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Virtual and Physical Laboratory Applications on the Verification of Ohm's Law and Undergraduate Physics Students' Performance and Retention in Port Harcourt, Nigeria

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ABTRACT

This study investigated virtual and physical laboratory applications on the verification of Ohm's law and undergraduate physics students' performance and retention in Ignatius Ajuru University of Education, Port Harcourt. Two research questions and two hypotheses were formulated to guide this study. The design for the study was quasi experimental of the type, pretest, post-test control group design. The population of the study comprised of all year 2 undergraduate physics students of Ignatius Ajuru University of Education, numbering one hundred and eight (108). Census Sampling Technique was adopted since same number of the population of the study of one hundred and eight (108) year 2 undergraduate physics students made up the sample size. Two experimental groups and one control group were used for the study. The instrument used for this study is Physics Practical Test for the Verification of Ohm's Law (PPTVOL). A reliability index of 0.72 was obtained for (PPTVOL). Experimental group 1 and experimental group 2 were taught practical Physics using a virtual laboratory and a physical laboratory respectively while the control group was taught using the demonstration method. Data were analyzed using mean and standard deviation to answer the research questions while Analysis of Variance (ANOVA) and Post Hoc Test were used to test the hypotheses at 0.05 level of significance. The findings of the study revealed that students taught with virtual laboratory had higher performance and retention than their counterparts taught with physical laboratory and demonstration method; it was found also that there is no significant difference in the performance and retention scores of students taught with physical laboratory and those taught with demonstration method. It was recommended among others that virtual laboratory method of teaching physics practical should be included in the physics curriculum of universities, curriculum planners should create a forum to raise experts who will be educating university teachers on the use of virtual laboratories and government and other stakeholders in education should equip the physical laboratories both in equipment and personnel adequately.

Keywords: *Ohm's Law, Virtual Learning, Students, Undergraduate, Physics, Nigeria*

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INTRODUCTION

Measurement is a very delicate part in the teaching and learning of physics. Accuracy in measurement is important because technological inventions solely depend on it. Corroborating that, Omosewo (2009) stated that its understanding has aided in the development of equipment and devices that are extremely beneficial to humanity. Dirisu and Amodu (2017) stated that it is necessary to have a high degree of accuracy in measurement while conducting experiments since they produce data that can be interpreted, evaluated and analyzed. Ojediran et al. (2014) noted in their research that the principle of physics is founded on the test of all knowledge by experiment.

Experimentation, in their view, is the only reliable way to determine what constitutes "truth" in the scientific community. This can be compared with the saying that as the church is the holy ground for the Christian likewise the mosque is the holy ground for the muslim, that's how the laboratory can as well say to be the holy ground for the physicist. This is because it is always expected of the church and the mosque to speak truth. It is therefore imperative that scientific measurements should be taken very seriously in the physics laboratory because any aberration from that can cause a great technological damage. Technological inventions, devices and gadgets are all designed because of existing laws in physics. Where do the laws originate from that are going to be put to the test? Ojediran et al. (2014) who are the architect of this question, also answered by stating that experiment, in and of itself, contributes to the production of these laws, in the sense that it provides us with indications. The purpose of physics is to apply the findings of these experiments to the formulation of scientific laws, which are often communicated via the medium of mathematics (Uko & Dibie, 2020). By understanding scientific laws, we can develop new technologies, improve existing processes and make informed decisions about the world around us. Also, these laws may then be used to anticipate the occurrence of other events. In addition, theories and laws of physics are validated in the laboratory by the precise measurement of quantities, which contributes to a better comprehension of ideas in Physics. Experiments, which are the means by which measurements are taken, are carried out in physics laboratories, as is common knowledge. This indicates that laboratory work is very vital for the achievement of the goals and objectives of teaching physics.

The physical laboratory refers to our traditional laboratories. Guided inquiry and demonstration are physical laboratory teaching strategies often used by physics teachers. In the guided inquiry method, students are only given the information needed to complete the activity, and then are left to work independently on the lesson. On the other hand, in the demonstration method, the teacher is the one who performs the practical, and the students' only responsibility is to observe. Attah and Nwagbo (2024) found that students taught animal nutrition using the guided inquiry method achieved higher mean scores than those taught with the unguided inquiry method. Similarly, Ochogba et al. (2019) reported that students taught using the demonstration method outperformed those taught through lectures. Mohammed et al. (2017) also observed that students who received instruction via the demonstration method performed better than those who did not. Additionally, Omeodu (2019) emphasized that effective teaching strategies enhance student motivation, sustain attention, and improve focus.

However, the traditional physics laboratory has been earnestly criticized by several educational researchers. Some issues faced by the conventional laboratory are inadequate equipment, incompetence on the part of teachers, overcrowded classes, safety challenges due to lab work hazards, unavailability of a particular equipment because of high cost, insufficient time, paucity of laboratory technicians and most of all accuracy problems due to technical or human errors that can never be avoided. These problems cited may have contributed to the reason why several sciences educationists frown at the laboratory method of teaching as earlier mentioned. The traditional laboratory teaching and learning method may also be a contributing factor to the poor performance in physics across the various levels of education as reported by some scholars (Gbore, 2014; Guido, 2018; Adolphus, 2018). Building on this, Abdullahi et al. (2020) argued that traditional instructional strategies used in teaching physics practicals in secondary schools have not significantly improved students' academic performance in the subject. Several studies (Bello, 2012; Musa, 2017; Saleh & Subramaniam, 2017; Adulphus et al., 2021) reported that inadequate teaching strategies are to blame for low performance. The benefits of physics education, as well as other science disciplines, cannot be effectively accessible to society if nothing is done to improve this deplorable circumstance, and the society will be the one to suffer the consequences of this loss. As a result, it is necessary to create room for new pedagogical approaches in the teaching and learning of physics. Modern educators exclusively employ traditional techniques to educate without making advantage of the superior ways that technology has brought in recent years.

To proffer solution to the problems faced by teachers and students in the traditional physics laboratory, it is necessary to activate and make use of innovations that Information and Communication Technology (ICT) has made possible. ICT for teaching or in education comes in various forms namely electronic-learning, mobile-learning, ubiquitous-learning, distance learning, simulation learning, flip-classroom , audio learning, video learning and virtual learning. GeoGebra, circuitlab, oscillations educational, science of music, Physics Education Technology (PhET), fluid mechanics, algodoo among others are educational softwares which ICT has also made possible. Educational software make use of sound, pictures and graphics and allows for active learning. Educational software has been found by researchers to bring succour to the challenges faced by the traditional science laboratory works, physics in particular. Educational researchers are now opting for the virtual laboratory which makes use of educational softwares for the teaching and learning of physics practicals.

Virtual laboratories are interactive digital simulations that replicate tasks commonly performed in physical labs, including tools, equipment, tests, and procedures used in subjects like chemistry, biochemistry, physics, and biology (Gamage et al., 2020). Sypsas and Kalles (2018) described virtual laboratories as interactive environments designed for conducting simulated experiments without real lab tools.

Simulation-based education allows students to practice skills in realistic scenarios (Olga et al., 2020). Venable (2021) highlighted that research confirms simulations are as effective as traditional teaching methods and enhance retention, as students can repeat experiments multiple times. Aina (2013) noted that certain physics experiments, such as those involving optical, magnetic, and mechanical phenomena, are too rapid for students to grasp in traditional labs but can be slowed down through computer simulations, improving comprehension. Additionally, virtual laboratories eliminate spatial constraints, enabling students to participate from different locations at any time (Elfeky et al., 2024).

Supporting the effectiveness of virtual laboratories, Saif (2019) emphasized that they not only address the issue of inadequate facilities and space but also introduce students to modern technological advancements and innovations. Radu and Schneider (2019) highlighted that virtual labs enable students to explore phenomena beyond the visible spectrum, establish connections between visible and invisible elements, emphasize key concepts, and conduct multiple experiments efficiently. Chacko and Kapila (2019) further described virtual labs as user-friendly, providing feedback after simulations, which enhances student understanding and motivation.

Several educationists have studied the impact of virtual laboratories on teaching and learning. Research by Yildirim (2021), Hussaini et al. (2021), and Usen (2022) indicated that students exposed to virtual labs outperformed those taught using conventional methods in terms of achievement, retention, and attitude. Shopi and Eka (2018) found that employing Phet software as a virtual lab to study waves and noise positively influenced cognitive development and improved the scientific lab environment. In their study on the effects of guided inquiry in virtual and physical laboratories, Husnaini and Chen (2019) discovered that both approaches were effective for different learning objectives. However, their findings suggested that while guided inquiry in virtual labs was equally effective as physical labs for simple concepts, it proved superior for teaching complex concepts and enhancing students' scientific inquiry self-efficacy Prof. Duro Ajeyalemi, in his memorial address at the 52nd annual conference of the Science Teachers Association of Nigeria (STAN, 2011 p 4), stated that "alternatives to practical work should be incorporated into our schools" in light of the difficulties presented by our practical courses. These according to him include presenting students with videotaped recordings of carefully designed demonstrations and computer simulations of experiments, such as magnetic and mechanical phenomena in physics which innovations in pedagogies have made feasible. Similarly, Aina (2013) noted that students can better understand the rotation of a coil in a magnetic field when demonstrated through software. He further emphasized that many physics teachers struggle to effectively explain the mechanisms of electric motors and generators due to their complexity. Virtual laboratories offer a viable teaching method to address these challenges and enhance learning in physics laboratory classes. Thus, the researchers deemed it necessary to investigate on virtual and physical laboratory applications on the verification of Ohm's law and undergraduate physics students' performance and retention in Port Harcourt.

Statement of the Problem

Teachers of physics have been carrying out laboratory practicals conventionally or through the traditional methods which have been vilified by several researchers. Scholars are also lamenting the poor performance of undergraduate physics students. Government, teachers, students and the university system share some of the blames in the failure. Ineffective teaching strategies were blamed by a number of scientific education professionals for the decline in students' physics proficiency. Because of the difficulties in using them, educators are quite concerned about the traditional ways of conducting laboratory sessions. The virtual laboratory which has brought in innovation in doing laboratory work earnestly demands attention. Some scholars have carried out research to prove or disprove its efficacy. Nonetheless, more work still needs to be done on use of the virtual and physical laboratory classes. In a nut shell, the major problem of this research work is to investigate which between virtual and physical laboratory applications of teaching and learning can improve undergraduate physics students' performance and retention.

Research Questions

The following research questions guided the study:

I. What are the differences in the mean performance scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics?
II. What are the differences in the mean retention scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics?

Hypotheses

This study was guided by the following hypotheses:

HO_1: There is no significant difference in the mean performance scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics.

HO_2: There is no significant difference in the mean

Table 1: Mean and Standard Deviation of the Pre-test and Post--test Performance Scores of Students in the VL, PL and DM Groups

Group	N	Pre-test mean	SD	Post-test mean	SD	Mean gain
VL	36	10.50	2.408	15.31	1.527	4.81
PL	36	10.53	2.118	11.78	2.244	1.25
DM	36	10.28	2.106	11.61	2.046	1.33

Table 2: Mean and Standard Deviation of the Pre-Test, Post Test and Retention Scores of Students in the VL, PL and DM Groups

Group	N	Pre-test mean	SD	Post-test mean	SD	Post-posttest	SD	Mean gain
VL	36	10.50	2.408	15.31	1.527	16.03	1.404	0.72
PL	36	10.53	2.118	11.78	2.244	11.69	2.352	-0.09
DM	36	10.28	2.106	11.61	2.046	11.17	2.467	-0.44

retention scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics.

METHODOLOGY

Two research questions and two hypotheses were formulated to guide this study. The design for the study was quasi experimental of the type, pretest-posttest, post-posttest control group design. The population of the study comprised of all year 2 undergraduate physics students of Ignatius Ajuru university of education, numbering one hundred and eight (108). Census Sampling Technique was used since same number of the population of one hundred and eight (108) of the study made up the sample size. Two experimental groups and one control group were used for the study. The instrument for this study is Physics Practical Test for the Verification of Ohm's Law (PPTVOL). The instrument was validated by an expert in science education and a physics lecturer. A reliability index of 0.72 was obtained for (PPTVOL). The study was made up of two experimental groups and one control group. Experimental group 1 and experimental group 2 were taught practical physics using a virtual laboratory (Circuit lab software) and guided inquiry method respectively while the control group was taught using the demonstration method. An adopted circuit lab software developed by Robbins (2021) was downloaded from this cite "circuitlab.com/cu5584wxrenxw" to teach the experimental group 1. Data were analyzed using mean and standard deviation to answer the research questions while Analysis of variance (ANOVA) and Post Hoc Test were used to test the hypotheses at 0.05 level of significance.

RESULTS:

Research Question 1: What are the differences in the mean performance scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics?

VL = Virtual Laboratory = Experimental group 1
PL = Physical Laboratory = Experimental group 2
DM = Demonstration Method = Control group

Table 1 shows that the pre- tests mean and SD for VL was 10.50 and 2.408, PL was 10.53 and 2.118 while that of DM was 10.28 and 2.106 respectively. A look at the means of the pre- test for the three groups revealed that students in VL scored higher on the pretest than those in the PL and DM group. Similarly, the post- test means and SD for VL was 15.31 and 1.527, PL was11.78 and 2.244 while that of DM was 11.61 and 2.046 respectively. Furthermore, the mean gain on the basis of the differences between the pre-test scores and post- test scores of each group indicated 4.81 for VL,1.25 for PL and 1.33 for DM as shown on Table 1. Consequently, a cursory look at the post- test mean scores for the three groups shows that students in VL group (15.31) again scored higher than those in PL group (11.78) and those in the DM group (11.61). The result is that students exposed to virtual laboratory performed better than their counterparts in the other groups. Results also showed that students taught with guided inquiry and those taught with the demonstration method almost had equal performance scores. That is none outperformed the other.

Research Question 2: What are the differences in the mean retention scores of students taught using virtual laboratory, physical laboratory and demonstration method in practical physics?

Table 2 shows the pre- tests mean and SD for VL was 10.50 and 2.408, PL was 10.53 and 2.118 while that of DM was 10.28 and 2.106 respectively. A look at the means of the pre- test for the three groups revealed that students in PL scored a little higher on the pre- test than those in the VL and DM group. Similarly, the post- test means and SD for VL was 15.31 and 1.527, GI was11.78 and 2.244 while that of DM was 11.61 and 2.046 respectively. Furthermore, the post-posttests mean and SD for VL was 16.03 and 1.104, PL was11.69 and 2.352while that of DM was11.17 and 2. 467.Also, the mean gain on the basis of the differences between the post- test scores and post-post test scores of each group indicated 0.72 for VL, -0.09 for PL and -0.44 for DM as shown on Table 2. Consequently,

Table 3a: Summary of ANOVA analysis on students' performance in the three groups

Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Decision
Between Groups	313.462	2	156.731	40.693*	.000	Significant
Within Groups	404.417	105	3.852			
Total	717.880	107				

*p < 0.05 = Significant

Table 4a: Summary of ANOVA analysis on students' retention in the three groups

Source of variation	Sum of Squares	Df	Mean Square	F	Sig.	Decision
Between Groups	512.241	2	256.120	56.543*	.000	Significant
Within Groups	475.611	105	4.530			
Total	987.852	107				

*p < 0.05 = Significant

a cursory look at the post-posttest mean scores for the three groups shows that students in VL group (16.03) again have better retention than those in PL group (11.69) and those in the DM group (11.17). The result is that students exposed to virtual laboratory have better retention than their counterparts in the other groups. Results also showed that students taught with guided inquiry have better retention than those taught with the demonstration method.

Hypothesis 1: There is no significant difference in the mean performance scores of students taught using virtual laboratory, physical laboratory and demonstration methods in practical physics. On further statistical analysis of the mean values using Analysis of Variance, the calculated F (2,105) = 40.693 is significant since p (.000) is less than 0.05 level of significant. Hence, the stated hypothesis is rejected (Table 3b). That is, there is significant difference in the mean performance scores of students taught using (VL, PL and DM) in practical physics. Table 3b is the post hoc analysis of the three groups on undergraduate students' academic performance in practical physics. The results revealed that there is significant difference between the performance of undergraduate physics students taught with VL and those taught with PL. There is also significant difference between students taught with VL and those taught with DM showing where the difference lies. However, there is no significant difference between the performance of undergraduate physics students exposed to guided inquiry method and those taught with demonstration met

Hypothesis 2: There is no significant difference in the mean retention scores of students taught using virtual laboratory, physical laboratory and demonstration methods in practical physics.

On further statistical analysis of the mean values using Analysis of Variance, the calculated F (2,105) = 56.543 is significant since p (.000) is less than 0.05 level of significant. Hence, the stated hypothesis is rejected (Table 4a). The result is that there is significant difference in the mean retention scores of students taught using (VL, PL and DM) in practical physics.

Table 4b: Post Hoc analysis of the three groups on students' retention

Group Comparison	Mean Difference	Sig. (0.05)	Decision
E1 versus E2	4.33*	.000	Significant
E1versus CG	4.86*	.000	Significant
E2versus CG	.528	.719	Not Significant

*p < 0.05 = Significant

Table 4b is the post hoc analysis of the three groups on undergraduate students' retention in practical physics. The results revealed that there is significant difference in the mean retention scores of undergraduate physics students taught with VL and those taught with PL. There is also significant difference in the mean retention scores of undergraduate physics students taught with VL and those taught with DM showing where the difference lies. There is no significant difference in the mean retention scores of undergraduate physics students exposed to PL and those taught with DM.

DISCUSSION

Table 3b: Post Hoc analysis of the three groups on students' performance

Group Comparison	Mean Difference	Sig. (0.05)	Decision
E1 versus E2	3.53*	.000	Significant
E1versus CG	3.69*	.000	Significant
E2versus CG	.167	.295	Not Significant

*p < 0.05 = Significant

The result of hypothesis 1 as shown in table 3a and 3b indicated a significant difference in the performance of undergraduate physics students taught with the virtual laboratory, physical laboratory (guided-inquiry approach), and demonstration method. Students who had the chance to learn physics via the virtual laboratory method outperformed their counterparts who did not. The findings of this research is consistent with those of Yildirim (2021), Babalola and Alabi (2021), Etukakpan (2021) and Usen (2022), all of whose studies showed that there is, in fact, a significant difference between students who were exposed to virtual laboratory method and those who were not. However, the findings of this study contradict the study conducted by Ambusaidi et al. (2018). The effectiveness of virtual laboratories in education is comparable to that of traditional teaching methods, according to the findings of those researchers.

The study also showed that there is no significant difference between the outcomes of undergraduate students taught physics using the physical laboratory (guided-inquiry approach) technique and those who were taught using the demonstration method. The result of this study run counter to the conclusions of previous research carried out by Baloyi et al. (2015) study which revealed that students who received instruction in a physical laboratory performed considerably better than those who did not. This study also contradicts the findings of the research conducted by Akinwumi and Bello (2015), who discovered that the students who participated in the inquiry-teaching approach performed better than their peers who were assigned to the control group.

Furthermore, the findings of hypothesis two, which are presented in tables 4a and 4b, there was discovered to be a statistically significant difference between the retention scores of undergraduate physics students taught using the virtual laboratory method, the physical laboratory(guided-inquiry method), and the demonstration method. The findings of this work indicated that the use of a virtual laboratory has the potential to boost students' long-term memory of previously learned material. Additionally, the results demonstrated that students who were taught in a virtual laboratory had a higher memory rate than those who were taught in a real laboratory or using the demonstration approach. The findings of this research is consistent with the findings of Usen (2022), whose study discovered that the retention of information by students improved and became better when the material was presented to them using a virtual laboratory. In contrast, Croom (2013) reported that students who participated in physical (hands-on) laboratory activities retained more knowledge than those who participated in virtual laboratory activities. He claims that the results of his investigation show a link between better long-term memory recall and a laboratory's hands-on component. This study also disagrees with Hussaini et al. (2021) work which found that physical and virtual laboratories improved secondary school students' retention towards geography more effectively than the lecture method. In addition, the findings of this research reveal that there is no significant difference, as measured by mean retention scores, between undergraduate physics students taught using the demonstration approach and those taught using the physical laboratory (guided inquiry) method. This study negates the findings of Akinwumi and Bello (2015) whose research showed that there is a significant difference, the reason being that students taught with the inquiry teaching approach have better retention than those in the control group.

Conclusion

From the findings of this study, the researchers concluded that virtual laboratory and physical laboratory (guided inquiry) applications improves performance and retention of students greatly in physics practical. However, this good performance cannot be achieved without a well-equipped computer classroom and a well-equipped traditional laboratory with qualified personnels. Additionally, this work has reaffirmed the notion that there are many innovative teaching pedagogies in the twenty-first century that ought to have an impact on today's university instructors and undergraduate students. Undoubtedly, integrating technology into our teaching methods would result in excellent students who can help Nigeria transition from a developing to a developed country while also boosting the country's economy. Also, teachers and students have not started adopting virtual laboratory method of teaching and learning. Therefore, physics teachers should embrace new technological methodologies to meet the evolving needs of today's physics students, adapt to emerging technologies, and keep pace with the constantly changing educational landscape. This if implemented by teachers is believe to be able to bring to the barest minimum, poor performance among undergraduate physics students. Importance should also be attached to physical laboratory classes. Consequently, the researchers are advocating that educational authorities should do more for school laboratories be it the conventional or digital (online).

Recommendations

Based on the findings of this study, the researchers recommended that:

1. Curriculum designers should establish a platform to develop professionals who will instruct teachers in the usage of virtual labs in workshops and seminars.
2. Teachers of physics at all educational levels should receive ongoing training on how to use the virtual laboratory.
3. Since virtual laboratories have been shown to increase performance and retention, they should be used as teaching tools in both our secondary schools and universities while teaching physics practicals.
4. Our higher education institutions should have a reliable and sufficient power supply; otherwise, the operation of a virtual laboratory will be hindered.
5. The government and other educational stakeholders should provide the physical laboratories with sufficient staffing and equipment.

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