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THE AFFORDANCES OF PhET SIMULATION AS A SUPPLEMENTAL LEARNING TOOL IN PHYSICS COURSE DURING THE COVID-19 PANDEMIC

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ABSTRACT

The modular distance learning modality exacerbates students' difficulties in physics. The COVID-19 pandemic has impacted traditional laboratory and direct instruction and facilitation of learning. To support and enhance modular distance education, virtual laboratories like PhET interactive simulation are among the few supplemental tools available. In this study, the effectiveness and benefits of the PhET simulation tool were examined in direct current circuit lessons using quasi-experimental matched-pairing. Students' test scores increased significantly after using the PhET simulation compared to students who used printed modules only. Because of the favorable learning environment, valid and reliable instructional characteristics and a positive impact on learning, the students' outcomes improved. Thus, this study recommends integrating the tool into classroom instruction and distance education in order to maximize its potential for improving student performance. To ensure that the findings are accurate, additional research is needed. Other research design and methods (e.g., experimental crossover design and mixed-methods) and including other participants (e.g., teachers) will be beneficial in this endeavor as well.

Keywords: Virtual laboratory, Learning with Technology, Distance Learning, Science Education

INTRODUCTION

The COVID-19 pandemic necessitated an abrupt rethinking of education to counterbalance learning loss among students. Many educational institutions have adopted distance learning for the first time. Synchronous or asynchronous discussion is the most popular method of online learning (Jariyah & Tyastirin, 2020). However, learning delivery for some courses has not been easy for such modalities. For instance, science courses require laboratory experiments to be better understood. Hands-on laboratory experience is required to fully grasp concepts because it allows students to think critically and scientifically (Inayah et al., 2021). It plays a critical role in science education, and it is obvious that instruction in science can't be as effective without laboratory activity (Hofstein & Mamlok-Naaman, 2007). In distance learning, the only way to teach lab-based skills is to use virtual labs (Sugiharti & Suganda, 2020).

Virtual laboratories enable students to acquire scientific ideas through visualization and experience using simulations and remotely initiated laboratory experiments (Jones, 2018). Several research highlights have highlighted the impact of virtual settings on students' self-efficacy (Wilde & Hsu 2019; Wang et al., 2019). According to Husnaini and Chen (2019), virtual laboratories were found to be more successful at improving difficult concepts and self-efficacy in scientific inquiry than other methods. Tomás et al. (2020) argue that self-efficacy contributes to student academic success. Students with high self-efficacy have been reported to have more classroom participation, more study effort, and better exam performance (AlDahdouh, 2018). Other studies emphasized that student' learning gains, engagement, and self-efficacy significantly improved after conducting experiments in virtual labs (Goudsouzian et al. 2018; Su & Cheng 2019).There are thousands of free virtual labs and simulations available to educators worldwide. A few examples include Molecular Workbench, Learn. Genetics, HHMI Bio Interactive, Glencoe Virtual Labs, and Nova Labs, among others. However, the Physics Education Technology or PhET simulation has grown in popularity and availability (Byrne, 2020). The PhET simulation may be a viable option in cases where laboratory practices are required that cannot be taught remotely during COVID-19 (Inayah et al., 2021). Student interaction and exploration of phenomena that would otherwise be unattainable in the laboratory are made possible through PHET simulations. This also makes it possible for students to run experiments with different variables and get real-time feedback with these tools (Byrne, 2020).

The PhET site offers free learning simulations in physics, math, chemistry, biology, and earth sciences that can be downloaded for classroom use or individual study (Sinulingga et al., 2016). These learning simulations work with a wide range of learning objectives, contexts, pedagogies, grade levels, and students and offer educators flexibility in delivering their content and often allow students to visualize, manipulate, and explore material that would be impossible in a traditional lab (Perkins, et al. 2014). According to previous studies, students' conceptual understanding improved when PhET simulation was used in the learning process (Najib, 2015). Teachers can use PhET simulation to teach new topics, build concepts and skills, reinforce scientific ideas, and conduct learning reflection (Wieman et al., 2010). There are numerous benefits to using PhET simulations for chemistry and physics instruction (e.g., Saregar, 2016). Following the use of PhET simulation in their learning activities, Saregar (2016) found that students gained a better understanding of physics concepts. Students' understanding of solar system concepts improves dramatically when using PhET simulation in class (Prima et al., 2018). There are also studies that proved the effectiveness of the interactive simulation in other physics topics such as electromagnetism, electrodynamics circuits, and sound waves, among others (e.g., Halim et al., 2021; Yunzal et al., 2020; Batuyong & Antonio, 2018). As a result of using PhET simulation activities in physics education, students may gain a better understanding of the ideas. Structures and processes that are typically hidden from students' view can be brought to light through the use of interactive simulations (Batuyong et al., 2018).

Even before the pandemic strikes, there are already issues with the way physics is taught and learned in the classroom.Student performance in physics is declining as a result of difficult problems that are being presented to them today (Mekonnen, 2014). Several studies and researches conducted by different researchers (e.g., Batuyong et al., 2018; Rutten et al., 2012) have revealed that students' performance in Physics is declining, which is a situation that needs to be addressed by teachers, and which represents a challenge for science educators to devise or innovate ways to make teaching-learning stimulating. It is for this reason that physics educators should look for methods and interventions that will help students improve their overall performance in the subject matter (Antonio, 2015).Many science educators are still grappling with the same dilemma today, and the pandemic has only exacerbated the situation.

It is imperative that virtual laboratory work be used to supplement real laboratory work and enhance student experience and understanding in the midst of the COVID-19 pandemic. Academic laboratory practical sessions for the school year 2020-2021 have been canceled or postponed in numerous countries (Vasiliadou, 2020). Many schools in the Philippines have faced the same dilemma. Despite the negative effects on education caused by the pandemic, this hiatus has paved the way to more research into the advantages and effectiveness of using the PhET interactive simulation in the country's public high school science education context.

The purpose of this study was to determine the effectiveness of the PhET simulation and its users' perceptions in learning direct current circuit concepts to grade 12 students in a public school. Prior to the pandemic, the affordances of PhET simulation were investigated, but the majority of studies focused on or utilized simulation in a face-to-face classroom setting. The current study examined the simulation's effects and benefits in a different type of learning environment not common to many public school students in the Philippines.

MATERIALS AND METHODS

This quantitative study utilized a quasi-experimental matched pairing design with a posttest only. A total of 50 students enrolled in the Physics 2 course participated in the study. The experimental group, consisting of 25 students, was given a PhET interactive simulation as a supplemental tool for learning, while the comparison group received no treatment other than the printed learning module. All students were enrolled in a modular distance learning modality. The said modality was mandated by the Department of Education as online learning is not feasible to majority of public high school students. As such, studentsreceived printed modules to study the lessons each week. The PhET simulation was available online and can be accessed using any smart phone, tablet, iPad, or laptop. Students were briefed on the research plan, and their permission was obtained. Prior to the experiment, students were given a 25-item multiple-choice pretest to measure their level of understanding of the topic. This was conducted during the schedule of module distribution in the school. Another 25-item posttest was administered to them after two weeks and was done after the retrieval of the modules. In addition, the experimental group was given a 4-point Likert survey questionnaire to collect their perceptions about the use of PhET simulation tool. The survey contains twenty (20) statements describing the learning situation (n = 5), the instructional characteristics (n = 5), and the effects on learning (n = 10) of using PhET simulation. The respondents' answers varied from "strongly agree" to "strongly disagree." Meanwhile, the interpretation of results ranges from "very good" to "poor." The above-mentioned questionnaire and descriptive interpretation were adopted and revised from the study of Lamina (2019). However, the original survey questionnaire was made by Batuyong et al. (2018).

The mean percentage score and standard deviation were used to describe the performance of the students in their pretest and posttest, while the mean was used for the analysis of perceptions. An independent sample *t*-test was used to determine the significant difference between the test results of both groups. In addition, the tests for normality using the Shapiro-Wilk test and homogeneity of variance using the Levene's test were conducted before the *t*-test.

RESULTS

The aim of this study was to determine the effectiveness and learning benefits of using the PhET interactive simulation as a supplemental tool in teaching and learning the direct current circuit lessons during this pandemic, where face-to-face instruction is prohibited and modular distance learning is the most viable modality for many public school students in the Philippines. First, the pretest was administered to compare the performance of both groups regarding the topics discussed for this study. Based on the results, all of the students have comparable knowledge of direct current circuits; hence, matched-paired grouping became possible. The mean percentage score (M = 35%) of both groups was not significantly different, where t (48) = 0.08, $p > 0.05$.

A post test was administered to them after the two-week intervention to determine the effect of the supplemental tool on the experimental group. Results indicated that both groups gained an increase in their test performance, wherein the comparison group has a mean percentage score of 74.40 (SD = 2.99) and the experimental group has a mean percentage score of 81.28 (SD = 2.88), yielding a mean difference of 6.88. The mean percentage scores in the posttest were normally distributed, as assessed by Shapiro-Wilk's test ($p > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.12$). When the significance was tested using an independent sample *t*-test at alpha level of 0.05, the results revealed a statistically significant difference between the means, t (48) =-2.08, $p < 0.05$ (Table 1). Although both groups gained better post-test results compared to their pretests, the significant difference between the two groups' post-tests can be attributed to the use of PhET simulation, for there was no other intervention made aside from the printed module itself.

Table 1: The Post-test Results of the Students

Groups	Mean Percentage Score	SD	*t-value*	*df*	p-value
Comparison	74.40	2.99	-2.08	48	0.04
Experimental	81.28	2.88			

Scaling: Mean Percentage Score
- 84.0 – 100 Outstanding
- 76.0 – 83.9 Very Satisfactory
- 68.0 – 75.9 Satisfactory
- 60.0 – 67.9 Fairly Satisfactory
- 0.0 – 59.9Did Not Meet Expectation

To gain better insights about the benefits of using PhET simulation as a supplemental tool, a survey about students' perceptions were conducted. The survey is composed of statements that describe the learning situation, the instructional characteristics, and the effects on learning of the simulation.

The results indicated that students were positive in the use of the simulation as they rated all the dimensions as "very good" (Table 2). This implied that the PhET simulation as a supplemental tool is beneficial and contributed to their learning success during the modular distance learning.

Table 2: The Perceptions of the Students toward PhET simulation

	Mean	SD	Interpretation
Learning Situation			
The learning situation under the of the PhET Interactive Simulation- based activity is:			
1.1 enjoyable			
1.2 stress free	3.80	0.41	Very Good
1.3 addresses individual needs	3.68	0.48	Very Good
1.4 supportive of learning	3.68	0.48	Very Good
1.5 promotes positive attitude towards	3.96	0.20	Very Good
learning	3.96	0.20	Very Good
Instructional Characteristics			
The PhET Interactive Simulation-based activity:			
2.1 help in the development of critical thinking skills and analyzing skills of students.	3.96	0.20	Very Good
2.2 presents real-life situations.	3.60	0.50	Very Good
2.3 give appropriate and relevant information for the development of concept.	3.68	0.48	Very Good
2.4 the activities are aligned to the learning objectives of the K-12	4.00	0.00	Very Good

Curriculum.			
2.5 focus on specific skill and concepts.	3.92	0.28	Very Good
Effects on Learning			
The PhET Interactive Simulation-based activity:			
3.1 develop creativity and ignite curiosity of the students.			
3.2 simplify the task to make it more manageable and achievable to a	3.52	0.51	Very Good
learner.	3.76	0.44	Very Good
3.3 provide some direction to help the student focus on the learning outcome.	3.44	0.51	Very Good
3.4 model and clearly state activities to be performed.	3.70	0.20	Very Good
3.5 promote active learning.	4.00	0.00	Very Good
3.6 introduce ideas/concepts in logical learning sequence.	3.68	0.63	Very Good
3.7 are engaging and challenging.	3.92	0.28	Very Good
3.8 are learner-centered.	3.920.28		Very Good
3.9 allow students to engage and motivate students to a greater degree.	3.920.28		Very Good
3.10 provide more opportunities for independent, self- focus on the learning outcome.	3.68	0.48	Very Good
Average Mean	3.74	0.44	Very Good

DISCUSSION

There are many studies that support the findings of this study, including Potané et al. (2017), Bandoy et al. (2015), Batuyong et al. 2018, Mallari et al. (2018) and Halim et al. (2021). According to their research, using the PhET simulation resulted in a statistically significant improvement in student academic performance. The interactive simulation has proven to be an effective instructional tool for students studying direct current circuits in Grade 12.Similar results were collected in using the simulation tool in other topics in physics such as sound waves, electromagnetism, and projectile motion to name a few (Halim et al., 2021; Batuyong et al., 2018; Lamina, 2019). Likewise, student feedback on the PhET simulation is generally positive, which is consistent with previous findings (e.g., Bandoy et al., 2015). The use of PhET simulation tool provides students with meaningful learning situations and experiences. Critical thinking skills are improved as a result (Hasyim, 2020). Furthermore, the students who used the toolenjoyed the learning experience, developed into active learners, and were motivated while also being challenged throughout the learning experience (Batuyong et al., 2018; Mallari et al., 2020). There are, however, studies that contradict the findings. According to Adams et al. (2008); Hsin et al. (2014); and Yunzal et al. (2020), using PhET virtual lab simulations did not result in an increase in student outcomes. Their studies revealed no statistically significant improvement in students' test scores following implementation of the tool in the classroom.

CONCLUSION

In many ways, the modular distance learning modality makes physics even more challenging for students. Students are forced to adapt to a new learning environment where self-directed learning is essential. The use of PhET simulation is seen as a viable alternative to traditional laboratories and a supplemental tool in Grade 12 Physics 2 for learning about direct current circuits. While learning remotely and autonomously, the interactive simulation allows students to gain a deeper understanding of scientific content and perform better on tests. The PhET simulation fosters a favorable learning climate, valid and reliable instructional characteristics and have a positive effect on learning.In light of these findings, it is suggested that technology should be further integrated into classroom instruction and distance education to maximize its potential for improving student outcomes.

Given the limitations of this study's implementation, the researcher recommends that the efficacy of PhET simulation be investigated further using other research designs than the quasi-experimental matched-pair and one group pretest-posttest (e.g., experimental crossover and mixed-method). Likewise, investigating the qualitative aspects of the tool through focus group discussions and interviews with students can provide more in-depth insights into its advantages and disadvantages than simply looking at the quantitative aspects. Examining the viewpoints of educators will also be helpful in this endeavor.

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