



Effect of Physics Education Technology (PHET) Virtual Laboratory Experiment Simulation on Students' Academic Performance in Practical Physics in Ogoja Education Zone

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Abstract

The study examined the effectiveness of Physics Education Technology (PhET) virtual laboratory experiment on students' academic performance in practical physics in Ogoja Education Zone. This study was guided by three specific purposes, research questions and null hypotheses respectively. The study employed an experimental randomized post-test only control group factorial design. The population of the study was 2,797 senior secondary school three students. The sample size was 42 SSIII students which comprised of 19 male students and 23 female students. Purposive sampling technique was used to select one co-educational school while simple random sampling was used to draw two groups of randomized subjects which were used for the experiment. The instruments used for data collection was adopted and titled Ohms Law Practical Physics Assessment Scale (OLPPAS). Pearson Correlation Coefficient inter-rater statistics was used to determine the reliability of the OLPPAS with reliability index of 0.87. Mean and standard deviation were used to answer the research questions while a two-way between group analysis of variance (ANOVA) was used to test the hypotheses at 0.05 level of significance. The result showed that students that were engaged through the virtual physics laboratory performed better than students taught in the traditional physics laboratory. The result also indicated that female students performed better than male students and finally there was no significant interaction effect between type of laboratory and gender in students mean performance scores in practical physics.

Keywords: Practical physics, educational technology, Physics Education Technology (PhET), simulation and Virtual learning.

Introduction

Physics is a science subject that necessitates the execution of lab activities. An approach to studying natural phenomena that requires inquiry based learning through a variety of do-it-yourself activities and experiments that are guided by the teacher (Irwanto, 2017). Practical work is an important component of physics instruction as it serves as a springboard for conceptual knowledge acquisition and builds in the learners' science process skills which are skills used by scientists in the laboratory to solve an identified problem.

In a typical laboratory activity where students deal with the concept and idea that gives the activity its meaning, the physical manipulation of apparatus and materials which may be hazardous and often times not available, requires quite fine motor skills, the planning and sequencing of actions to carry out procedures and record results manually, as well as the social interactions and disturbance in the lab due to group work. Conversely, Carruthers (2015) opines that a typical laboratory has a number of issues, including ineffective lab teaching

materials, lack of apparatus and negative feedback from the lab's instructors and students, among other things. According to Babalola and Alabi (2021), ICT provides a means of dampening this noise. This calls for more cutting-edge methods, such as virtual labs (VLs) for the study of practical physics, which enable students to conduct real-world modelling using computer equipment provided to them in virtual environments.

A virtual lab realistically simulates a real lab environment as precisely as possible, it enables students to learn through hands-on and brains-on experience. According to Stahre-Wästberg et al. (2019), virtual lab (VL) is an interactive learning environment where students can do simulated experiments while they are studying. Khaskheli et al. (2022) advance that VL is one of the most significant e-learning techniques because they give both students and teachers the chance to accomplish the objectives of the educational process by facilitating the application of the practical component of the curriculum anywhere,

at any time irrespective of geographical restrictions. On this note a virtual lab, can be used to supplement, substitute, or make up a lab to fill the time between lab and lecture. Students learn the physical and conceptual skills necessary to successfully complete physics experiments through these laboratory simulations which is not possible in a typical lab. Thus, Babalola (2017) emphasized that ICT offers VL simulations which gives students the opportunity to study from a perspective that lies in between the practical and the theoretical aspects. Thus, the need for PhET simulations in practical physics education.

Originally standing for "Physics Education Technology," the project's abbreviation "PhET" soon included additional academic fields.

According to carleton.edu. (2023) PhET is a collection of interactive computer simulations for teaching and learning physics, chemistry, math, and other disciplines. The University of Colorado Boulder created and hosts the explorable explanations as part of their non-profit open educational resource project. Carl Wieman, a Nobel laureate, founded it in 2002. Wieman's objective for PhET was to enhance the way science is taught and learned. Their goal statement is, "To advance science and math literacy and education worldwide through free interactive simulations." More than 125 free interactive simulations in the areas of physics, chemistry, biology, earth science, and mathematics have now been created, developed, and released by the project (Guttenplan, 2011).

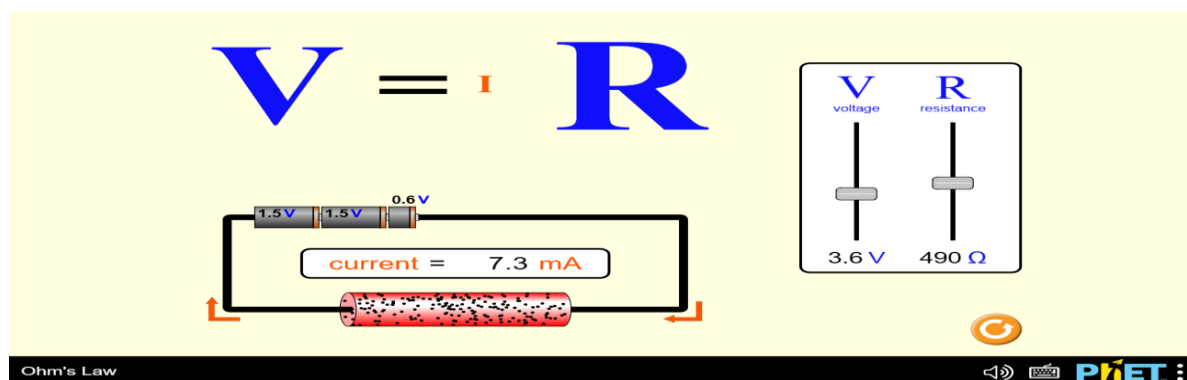


Fig 1: Ohms Law simulation user interface (UI) in PhET

In spite of the alluring benefits of virtual lab by numerous studies, there is continuous argument on the role/effect of using virtual lab in students' physics learning (Swan et al., 2015). Many studies showed positive effects of using virtual experiments on students' level of achievement (Pyatt & Sims, 2012; Tatli & Ayas, 2013; Antwi et al. 2014; Radhamani et al., 2014; Aljuhani et al., 2018; Alneyadi, 2019; Penn & Umesh, 2019; Babalola & Alabi 2021) while others showed no significant differences (Ambusaidi et al., 2018; Crandall et al., 2015; Darrah et al., 2014).

The continuing disagreement in the findings of researches as pointed out above in the literature, showed a need toward carrying out more investigations on the use of virtual lab in learning and teaching practical physics in a different area especially in Cross River State. Therefore, the aim of this study is to explore the effect of a virtual lab and a physical lab on senior secondary school students' performance in practical physics in Ogoja education zone. Thus, the importance of this study lies in trying to fill the gap created by the mixed results of the

research conducted so far on the effectiveness of using virtual labs on students' performance in practical physics. The results will offer evidence of the effect of using virtual lab on students' performance in practical physics using the PhET.

Theoretical Framework

This research was based on the Pragmatism Theory John Dewey, 1938. Pragmatism, also known as Experimentalism, accentuates the practical value of reasoning while stimulating the experimental scheme of science. Experimentalism present the idea that mental performance is permanently a sort of testing of preliminary discoveries and hypotheses such that students are more likely to be affianced and engrossed in what is being taught when they partake actively in laboratory experiments. Problem-solving and adopting democratic procedures are the most gainful teaching strategies in the current style of education in the world now. Student-centred activities, a focus on content, and a democratic approach to managing the classroom are all part of the pragmatic method. Dewey suggested that learners perform



well in environments that promote first-hand experience and that very much aligned with the formulated curriculum and activate the general personal participation of each learner.

Statement of the Problem

Most secondary schools in impoverished nations, including Nigeria, do not have adequate facilities for carrying out practical work. Some schools do not have physics labs, while in others, the physics lab is intended to be shared with other science classes to give students more hands-on experience. Teachers at schools with equipment complain that there is not enough time allotted for doing practical work in schools and students complain of lack of practical activities in public schools in Cross River State. This is due to the fact that teachers spend little to no time on practical work and a lot of their time on administrative tasks and the majority of the teachers favour doing teacher-centered demos. Many school principals place more emphasis on completing the curriculum than on good teaching and learning of physics with practical experience. Many students perform practical work for the first time when preparing for external examinations like MOCK, WAEC and NECO without the necessary prior preparation or background in practical physics. Most secondary school laboratories are underequipped too, which may prevent teachers from using the highly recommended practical approach. Due to the lack of time for practical activities and practical apparatus in public schools in Ogoja Education Zone of Cross River state, a more innovative approach to conducting physics experiments is therefore required.

Purpose of the Study

The general purpose of the study is to examine the effect of Physics Education Technology (PhET) virtual laboratory experiment simulation on students' academic performance in practical physics in Ogoja education zone of Cross River state, Nigeria. Specifically, the study seeks to determine:

1. The effect of virtual and physical laboratories on students' performance in practical physics.
2. Influence of gender on students' performance in practical physics
3. Interaction effect of type of laboratory and gender on students' performance in practical physics.

Research Questions

The following research questions were posed to guide the study

1. What are the effects of the physics virtual laboratory and physical laboratory on the mean performance score of students in practical physics?
2. What is the influence of gender on the mean performance score of students in practical physics?
3. What is the interaction effect of type of laboratory and gender on the mean performance score of students in practical physics?

Research Hypotheses

The study tested the following null hypotheses:

1. There is no significant difference in the mean performance scores of students exposed to practical physics using virtual laboratory and physical laboratory.
2. There is no significant difference in the mean performance scores of male and female students in practical physics.
3. There is no significant interaction effect of type of laboratory and gender on the mean performance score of students in practical physics.

Method

An experimental 2×2 randomised post-test only control group factorial design was used for the investigation. Two thousand eight hundred (2,797) senior secondary school three students made up the study's population. The sample size was 42 SSIII students, 19 male and 23 female, who had taken physics for two years and had established positive views towards the subject. One co-educational school was chosen using the purposeful sampling technique, and the two groups of students for the experiment were selected using simple random selection. The experiment of the study was to validate Ohm's law in both groups. The experimental group had ICT classroom sessions with exposure to the virtual physics laboratory (PhET) for the accompanying practical work, whereas the control group received instruction in the real physics laboratory. Before providing the students the practical lessons and the test, permission from the principals of the chosen school was requested. The subject instructors were then used as research assistants after obtaining training from the

researcher. The researcher used the Ohms Law Practical Physics Assessment Scale (OLPPAS) as a tool for collecting data. The OLPPAS's Section A had information on the respondent's bio, while Section B contained items that could be used by teachers to assess students' ability to demonstrate that the Voltage to Current ratio is constant and so verify the Ohm's law experiment in either type of the laboratory. Three experts face-validated the tool. In the school that was not utilised for the main study, the instrument was trial-tested on 20 students to determine its reliability. To determine the reliability of OLPPAS, Pearson product moment correlation inter-rater statistics was used. According to the analysis, OLPPAS has a reliability index of 0.87. In order to analyse the data, SPSS version 23 was used. Mean and standard deviation were used to answer the research questions while the two-way between group analysis of variance (ANOVA) was used to test the hypotheses at 0.05 level of significance.

Results

Table 1: Post-test mean performance scores of students exposed to practical physics using virtual laboratory and physical laboratory

	N	Post-test \bar{X}	SD
Virtual laboratory	21	47.48	6.36
Physical laboratory	21	40.29	6.57

Note: N = Number of Respondents, \bar{X} = Mean, SD = Standard Deviation

The result in table 1 showed that students who were exposed to practical physics using the virtual laboratory had a post-test mean performance score of (\bar{X} = 47.48, SD = 6.36)

while those taught using the physical laboratory had a post-test mean performance score of (\bar{X} = 40.29, SD = 6.57). The standard deviation of 6.36 and 6.57 for the virtual laboratory and physical laboratory at post-test respectively, indicate that the performance scores of students in the virtual laboratory were widely spread than the scores of the students in the physical laboratory. This implies that senior secondary school students taught practical physics with the virtual laboratory had higher mean performance scores than those taught using the physical laboratory.

Table 2: Post-test mean influence of gender on performance scores of students in practical physics

	N	Post-test \bar{X}	SD
Male	19	39.74	7.01
Female	23	47.30	5.78

Note: N = Number of Respondents, \bar{X} = Mean, SD = Standard Deviation

The result in table 2 showed that male students had a post-test mean performance score of (\bar{X} = 39.74, SD = 7.01) while on the other hand, the female students had a post-test mean performance score of (\bar{X} = 47.30, SD = 5.78). The standard deviation of 7.01 and 5.78 for the male and female students at post-test respectively, portray that the performance scores of male students were widely spread than the scores of the female students. The mean scores of 39.74 and 47.30 for male and female students respectively imply that female students taught practical physics had higher mean performance scores than male students.

Table 3: Post-test mean interaction effect of modes of type of laboratory and gender on mean performance scores of students in practical physics.

Flipped Classroom Mode	Gender	Post-test		
		N	\bar{X}	SD
Virtual laboratory	Male	9	42.67	6.38
	Female	12	51.08	3.29
Physical laboratory	Male	10	37.10	6.78
	Female	11	43.18	5.08

Note: N = Number of Respondents, \bar{X} = Mean, SD = Standard Deviation

Results in table 3 showed the interaction effect of type of laboratory and gender on mean performance scores of students in practical physics. The results showed that male students

taught practical physics using the virtual laboratory had a mean performance score of (\bar{X} = 42.67, SD = 6.38) at post-test. Whereas the female students taught practical physics using the

virtual laboratory had a mean performance score of ($\bar{X}=51.08$, $SD = 3.29$) at post-test. Furthermore, the results showed that male students taught practical physics using the physical laboratory had a mean performance score of ($\bar{X}=37.10$, $SD = 6.78$) at post-test. Whereas the female students taught practical physics using the physical laboratory had a mean performance score of ($\bar{X}=43.18$, $SD = 5.08$) at post-test

respectively. Observably, the result shows that the female students had a higher performance scores than their male counterparts in practical physics when taught with either the virtual laboratory or physical laboratory. To test for the interaction effect of type of laboratory and gender on mean performance scores of students in practical physics, see hypothesis three.

Table 4: Analysis of Variance (ANOVA) of the difference in the mean performance scores of senior secondary school students exposed to practical physics using virtual laboratory and physical laboratory.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Dec
Corrected Model	1100.952 ^a	3	366.984	12.502	.000	.497	
Intercept	78595.552	1	78595.552	2677.505	.000	.986	
Gender	545.489	1	545.489	18.583	.000	.328	S
Group	470.716	1	470.716	16.036	.000	.297	S
gender * group	14.147	1	14.147	.482	.492	.013	NS
Error	1115.453	38	29.354				
Total	83089.000	42					
Corrected Total	2216.405	41					

Note: df= Degree of Freedom, F= F-ratio, Sig= Significant/probability value, Dec. = Decision, S= Significant, NS= Not Significant

The result in table 4 showed that there is a statistically significant difference between the mean performance scores of senior secondary school students exposed to the virtual laboratory and physical laboratory in practical physics, $F(1, 38) = 16.036$, $p = .000$, $\eta^2_p = .297$. This is because the associated probability (sig) value of .000 is less than 0.05 level of significance at which the hypothesis was tested. Hence, the null hypothesis one (H_{01}) is rejected. Furthermore, the effect size difference of ($\eta^2_p = .297$), indicates that 29.7% variance exist between the mean performance scores of students exposed to the virtual laboratory and physical laboratory.

The result in table 4 also showed that the difference between the mean performance scores of male and female students in practical physics is statistically significant, $F(1, 38) = 18.583$, $p = .000$, $\eta^2_p = .328$. This is because the associated probability (sig) value of .000 is less than 0.05 level of significance at which the hypothesis was being tested. Hence, the null hypothesis three (H_{03}) which stated that there is no significant difference in the mean performance scores of

male and female students in practical physics is rejected. Furthermore, the effect size difference of ($\eta^2_p = .328$), indicates that 32.8% variance exist between the mean performance scores of male and female students. This means that 32.8% variance in students' performance in practical physics is accounted for by gender influence.

Result in table 4 showed that the interaction effect of type of laboratory and gender on the mean performance scores of students in practical physics is not statistically significant, $F(1, 38) = .482$, $p = .492$, $\eta^2_p = .013$. This is because the associated probability (sig) value of .492 is greater than 0.05 level of significance at which the hypothesis was tested. Hence, the null hypothesis three (H_{05}) which stated that there is no significant interaction effect of modes of flipped classroom strategies and gender on the mean performance scores of students in practical physics is therefore not rejected. Moreover, the effect size difference of ($\eta^2_p = .013$), indicates that 1% variance in mean performance scores of students in practical physics is attributable to the gender.



Discussion

Findings from research question one showed that senior secondary school students taught practical physics with the virtual laboratory had higher mean performance scores than those taught using the physical laboratory. These findings are in line with previous studies by Pyatt & Sims (2012), Tatli & Ayas (2013), Antwi et al. (2014), Radhamani et al. (2014), Aljuhani et al. (2018), Alneyadi (2019), Penn & Umesh (2019), Babalola and Alabi (2021) who stated that students that were engaged through the virtual physics laboratory performed better than students taught in the traditional physics laboratory but refutes findings of the studies of Ambusaidi et al. (2018), Crandall et al. (2015), and Darrah et al. (2014).

Findings from research question two showed that female students taught practical physics had higher mean performance scores than male students. These findings are in line with previous studies by Antwi et al. (2014), Radhamani et al. (2014), Aljuhani et al. (2018), Penn & Umesh (2019), who stated that female students that were instructed with the virtual physics laboratory performed better than the male students taught in the same virtual physics laboratory.

The findings from research question three shows that the female students had a higher performance scores than their male counterparts in practical physics when taught with either the virtual laboratory or physical laboratory. These findings are also in line with previous studies by Penn & Umesh (2019), who stated that female students performed better than the male students while carrying out a study but refutes findings of the studies of Ambusaidi et al. (2018) which was in favour of male students.

Conclusions

From the findings of the study, it can be concluded that students who had the learning experience with a virtual laboratory had a highly significant performance score than their counterparts who were exposed to the conventional physics laboratory.

Again, female students performed better than the male students hence there was a significant difference in performance due to gender and finally in both groups female students performed better than the male students and as such it can be concluded that female students generally performed better than the male students.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Physics teachers should implement virtual laboratory (PhET) in the teaching of practical physics.
2. Training and retraining of physics teachers in the use of educational technologies by government and ministry of education. Most of the physics teachers lack the skills to deliver effective practical physics lessons through the use of learning technologies due to their lack of exposure. Therefore, any adoption of ICT will require systemic re-education and vision.

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