Teaching Efficiency
Ефективност на обучението

TEACHING AND LEARNING EFFICACY OF VIRTUAL LABORATORY PACKAGE ON SELECTED NIGERIAN SECONDARY SCHOOL PHYSICS CONCEPTS

[1]Oluwole Caleb Falode, [2]Samuel Adenubi Onasanya
Federal University of Technology, Nigeria
University of Ilorin, Nigeria

Abstract. The study investigated the teaching and learning efficacy of virtual laboratory package on three Nigerian secondary school physics concepts. Three research questions were raised while two hypotheses were tested. The study adopted mix-method for analysis. A quasi-experimental procedure involving two levels of independent primary variable and one dependent variable was used while questionnaire was used to elicit responses of physics teachers who evaluated the Virtual Physics Laboratory Package (VPLP). Purposive sampling technique was employed to select 22 physics teachers and 60 physics students from Federal Government Colleges in Nigeria. Intact classes of secondary school class two physics students were randomly assigned to experimental and control groups. VPLP, physics teachers' evaluation questionnaire and physics achievement test were used as research instruments after have been determined to be valid and reliable for the study. Data gathered from the administration of research instruments were analyzed using mean, standard deviation and t-test statistic in SPSS 16.0 version. Findings revealed that physics teachers agreed that VPLP satisfies the objectives and procedures of learning simple pendulum, Hooke's law and momentum experiments with average mean response of 2.85 out of 5, there was no significant difference between the mean achievement scores of students taught the selected physics concepts using virtual physics laboratory package and those taught using conventional laboratory instruction $t(58) = 0.139$, $p > 0.05$. The package was found adequate and effective in the teaching and learning of selected physics concepts. Hence it was recommended that physics students should endeavor to explore the opportunities offered by virtual physics laboratory package for revision purpose as well as for individualized learning of physics experiments.

Keywords: achievement, efficacy, learning, physics, teaching, virtual laboratory

Introduction

The application of computer technology in classroom environment has a significant role in enhancing teaching and learning. For instance, the use of artificial educational

environment such as simulations and virtual reality in teaching and learning is increasingly becoming widespread and has proven to be effective in teaching difficult subjects in science for over two decades (Babateen, 2011; Kennepohl, 2011).

The technological development of any nation lies in the study of science. Science comprises of basic disciplines such as physics, chemistry, biology and mathematics. Essentially, science and technology would be incomplete without physics. It has proven its benefits to mankind as almost every human activity and virtually every profession involves some element of physics (Gambari, 2010).

However, in spite of the importance of physics to technological development and as a requirement for many specialized science and engineering courses at the universities and other tertiary institutions, a large number of students still perform poorly in physics at Senior School Certificate Examination (SSCE) in Nigeria. Table 1 and Fig. 1 show students' performance in SSCE physics conducted by West Africa Examinations Council in Nigeria from 2007 to 2011.

Table 1 and Fig. 1 revealed that only 43.19% of the students that sat for SSCE physics in 2007, 48.26% in 2008, 47.83 in 2009, 51.27% in 2010 and 63.94% in 2011 got at least credit pass in the subject while the rest failed. Gambari, et al. (2012) and Biodun (2004) attributed poor performance of students in science, particularly in physics to lack of qualified teachers, poor instructional strategies, poor infrastructure and non-availability of standard laboratory and poor utilization of instructional materials.

Table 1. Students' performance in SSCE physics between 2007-2011

Year	Total Entry	(%)	Total Pass (A1-C6)	(%)	Total Fail (D7-F9)	(%)
2007	418660	100	180797	43.19	228652	54.61
2008	415170	100	200345	48.26	207892	50.07
2009	465656	100	222722	47.83	221514	47.57
2010	463716	100	237756	51.27	207133	44.67
2011	563172	100	360096	63.94	181394	32.21

Source: WAEC Chief Examiner's report (2007-2011)

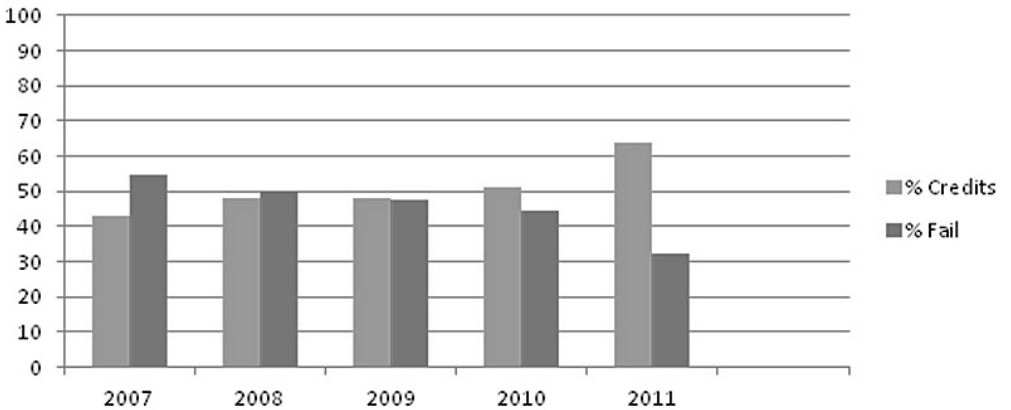

Fig. 1. Graphical representation of students' performance in SSCE physics conducted by WAEC, 2007-2011

The poor performance in physics recorded on the concepts of mechanics are mainly in the area of elasticity properties of solid, kinetic theory, simple harmonic motion and this menace is connected to inability of students to understand contents while studying independently and poor skills in physics laboratory exercise. One innovation that supports students' independent study and interactive engagement in learning process is virtual laboratory.

Virtual laboratory is an interactive environment without real laboratory tools meant for creating and conducting simulated experiments (Babateen, 2011; Harry & Edward, 2005). It provides students with tools and materials set on computer in order to perform experiments saved on CDs or on web site (Babateen, 2011). Several studies have been carried out on the effects of virtual laboratory on students' achievement. Kerr et al. (2004) found that students' performance in chemistry was improved when taught using virtual laboratory, Tuysuz (2010) found that virtual laboratory improved students' achievement and attitude towards chemistry, Murniza, et al. (2010) found that virtual laboratory improved students' performance in biology and Gambari, et al. (2012) in another study found that students taught physics practical using virtual laboratory strategy performed better than those taught using conventional laboratory method.

Gender has been described as one of the factor that influences students' performance in science subjects. While some studies have proven that male students performed better than their female counterparts in learning process, others have shown that female students performed better (Yusuf, 2004). However, Gambari, et al. (2012) in a study

observed that there was no significant difference between the mean achievement scores of male and female students taught physics practical using virtual laboratory strategy.

This study was therefore carried out to determine whether virtual physics laboratory package will be effective in the teaching and learning of Nigerian secondary school simple pendulum, Hooke's law and momentum experiments irrespective of students' gender.

Research questions

The study provided answers to the following research questions: (1) do physics teachers consider the virtual laboratory package adequate to meet the objectives of learning simple pendulum, Hooke's law and momentum experiments in Nigerian secondary school physics curriculum; (2) is there any difference in the mean achievement score of physics students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package and those taught using conventional laboratory; (3) is there any difference in the achievement score of male and female physics students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package.

Research hypotheses

Ho_1. There is no significant difference between the mean achievement score of secondary school students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package and those taught using conventional laboratory.

Ho_2. There is no significance difference between the mean achievement score of male and female secondary school physics students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package.

Methodology

The study was an evaluation research which involved the use of mix-method for analysis. To determine the learning effectiveness of virtual laboratory package on secondary school physics students' achievement in physics, a quasi-experimental procedure (pretest, posttest, non-randomized, experimental and control groups) was used with two levels of independent primary variable. The independent variables were the Virtual Physics Laboratory Package (VPLP) and the Conventional Physics Laboratory Instruction (CVLI) while the dependent variable was the post-test performance of the students. To determine the teaching and learni9ng functions of the virtual laboratory package, questionnaire was used to elicit needed information from physics teachers who evaluated the package.

The population for this research consisted of all physics teachers and SSII physics students in secondary schools in Nigeria. Samples for the study were selected from Federal Government Colleges in southwest Nigeria because of equivalence of their schools in terms of physics laboratories, computer laboratories, being co-educational schools, availability of physics teachers and students' exposure to computer-based learning. Purposive sampling technique was employed to select five co-educational Federal Government Colleges in southwest Nigeria from where physics teachers were purposively sampled to evaluate the package. Also, simple random sampling technique was employed to select two out of the five sampled schools from where two intact classes of SSII physics students were selected and assigned to each of the experimental and control group.

Three research instruments were used for the study. They are Virtual Physics Laboratory Package (VPLP), Physics Teachers' Virtual Physics Laboratory Package Evaluation Questionnaire (PTVPLPEQ) and Physics Achievement Test (PAT). The package was developed using Adobe Flash CS6. The programming language used was Actions script 3.0 while the Graphic User Interface (GUI) was created using Adobe Fireworks CS6. Box2D was used for the physics simulation engine and Camstudio software was used in recording the video tutorial. The package is meant for performing three SSII physics experiments (simple pendulum experiment, Hooke's law experiment and momentum experiment). The entrance menu of the package consisted of introduction/ student's registration edifice, list of practical lessons (Lessons 1-3) and exit button. The main menu is divided into three sections, namely, lesson note section, where the learner is able to study the content for the experiments; Video section, where the learner is able to watch tutorial of how to use the package; and laboratory section where the learner is able to perform the experiments virtually.

PTVPLPEQ was adapted[2)] and employed to elicit responses from physics teachers based on their evaluation of VPLP in terms of teaching and learning functions. The questionnaire was divided into two sections (Sections A & B). Section A was designed to collect demographic information of the respondents. Section B was designed using the 4-point Likert scale (namely, 1 as Strongly Disagree, 2 as Disagree, 3 as Agree and 4 as Strongly Agree) and it contains statement in line with the evaluation of teaching and learning functions of the package.

PAT was adapted from Senior Secondary School Examinations past questions (2006-2010) conducted by West African Examinations Council (WAEC) and National Examinations Council (NECO). It consisted of 30 multiple choice objectives question items on the concepts treated in the package. Each of the items of the test had four options (A-D) out of which students were to indicate correct answers by ticking the correct ones.

VPLP, PTVPLPEQ and PAT were validated by four computer experts, two physics teachers and four educational technology experts. The reliability coefficient of PT-VPLEQ and PAT (in a single administration on five physics teachers and twenty-one physics students) yielded 0.90 and 0.95 using Cronbach's alpha and Kudar Richardson (KR-21) formula respectively.

The data gathered from the administration of research instruments were analyzed using qualitative and quantitative statistic. A four-point Likert rating scale of Strongly Agree (4 points), Agree (3 points), Disagree (2 points) and Strongly Disagree (1 point) was used in weighing responses to items in the questionnaire. A mean response below 2.50 was considered disagree while a mean response of 2.50 and above was considered agree. The two hypotheses were tested using t-test statistics in Statistical Package for Social Sciences (SPSS) version 16.0 and the significance of the statistical analyses were ascertained at 0.05 alpha level.

Results

Teaching and learning functions of Virtual Physics Laboratory Package (VPLP) were evaluated by 24 secondary school physics teachers and 29 SSII physics students.

Research question 1: Do physics teachers consider the virtual laboratory package adequate to meet the objectives of learning simple pendulum, Hooke's law and momentum experiments in Nigerian secondary school physics curriculum?

Table 2. Mean response of physics teachers' evaluation of teaching and learning functions of virtual physics laboratory package

S/N	Statement	N	SA	A	D	SD	Mean	S. Dev.	Decision
1	Virtual physics laboratory package will help to attain the objectives of learning simple pendulum, Hooke's law and momentum experiments	24	8	10	3	3	2.95	0.45	Agree
2	Learning through virtual physics laboratory package will help to develop psychomotor and cognitive skills in learners	24	7	10	4	3	2.87	0.37	Agree

3	Learning contents of simple pendulum, Hooke's law and momentum experiments are effectively captured in virtual physics laboratory package	24	6	8	6	4	2.66	0.16	Agree
4	Virtual physics laboratory package put every required steps and procedures of learning simple pendulum, Hooke's law and momentum experiments in appropriate learning shapes	24	10	7	3	4	2.95	0.45	Agree
5	Learning simple pendulum, Hooke's law and momentum experiments through virtual physics laboratory package will be as effective as learning it in a conventional physics laboratory	24	7	9	5	3	2.83	0.33	Agree
	Average Mean						**2.85**		

Table 2 shows the mean response of physics teachers' evaluation of virtual physics laboratory package in terms of teaching and learning functions. The table reveals that the mean response to each of the five items is above 2.50 while the average mean of the five items is 2.85. This indicates that physics teachers agreed that the virtual physics laboratory package satisfies the objectives and procedures of learning simple pendulum, Hooke's law and momentum experiments.

Hypothesis one: There is no significant difference between the mean achievement score of secondary school students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package and those taught using conventional laboratory.

Table 3 shows the t-test pre-test analysis on achievement scores of experimental and control groups before treatment was administered. The average mean scores of experimental and control groups are 24.93 and 26.03 respectively. The t-value of 1.161 was not significant at 0.05 level. This indicates that there was no significant difference between students in the experimental and control groups at the pre-test $t(58) = 1.161$, $p > 0.05$. Hence the two groups are equivalent and comparable.

Table 3. t-test pre-test analysis on achievement scores of experimental and control groups

Group	N	df	Mean	SD	t-value	p-value
Experimental	29		24.93	5.96		
		58			1.161^{ns}	0.393
Control	31		26.03	3.78		

ns: not significant at 0.05 level

Table 4. t-test post-test analysis on achievement scores of experimental and control groups

Group	N	df	Mean	SD	t-value	p-value
Experimental	29		59.34	9.79		
		58			0.139^{ns}	0.757
Control	31		60.16	10.46		

ns: not significant at 0.05 level

Table 4 presents the t-test post-test analysis of the experimental and control groups. The average mean scores of the experimental and control groups are 59.34 and 60.16 respectively. The t-value of 0.139 was not significant at 0.05 level. This indicates that there is no significant difference between the mean achievement scores of students taught simple pendulum, Hooke's law and momentum experiments using virtual physics laboratory package and those taught using conventional laboratory $t(58) = 0.139$, $p > 0.05$. Hence hypothesis one was not rejected.

Hypothesis two: There is no significance difference between the mean achievement score of male and female secondary school physics students taught simple pendulum, Hooke's law and momentum experiments using virtual laboratory package.

Table 5 presents the t-test analysis of the achievement scores of male and female students taught physics experiments using virtual physics laboratory package. The average mean scores of male and female students are 60.38 and 58.08 respectively. The t-value of 0.462 was not significant at 0.05 level. This indi-

cates that there is no significant difference between the achievement scores of male and female students taught simple pendulum, Hooke's law and momentum experiments t (27) = 0.462, p > 0.05. Hence hypothesis two was not rejected.

Table 5. t-test analysis on achievement scores of male and female students exposed to virtual physics laboratory package

Variable	N	df	Mean	SD	t-value	p-value
Male	16		60.38	10.64		
		27			0.462^{ns}	0.540
Female	13		58.08	8.90		

ns: not significant at 0.05 level

Discussion of findings

The result of the evaluation of teaching and learning functions of VPLP by physics teachers indicated that the package satisfies the objectives and procedures of learning the selected concepts. This finding is in line with the recommendation of Bates (1995) that learning technologies should meet learners' needs and that such needs should determine the approach and technology to be selected. The finding also agrees with the recommendation of Barbour & Reeves (2009) that virtual laboratory should be perfectly developed to meet the educational needs of learners for meaningful learning to take place.

The result of the analysis of the achievement scores of students at pretest and posttest (before and after exposure to VPLP) indicated that there was a significant improvement in the performance of students after learning simple pendulum, Hooke's law and momentum experiments using the package. Also, these students did not perform significantly different from their colleagues that learnt the same experiments using conventional laboratory. This finding agrees with the earlier findings of Murniza, et al. (2010), Mahmoud & Zoltan (2009) who found that virtual laboratory instruction improves students' academic achievements in science-based subjects. This finding also agrees with the earlier finding of Kerr, et al. (2004) who found that students who learnt chemistry through virtual laboratory performed well as their colleagues taught using traditional laboratory.

This finding however contradicts the earlier finding of Efe & Efe (2011) who found that students taught biology using virtual laboratory performed significantly better in

posttest than their counterparts taught using traditional laboratory. It also contradicts the finding of Tuysuz (2010) who found that students taught chemistry through virtual laboratory were more successful than those taught through traditional chalk and talk method. This finding is also not in agreement with the earlier finding of Gambari, et al. (2012) who found that students' taught physics practical using virtual laboratory strategy performed better than those taught using conventional laboratory method.

It can be deduced from this finding that the use of virtual physics laboratory package improves the performance of students just as the conventional laboratory does. The package, though very effective, should not be adopted to replace the conventional physics laboratory because of the missing real life experience in virtual laboratory learning which students enjoy in conventional one. Hence, the package should only be used to supplement and complement conventional laboratory instruction.

The result of the analysis on influence of gender on the performance of students exposed to Virtual Physics Laboratory Package (VPLP) indicated that both male and female students that learnt simple pendulum, Hooke's law and momentum experiments using VPLP did not perform significantly different. This finding agrees with the earlier finding of Gambari, et al. (2012) who found that there was no significant difference between the mean achievement scores of male and female students taught physics practical using virtual laboratory strategy. The researcher could not locate any other previous research on influence of gender on students' performance when instructed using virtual laboratory to support or oppose this present finding.

Conclusions

The result obtained from the data gathered and analyzed in this study indicated that the virtual laboratory package covers the required physics concept and content in the topic treated because physics teachers who evaluated the package rated the teaching and learning functions of it, in terms of objectives and procedures of learning the topics, satisfactory. The package was tested and found effective without gender disparity for learning simple pendulum, Hooke's law and momentum experiments in secondary school physics curriculum.

Recommendations

Based on the major findings of this study, the following recommendations were made: (i) Physics teachers should encourage the use of virtual physics laboratory package by students in their schools in order to enhance learning physics practical; (ii) Physics teachers should expose students to virtual learning strategies to promote students' autonomy to knowledge acquisition, discovery learning and student-centred instruc-

tional approach; and (iii) Students should endeavor to explore the opportunities offered by virtual physics laboratory package. The package can be utilized for revision purpose as well as for individualized learning.

NOTES

1. http://www.tlaweb.com/resources/VPLab_Handbook.pdf
2. http://www.slideshare.net/u059087/proposal-for-course-evaluation

REFERENCES

Babateen, H. M. (2011). *The role of virtual laboratories in science education.* Singapore: IACSIT.

Barbour, M.K. & Reeves, T.C. (2009). The reality of virtual schools: a review of the literature. *Computers & Education, 52*, 402-416.

Bates, A.W. (1995). *Technology, open learning and distance education*. London: Routledge.

Biodun, K. (2004). *A comparative study of the effect of teacher's qualification and teaching methods on students' achievement in chemistry*: *PhD thesis*. Calabar: University of Calabar.

Efe, H.A. & Efe, R. (2011). Evaluating the effect of computer simulations on secondary biology instruction: an application of bloom's taxonomy. *Scientific Research & Essays, 6,* 2137-2146.

Gambari, A.I. (2010). *Effectiveness of computer-assisted instructional package in cooperative settings on senior school students' performance in physics, in Minna, Nigeria: PhD thesis.* Ilorin: University of Ilorin.

Gambari, A.I., Falode, O.C., Fagbemi, P.O. & Idris, B. (2012). Effect of virtual laboratory strategy on the achievement of secondary school students in Nigeria. *Proceedings 33rd Annual Convention and National Conference of Nigeria Association for Educational Media and Technology (NAEMT*) held at Emmanuel Alayande College of Education, Oyo, Oyo State. October, 8-13.

Harry, E. & Edward, B. (2005). Making real virtual lab. *Science Educ. Rev., 4*(1), 2-11.

Kennepohl, D. (2011). Using computer simulations to supplement teaching laboratories in chemistry for distance delivery. *J. Distance Education, 16*(2), 58-68.

Kerr, M.S., Rynearson, K. & Kerr, M.C. (2004). Innovative educational practice: using virtual labs in the secondary classroom. *J. Educators Online, 1*(1), 1-9.

Mahmoud, A. & Zoltan, K. (2009). The impact of the virtual laboratory on the hands-on laboratory learning outcomes, a two years empirical study. *20th Australasian association for Engineering Education Conference. University of Adelaide, 6-9 December, 2009.*

Murniza, M., Halimah, B., & Azlina, A. (2010). Virtual laboratory for learning biology – a preliminary investigation. *Word Academy Science, Engineering & Technology, 1*, 272-575.

Tuysuz, C. (2010). The effect of the virtual laboratory on students' achievement and attitude in chemistry. *Intern. Online J. Education Sciences, 2*(1), 37-53.

Yusuf, A. (2004). *Effects of cooperative and competitive instructional strategies on junior secondary school students' performance in social studies, in Ilorin, Nigeria: PhD thesis*. Ilorin University of Ilorin.

✉ **Dr. Oluwole Caleb Falode,**
Science Education Department
Federal University of Technology, Minna
Minna, Nigeria
E-mail: facominsight2@gmail.com

✉ **Dr. Samuel Adenubi Onadanya**
Department of Educational Technology
University of Ilorin, Ilorin, Nigeria