IMPACT OF VIRTUAL PHYSICS LABORATORY ON STUDENTS' ACADEMIC ACHIEVEMENT IN PHYSICS

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Abstract
Practical science learning activities are relevant to both the acquisition of skills and the understanding of concepts. Unfortunately, there are considerable challenges in providing effective and efficient teaching of practical science. In most science classrooms across the economically developed countries, science learning has been supported and enabled for many years by a range of technologies that supplement traditional pedagogical approaches. However, the use of ICT in physics education in Africa's schools has been patchy and limited. This study examined the effectiveness of virtual physics laboratories on student understanding of physics concepts within an African context.120 secondary school students from two schools in south-western Nigeria were divided into experimental and control groups who carried out virtual and physical experimental activities respectively. Pre- and post-tests of conceptual understanding were administered to the groups and the results were analyzed using t-tests. Two hypotheses on the relative value of the two forms of learning activity and the relative performance of boys and girls were tested. The data showed that students that were engaged through the virtual physics laboratory performed better than students taught in the traditional physics laboratory. In the experimental group boys benefited more than girls from the virtual physics laboratory activities. Although these data are limited in scope they suggest that virtual laboratories could help in overcoming the challenges faced in the provision of traditional laboratories.
Key words: Practical physics, Learning technology, Physics education and Virtual learning

Introduction

Practical work constitutes a key component in the teaching and learning of physics. Bell (2004) states that practical work is not just about experiencing phenomena but also about thinking- a cognitive activity. According to Bell, practical work should be considered as a thinking activity in which each participant constructs understandings from experiences rather than being solely the domain of manipulative work with hands (Bell, 2004, p169).

The use of interactive computer-based simulations in which students experiment with virtual manipulation rather than physical manipulation is one approach for enhancing the effectiveness of practical work (Millar, 2010). Millar argues that ICT supports practical work by reducing 'noise' which can distract students when they carry out practical activities. In a typical activity, students have to deal simultaneously with the idea and concepts that give the activity meaning, the practical manipulation of apparatus and materials, perhaps involving some quite fine motor skills, the planning and sequencing of actions to carry out procedures and record outcomes and the social interactions involved in group work. ICT offers a way of reducing this noise. Babalola has pointed out that simulations allow students to learn from a viewpoint that stands somewhere between the practical and the theoretical (Babalola, 2017).

Previous research has showed that rapid advances in technology offer a wide range of new opportunities for innovative science and physics education. Jaakkole and Nurmi (2007) carried out research on the use of simulation and laboratory work among 66 students (10-11 years) in Finland. They found that a combination of simulation and laboratory experimentation on electric circuits led to statistically greater learning gains than the use of either simulation or laboratory activities alone, and that it also promoted students conceptual understanding most efficiently. In a similar study on the effectiveness of an interactive computer simulation for teaching basic electric circuit theory with undergraduate students in a large university in the USA, Finkelstein et al. (2005) noted that students who were exposed to simulations achieved higher scores both on assessment of conceptual knowledge and on a task involving assembling a real circuit and explaining how it worked. Parkinson in his book on *Improving Secondary Science Teaching* asserts that ICT has the potential to help pupils understand graphs through the various types of software that offer graphical display (Parkinson, 2004).

There is empirical evidence for the value of computer simulations in promoting learning. Zacharia and Anderson (2003) investigated the use of simulations presented before laboratory activities designed to develop students 'conceptual understanding of mechanics, waves and optics, and introductory thermal physics. The subjects in their study were postgraduate (in-service and trainee teachers) students without physics qualifications. Diagnostic written tests were used to assess understanding. The results indicated that exposure to simulation improved student's ability to offer acceptable predictions and explanations and led to significant conceptual changes in the area tested. In a recent study in Ghana, Antwi et al. (2014) investigated the effect of computer assisted instruction on Form 2 Senior High School (SHS) students' interests and attitudes towards some selected concepts in electricity and magnetism. They found that student interest was promoted and that the experience encouraged positive attitudes towards the teaching and learning of physics with computer assisted instruction.

Statement of the Problem

The conditions of most secondary schools in developing countries including Nigeria are not satisfactory for doing practical work. Some schools are without a physics laboratory while in some, the physics lab is meant to be shared with other science subjects for practical engagement with the students. At schools where there is equipment, teacher's claim that the school system does not allow enough time to do practical work. This is because teachers spend a lot of time doing administrative work and spend little or no time on practical work. Many of the teachers prefer to do demonstrations, which are very teacher-centered. The focus of many schools is on finishing the syllabus rather than on effective teaching and learning. Many learners do practical work for the first time at university level without having had the proper training and background on how to do such work. Practical work, which is supposed to be of great assistance and a motivating factor for students, has been a major source of problems for students. There is a mass failure in practical physics because of ignorance and neglect of some basic principles in the teaching of physics practical work (Okeke, 1999; Motlhabane, 2013; Institute of Physics (IoP), 2012). The majority of secondary school laboratories are not adequately equipped and this might hinder the teachers to use the much preferred practical approach. Hence the classroom situation is inadequate; and both the implemented and attained practical physics curriculum content is very low in Africa.

Objectives of the Study

This study was aimed at assessing the value of physics simulations at upper secondary level in Nigeria where the national curriculum objectives are as follows (NPE, 2004).

- To provide basic literacy in physics for functional living in the society;
- To acquire basic concepts and principles of physics as a preparation for further studies;
- To acquire essential scientific skills and attitudes as a preparation for the technological application of physics and
- To simulate and enhance creativity.

All these objectives whether general or specific can only be achieved when there is a connection between theory and practice. The study investigated the impact of the virtual physics laboratory compared to the physical laboratory in secondary schools in Ekiti State Nigeria. Specifically, the objectives of this study were: to establish the relative influence of virtual and physical laboratories on student understanding and to investigate whether the ICT intervention had different efficacy for girls and boys. In both cases, the analyses were based on the associated null hypotheses.

Research Hypothesis

The study tested the following null hypotheses:

1. There is no significant difference between the post-test performance of the control and experimental student's groups
2. There is no significant post-test difference between the performance of boys and girls taught using the virtual physics laboratory

Methodology Research Design

This study involved the use of a quantitative quasi experimental pre-test posttest control group design in which students were randomly assigned into experimental and control group. The two groups were pre-tested on the dependent variables before the implementation of the study and then post-tested after the treatment has been administered. Table 1 below show the design.

Table 1: Experimental design of the study

Experimental Group	O_1	X_1	O_2
Control Group	O_3	X_2	O_4

Where O_1 and O_3 represent pre-test, X_1= virtual lab method, X_2= physical lab method. Also O_2 and O_4 represent post-test. In this study, the independent variable was the teaching method (Virtual lab versus Physical lab methods). The dependent variables were the students' conceptual understanding of the physics topics taught by the teacher.

Population and Sampling Techniques

The study was based in two selected secondary schools in the Ado Local Government Area of Ekiti State, Nigeria. Both schools offer physics and have also presented candidates for the West African Senior School Certificate Examination (WASSE) in practical physics for 20 years. Opportunistic sampling techniques were used. 120 Senior Secondary school (SS3, Grade 12) science students were the subjects in the study. They had been taught physics for two years and had well developed attitudes to the subject.

Validation and Reliability of Instrument

The research instrument used in collecting data for the study was the Physics Achievement Test (PAT) which was designed by the researcher. Section A of the PAT consisted of information on bio data of the respondent while section B consisted of 20 multiple choice items that covers topic on Electricity, Light and Heat. Expert judgments were used to determine the face and content validity of the instrument. The instrument was trial-tested to establish the reliability of the instrument in the school not used for the main study. Split-half method was used to determine the reliability and reliability coefficient of 0.82 was obtained.

Research procedure

Permission was sought from the subject teachers of the selected schools before giving the students the test and the practical lessons. The selected one-hundred and twenty (120) students were divided into two groups of sixty (60) students. Both the control and experimental groups consisted of thirty-six (36) boys and twenty-four (24) girls. The gender difference reflects the gender differences in the class populations.

A pre-test that comprised twenty (20) items with three options was given to all students before the lessons were delivered. After the pre-test, the students in both groups were taught the following topics from the Grade 12 physics curriculum: mechanics, light and electricity. The control group was taught in the classroom and in the physical laboratory for the practical activities associated with the topics. The experimental group had the same classroom lessons with exposure to the virtual physics laboratory for the associated practical work. The school used for the control group possesses a physics laboratory with limited practical equipment while the other school had a computer laboratory which housed about 100 computers. The virtual experiments were mounted on 60 computers and presented to the students as a virtual physics laboratory. After the lessons in both groups, the post-test was given to the students and their response booklets were collected for assessment. The physics lessons were taught by the cooperate teachers in both school. The process lasted for eight weeks.

Data Analysis

The data collected were analyzed using mean and t-test statistics at 0.05 level of significance.

Results

To find out the differences in performance of students taught using the virtual physics laboratory and those taught without the virtual physics laboratory before the test was administered, the mean of the pre-test scores of students were compared. The results are shown in Table 1 below:

Table 1: Mean of pre-test scores of students.

	Male		**Female**		**Total**	
	N	Mean	N	Mean	N	Mean
Experimental group	36	10.89	24	13.80	60	12.34
Control group	36	11.89	24	14.33	60	13.11

The mean for the experimental group is 12.34 while that of the control group is 13.11. The difference in the performance level of both groups is insignificant. This might be expected as the groups were not taught or exposed to tailored learning experiences before the test level. was administered. The learning environments in the schools are broadly similar and they achieve similar results. As a result of this, the pre-test performances of the groups are almost at the same

Table 2: Mean of students' post-test scores

	Male		**Female**		**Total**	
	N	Mean	N	Mean	N	Mean
Experimental group	36	27.67	24	30.50	60	29.09
Control group	36	21.44	24	21.17	60	21.31

Table 2 shows the mean of students' scores in the post test both in the experimental and control groups. The mean of the experimental group (29.09) is higher than the mean of the control group (21.31). The difference is 7.78is very significant. The higher mean score in the experimental group is due to the exposure of students to the VPL during the teaching-learning process. But the mean score is low in the control group expose to the physical laboratory.

To compare the performance of the students before teaching and learning activities and after learning experiences have been administered, the mean of the pretest and post-test scores were compared. The result is presented in table 3.

Table 3: Comparison of the pre-test and post-test mean score

	Male		**Female**		**Total**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**	**N**	**Mean**
Experimental group	36	36	24	24	60	41.43
Control group	36	36	24	24	60	34.42

The table above shows clearly the performance of the group in the pre-test and post-test. The experimental group had mean score 41.43 and the control group has 34.42 mean score. However, a closer look at the table above revealed that there was an increase in the performance of students across the group after the treatment. From the table, the pre-test and post-test mean score for experimental group is 12.34 and 29.09 respectively give the difference of 16.75, the high mean score of the post-test experimental group is due to the use of the VPL. On the other hand, the pre-test mean score and post-test mean scores for control group is 13.11 and 21.32 respectively which give the difference of 7.2, the little difference was due to the exposure to the VPL that was not used when the lessons were administered in the control group. However, it can be observed that students in the experimental group performed better than those of the control group due to the VPL.

Hypothesis 1

There is no significant difference between the post-test performances of the control and experimental student groups. The results of the t-test analysis for the post test scores are shown in Table 4.

Table 4: t-test analysis of the performance of the control and experimental student groups.

Group	N	Mean	Standard deviation	Df	Total	T-table
Experimental	60	29.09	5.65	58	8.55	1.69
Control	60	21.31	4.17			

From Table 4 above, since the calculated t-value (8.55) is greater than the table value (1.69) at 0.05 level of significant, hypothesis 1 is therefore rejected. This implies that there is significant difference in the performance of students taught using the virtual physics laboratory and those taught without virtual physics laboratory.

Hypothesis 2

There is no significant post-test difference between the performance of boys and girls taught using the virtual physics laboratory. The t-test analysis for the post-test performances is presented in Table 5.

Table 5: t-test analysis on the performance of boys and girls taught using the virtual physics laboratory.

Group	N	Mean	Standard deviation	Df	T cal	T-table
Experimental Boys	36	26.67	5.51	58	7.25	1.70
Experimental Girls	24	30.50	6.02			

Since the calculated t-value (7.25) is more than the table value (1.70) at 0.05 level of significant, hypothesis 2 is rejected. This implies that there is significant difference in performance between the boys and girls taught using virtual physics laboratory.

Summary of Results

1. The students in both groups performed equally in the pre-test scores
2. The students in the experimental group performed significantly better than the students in the control group in their post-test scores
3. The girls perform better than the boys in the experimental group when exposed to the virtual physics laboratory.

Discussion

The pre-test results show that there is no significant difference between the experimental and the control group performances, implying that both groups have the same background knowledge of physics. In addition, Table 1 shows that there is no significant difference between the performance of the boys and girls. These data are important as they offer post hoc justification for framing the two groups around two different schools. Although not conclusive it eliminates some potentially confounding factors that arise from the practical requirement of delivering the two forms of practical experience. The means of the post-test scores showed that the experimental group performance is better than that of the control group simply because of the judicious use of the virtual physics laboratory in teaching them. The virtual physics laboratory made them to understand the concept taught the more and in consequence, made them to score higher marks. The result of hypothesis showed that student in experimental group performed better than the students in the control group. It can therefore be concluded that utilization of virtual physics laboratory most especially in areas with acute shortage of laboratory apparatus makes the teaching and learning of physics more meaningful to the learners. These findings are in line with previous studies in Finland and USA (Jaakkole & Nurmi (2008), Finkelstein etal. (2005))

The virtual physics laboratory employed in teaching the selected topics have facilitated the understanding and grasping of the content of the topics. Therefore, if the use of virtual physics laboratory is strictly adhered to and competently handled in our secondary schools, this will lead to a better performance from the students and in creating more interest in physics as a science subject.

Conclusions

Although this study only provides limited data on a complex issue, the main result is striking. There is a highly significant improvement in understanding in those students who had the learning experience of a virtual laboratory. This can be contrasted with the impoverished learning environment provided by the poorly equipped laboratories in most schools. It should be remembered that most students are only familiar with the theoretical aspects of physics from the classroom experience without any meaningful engagement with the practical aspects of what they have learned. Many physics teachers attach little or no importance to practical based methods of teaching physics. They tend to believe that spoken words alone are enough for teaching and the only methods necessary are the chalkboard. This assertion has been shown to be inadequate by this study.

Enhanced use of ICT in practical physics will be an inevitable part of the future landscape but there are barriers to adoption, most importantly the reasonable hesitations of scientists who are sceptical about the loss of physical presence and the lack of opportunity to practice traditional skills, particularly in manipulation. However, given the present lack of access to practical science in Sub-Sahara Africa, such losses would be a limited price to pay. It is also important to address the issue of training and retraining of physics teachers in the use of educational technologies. 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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