and magnetism principles. Create inquiry materials and laboratory activities that students may do on their own.

ACKNOWLEDGEMENT

The President Ramon Magsaysay State University – San Marcelino Campus, research colleagues who gladly supervised the whole writing process, as well as students who, in spite of difficult circumstances, willingly and actively took part in intervention and data collecting are all thanked by the author. Appreciation also goes to the study's editors and peer reviewers for their insightful comments.

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