EVALUATION OF VIRTUAL LABORATORY PACKAGE ON NIGERIAN SECONDARY SCHOOL PHYSICS CONCEPTS

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ABSTRACT

The study evaluated accessibility, flexibility, cost and learning effectiveness of researchers-developed virtual laboratory package for Nigerian secondary school physics. Based on these issues, four research questions were raised and answered. The study was a quantitative-based evaluation research. Sample for the study included 24 physics teachers, 35 computer experts and 29 physics students who evaluated the package using a questionnaire and physics achievement test. Data gathered were analyzed using descriptive statistics including mean and standard deviation. Findings from the study revealed that the package was adjudged accessible to students within the school (average mean response of 2.98 out of 5), the flexibility of the package was rated low (average mean response of 2.35 out of 5), and the package, though expensive to develop (total amount spent = $587.50) was considered profitable considering its unquantifiable educational benefits. Also, there was improvement in the achievement scores of students after learning the physics concepts using the package with mean gain score of 33.45. Based on these findings, it was recommended that, developers of learning packages such as virtual laboratories should ensure high flexibility of the packages in order to improve students' access to such on mobile devices and internet, and government should assist schools financially by providing needed funds for the development of contextually relevant learning packages as their benefits to students' learning of physics concepts are enormous.

Keywords: **Accessibility, achievement, cost, evaluation, flexibility, physics, virtual laboratory.**

INTRODUCTION

Advancement brought to teaching and learning by media and telecommunication technology cannot be over-emphasized. The rapid development in computer accompanied by ease of use, flexibility, storage effectiveness, suitability, reliability, versatility and interactive nature of the technology as an instructional medium for individualized instruction, have attracted educators more than any other medium ever developed as instructional delivery mode (Onasanya, 2004; Sadik, 2003).

As computers become more prevalent in education, students' familiarity with the technology has enabled the development of virtual reality tools (Kew, et al., 2003). In science and engineering education, virtual laboratories have emerged as alternative or supplementary

tools of the hands-on laboratory education, for instance, using them for preparing for the real laboratory task (Mahmoud & Zoltan, 2009). 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 website and it has been proven to improve students' performance in science based subjects globally (Babateen, 2011; Nunn, 2009). For instance, Murniza, Halimah, and Azlina, (2010) and Mahmoud and Zoltan (2009) found that virtual laboratory instruction improves students' academic achievements in science-based subjects.

There exists a danger that multimedia and other emerging technologies are being used in teaching and learning process simply because they are novel and available without an appropriate conceptual framework to guide their development and selection, hence, intended objectives may not be achieved (Bates, 1995). Facilities in many conventional physics laboratories in Nigerian schools are inadequate and where they are adequate, the laboratory is only opened to learners during the school working hours.

Students need adequate access to new technologies which increase flexibility of learning (Bates, 2000). This entails provision of adequate computers and/or network access, consideration of the varied needs of different groups of learners. There is improvement in student's accessibility to learning technologies in Nigeria because most schools are now well equipped with adequate and functional computers which according to Farida and Ezra (2005) are the basic requirement for facilitating access to computer-based learning activities. This was also observed and stressed by Kasozi (2003) that computers have increasingly become both exercise books and textbooks for students and this makes learning through technology easier. Barbour and Reeves (2009) were of the opinion that for virtual laboratory to meet the educational needs, it must provide a high level of flexibility in order to ensure freedom from constraints of time and place which hinder access.

Bates (1995) considered cost as an important determinant for selecting technologies. Cost is often the first issue considered by institutional decision-makers and administrators while making decision on the choice of technologies to be selected in teaching and learning process. It is likely that new technologies will be of high cost but since such increase pedagogical effectiveness, they will therefore be considered to be profitable (Bates, 2000). In spite of the high cost of developing learning packages, students taught using such technologies are worth the money spent on their development (Bartolic-Zlomislic & Bates, 1999). Although the cost of developing and utilizing learning packages can be expensive, the pedagogical values of such packages outweighed their cost implications. Once the package has been developed, it can be installed on computers, reproduced or uploaded on the internet and can eliminate the need for physical sets of expensive equipment; it can be employed to supplement conventional laboratory instruction; it can be stored permanently and used repeatedly, it can be used for individualized learning and for revision purposes, thus enhancing learning and understanding; conventional laboratory injuries can also be avoided among several other benefits (Manjit, et al., 2003).

PURPOSE OF THE STUDY

The purpose of the study was to evaluate a virtual laboratory package on physics concepts for Nigerian secondary schools. The accessibility, flexibility, cost-effectiveness and learning effectiveness of the package was evaluated by physics teachers, computer experts and physics students in Federal Government Colleges in South-western states of Nigeria.

Research Questions

- **Do physics teachers consider the virtual laboratory package on selected physics concepts accessible to Senior Secondary School II (SSII) physics students in Nigeria?**
- **Do computer experts consider the virtual laboratory package on selected physics concepts flexible for learning secondary school simple pendulum, Hooke's Law and momentum experiments?**
- **What is the cost structure of developing virtual laboratory package on selected physics concepts?**
- **Is the virtual laboratory package on selected physics concepts cost-effective in teaching and learning of secondary school simple pendulum, Hooke's Law and momentum experiments?**
- **Is there any improvement in the mean achievement score of physics students taught simple pendulum, Hooke's Law and momentum experiments using virtual laboratory package?**

RESEARCH METHODS AND MATERIALS

The study was a quantitative-based evaluation research. The investigation involved the use of researchers' adapted questionnaire to elicit needed information from physics teachers and computer experts who evaluated a virtual laboratory package in terms of accessibility and flexibility. Furthermore, to determine the learning effectiveness of the package, a physics achievement test was administered as pretest and posttest on secondary school students before and after performing physics experiments through the package. The researchers determined the cost effectiveness and cost implications of the package.

Participants

The population for this research consists of all secondary school physics students, physics teachers and computer experts in Nigeria. Purposive sampling technique was employed to select 24 physics teachers, 35 computer experts from five co-educational Federal Government Colleges in southwest Nigeria. The experts were purposively selected because of their relevance to the evaluation task and because of equivalence of their schools in terms of physics laboratories, computer laboratories, being public schools, being from the same geo-political zone, being co-educational schools, having enrolled students in SSCE physics for a minimum of ten years, availability of ICT staff who are computer experts, availability of physics teachers and students' exposure to computer-based learning. In addition, intact class of 29 SSII physics students in one randomly selected College was used to determine the learning effectiveness of the package.

Five research instruments, Virtual Physics Laboratory Package (VPLP), Physics Teachers' Evaluation Questionnaire (PTEQ), Computer Experts' Evaluation Questionnaire (CEEQ), Cost Analysis Instrument (CAI) and Physics Achievement Test (PAT). VPLP was developed by the researchers using Adobe Flash CS6, Actions script 3.0, Adobe Fireworks CS6, Box2D and CamStudio software. 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, 2 & 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.

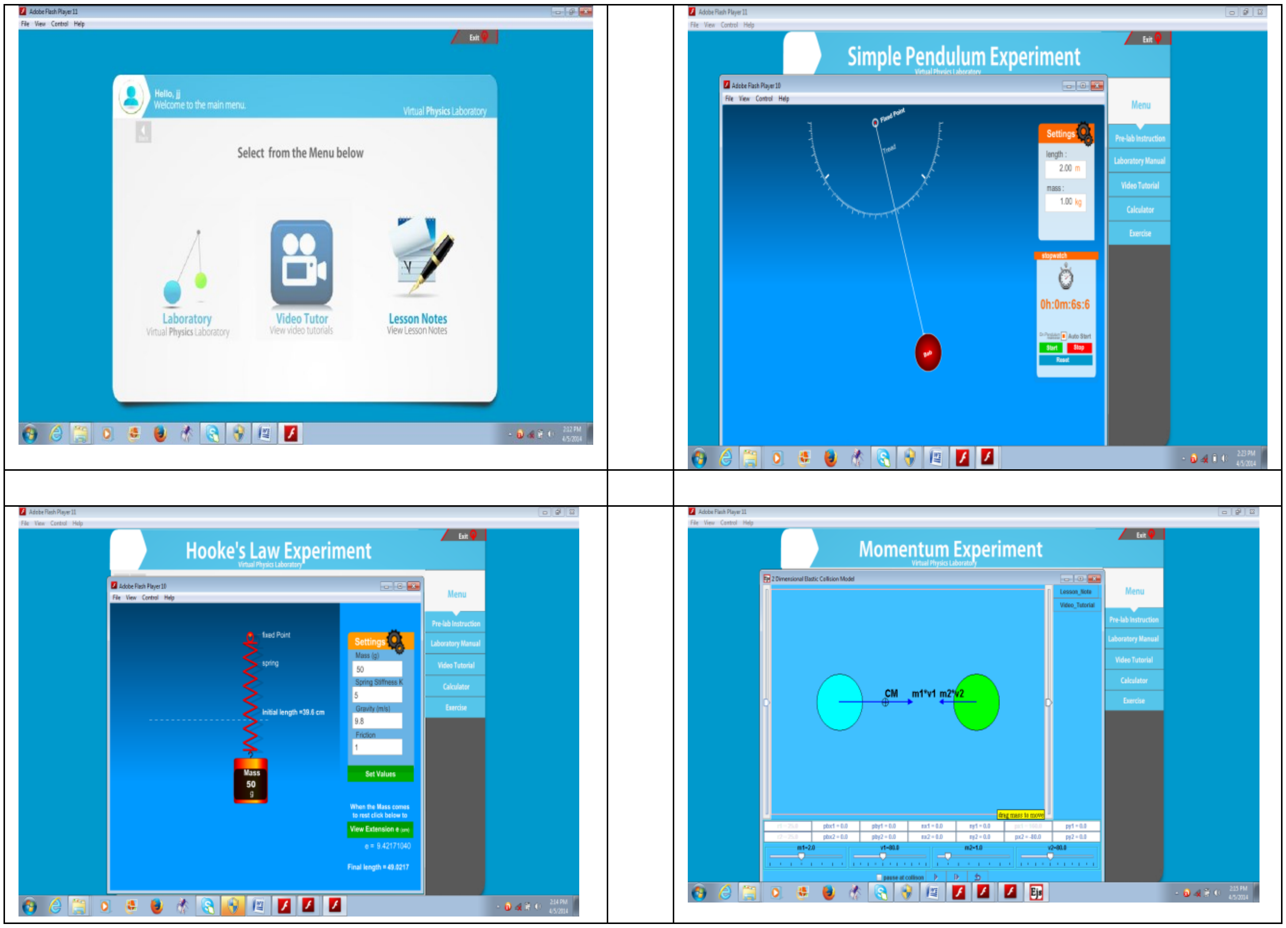

Figure 1. Screenshot of virtual laboratory package

PTEQ and CEEQ were adapted from Atsloom (2009) and they were respectively employed to elicit responses from physics teachers and computer experts based on their evaluation of VPLP in terms of students' accessibility to the package and the flexibility of their access. The questionnaires were 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 scale (namely, 1 as Strongly Disagree, 2 as Disagree, 3 as Agree and 4 as Strongly Agree).

CAI was adapted from Gambari (2010). It was a table showing the activities, rate and the expenditure involved in the development of the package. It was used by the researchers to determine the total cost of developing the virtual physics laboratory package. There were 10 activities in the table specifying the amount spent on each of the activities. PAT consists of 30 multiple-choice objective items on the physics concepts treated and it was administered to the students in the experimental group before and after the virtual laboratory package has been administered.

Data Collection and Analysis

The researchers and two trained research assistants administered the research instruments to the participants. The virtual laboratory package was installed on personal computers of participants (experts) and given a copy of the questionnaire to fill based on their observations. Similarly, the package was installed on personal computers of SSII students,

thereafter, the researchers conducted an orientation to familiarize them with the objectives of the study as well as steps to be followed in using the package. Immediately after the orientation, physics achievement test was administered followed by the administration of the virtual laboratory package which lasted for two weeks before the earlier administered achievement test was administered as posttest.

A four-point rating scale of Strongly Agree (SA, 4 points), Agree (A, 3 points), Disagree (D, 2 points) and Strongly Disagree (SD, 1 point) was used in weighing responses to items in the questionnaire. Responses on each questionnaire item were analyzed according to frequencies and mean rankings. First of all, total responses in each scale category (frequency) of every item were tabulated. Next, the number of points allocated to each category was multiplied by the frequency of each category (n). Lastly, the sum of these scores was divided by the sum of the frequency for each category (ΣN).

$$\text{Mean} = \frac{[4 \times N(SA)] + [3 \text{ X } N(A)] + [2 \times N(D)] + [1 \times N(SD)]}{\Sigma N}$$

A mean response below 2.50 was considered disagreement while a mean response of 2.50 and above was considered as agreement. The total cost of developing the package was computed and used to answer research questions three and four. Responses to questionnaire items meant for answering research questions one, two and five were analyzed using mean and standard deviation.

The Scale

The instruments were validated by two computer experts, two physics experts and four educational technology experts. Based on their suggestions, some items of the questionnaire were re-worked while some were removed. A pilot study was carried out in a school within the study area but that was not used for the main study. Five computer experts, five physics teachers and 20 SSII physics students were employed. The reliability of PTEQ and CEEQ were determined and Cronbach's alpha used to measure the internal consistency of the instruments yielded 0.90 and 0.93 values respectively. Also, the reliability coefficient of 0.95 was obtained for PAT using Kudar Richardson (KR-21) formula. Hence, the instrument were considered reliable.

FINDINGS

Accessibility of Virtual Physics Laboratory Package (VPLP) to students was evaluated by 24 secondary school physics teachers while 35 computer experts evaluated the flexibility of the package. Also, the researchers determined the cost implications of developing and utilizing the package in learning the selected physics concepts while 29 physics students evaluated the learning function of the package.

Table 1 helps to provide answers to the first research question. The results of data illustrate that the mean score for items 1 through 5 ranged between 2.58 and 3.62 and were therefore agreed by the respondents.

Table 1. Mean response of physics teachers' evaluation of students' accessibility to virtual physics laboratory package

S/N	Statement	N	SA	A	D	SD	Mean	St. Dev.	Decision
1	There is a computer laboratory in my school	24	15	9	0	0	3.62	1.12	Agree
2	Computers in the laboratory are functional	24	9	10	3	2	3.08	0.58	Agree
3	All SSII physics students in my school have access to computer laboratory	24	8	10	4	2	3.00	0.50	Agree
4	The number of computer systems in the computer laboratory can accommodate every SSII physics students in my school at once	24	8	6	4	6	2.66	0.16	Agree
5	Students can access virtual physics laboratory package with or without network connection	34	6	7	6	5	2.58	0.08	Agree
	Average Mean						2.98		

Table 1 shows the responses of computer experts on the flexibility of virtual physics laboratory package to SSII physics students in Nigeria. The table reveals that the mean response of physics teachers to each of the five items is above 2.50 while the average mean of the responses to the five items is 2.98. This indicates that physics teachers agreed that virtual physics laboratory package is accessible to SSII physics students in Nigeria.

Table 2 helps to provide answers to the second research question. The results of data illustrate that the mean score for four out of the five items ranged between 2.20 and 2.30 and were therefore disagreed by the respondents.

Table 2. Mean response of computer experts' evaluation of the flexibility of virtual physics laboratory package

S/N	Statement	N	SA	A	D	SD	Mean	St. Dev.	Decision
1	The adapted virtual physics laboratory package can run on different operating system platforms	35	8	11	10	6	2.60	1.04	Agree
2	The adapted virtual physics laboratory package has features that can allow online accessibility	35	7	7	10	11	2.30	0.20	Disagree
3	The adapted virtual physics laboratory package has features that can make it accessible on mobile devices	35	5	8	12	10	2.20	0.30	Disagree
4	The adapted virtual physics laboratory package allows learners to input values since inbuilt values are not constants	35	6	7	13	9	2.30	0.20	Disagree
	Average Mean						2.35		

Table 2 shows the evaluation of responses of computer experts on the flexibility of virtual physics laboratory package. The table reveals that the mean response of computer experts to each of the four items is below 2.50 except item 1 (ability of the package to run on different operating system platforms) with a mean response of 2.60. With an average mean of 2.35 for the four items which is below 2.50, the table reveals that computer experts disagreed that the package has features that can ensure its accessibility online, on mobile devices and the possibility of users to manipulate and input values of their choice. Hence, they disagreed that the virtual physics laboratory package is of high flexibility.

Table 3 helps to provide answers to the third research question and its implication assists in providing answers to the fourth research question.

Table 3. Cost analysis of developed virtual physics laboratory package

S/N	Activities	Rate	Amount in Naira (N)	Amount in U.S. Dollar ($)
1	Type-setting of physics laboratory manual (10pages)	N50/page	N500.00	$2.50
2	Type-setting of lesson note (24pages)	N50/page	N1,200.00	$6.00
3	Purchase of software for simulation and conversion (2 CD)	N300 each	N600.00	$3.00
4	Simulation and animation of tools (3 experiments)	N25,000each	N75,000.00	$375.00
5	Recording and editing of video tutorial in VPLP	-	N7,000.00	$35.00
6	Modification of VPLP after initial evaluation	-	N20,000.00	$100.00
7	Editing of laboratory manual and lesson note after initial evaluation	-	N200.00	$1.00
8	Editing of video tutorial in VPLP after initial evaluation	-	N2,000.00	$10.00
9	Transportation and recharge cards	-	N6,000.00	$30.00
10	Miscellaneous	-	N5,000.00	$25.00
	Total		N117,500.00	$587.50

From Table 3, the sum of five hundred and eighty-seven U.S dollars ($587.50) was spent in developing the virtual physics laboratory package meant for learning three secondary school physics experiments (simple pendulum, Hooke's law and momentum experiments).

The virtual laboratory package can be considered to be cost effective. Once the package has been developed, it can be reproduced on compact disc (CD) or uploaded on website of any secondary school in Nigeria for students to download and use. The package can enable students to perform experiments which otherwise require high level physical or technical skills; it can also eliminate the need for physical sets of specialized and expensive equipment. The package can be stored permanently and used repeatedly. It can be used for individualized learning and for revision purposes, thus enhancing learning and understanding; conventional laboratory accidents can also be avoided if virtual physics laboratory package is used among several other benefits (Manjit, Selvanathan & Ramesh; 2003).

In spite of the high cost of developing the package, students taught simple pendulum, Hooke's law and momentum experiments are worth the money spent on the package (Bartolic-Zlomislic & Bates, 1999). Also, the availability of the virtual laboratory package in

schools can help reduce the costs of some physical lab equipment as the package can replace some physical lab settings required for performing physics experiments (Campbell, et al., 2004). The benefits of the package are therefore unquantifiable and incomparable with its cost.

Table 4 helps to provide answers to the fifth research question. The results of data illustrate that the mean gain score of students was 33.45 and this shows that there was improvement in the students' achievement after being taught using virtual laboratory package.

Table 4. Mean achievement scores of students taught physics using virtual laboratory package

Treatment	N	Pretest Mean	Posttest Mean	Mean Gain Score
Virtual Laboratory	29	25.89	59.34	33.45

Table 4 shows that the mean score of students was 25.89 while at posttest, after the virtual laboratory package had been administered, their mean score was 59.34. The mean gain score of 33.45 obtained implies that the improvement in the mean score of the students recorded at posttest was caused by the virtual laboratory package. This implies that virtual laboratory package improves physics students' achievement in simple pendulum, Hooke's Law and momentum experiments.

DISCUSSION

The result of the analysis of students' accessibility to the package revealed that SSII physics students had access to the package. This finding is in line with the recommendations of Bates (1995) that users of learning technologies must have adequate access to it before effective learning can take place. This finding also agrees with the finding of Bates (2000) that students need adequate access to learning technologies because they improve flexibility of learning.

Result of the analysis on flexibility of virtual physics laboratory package indicated that the package has low flexibility. This finding is not in line with the recommendations of Bates (1995) that learning technologies requires high flexibility. This finding also contradicts the recommendation of Barbour and Reeves (2009) that virtual laboratory should provide a high level of flexibility in order to ensure freedom from constraints of time and place which hinder access.

It can be deduced that students have access to virtual physics laboratory package within the school because these schools are well-equipped with adequate and functional computers which according to Farida and Ezra (2005) are the basic requirement for facilitating access to computer-based learning activities. This was also observed and stressed by Kasozi (2003) that computers have increasingly become both exercise books and textbooks for students and this makes learning through technology easier. Students that have computers at home (with or without internet facilities) will also have access to virtual physics laboratory package outside the school because the package is available on compact disc and can also be downloaded online. However, flexibility of the package was low because it is not possible for learners to perform the selected experiments on the internet neither can they use the package on small screen mobile devices.

The result of the breakdown of cost analysis of developing and modifying the package indicated that VPLP is expensive to develop. This finding does not contradict the observation of Bates (1995) and the finding of Bates (2000) that the development of new learning technologies is usually of high cost but since such increase pedagogical effectiveness, they

will therefore be considered to be profitable. It also agrees with the earlier finding of Lambert and Williams (1999) that one-way technologies such as print, audio or video cassettes and computer-based learning/multimedia have high initial production costs but lower costs subsequently.

It can be deduced from this finding that though the development of VPLP is expensive, its pedagogical values outweighed its cost implications. The package can enable students to perform sophisticated experiments which otherwise require high level of physical or technical skills; it can eliminate the need for physical sets of specialized and expensive equipment; it can be employed to supplement conventional laboratory instruction; it can be stored permanently and used repeatedly (Manjit, et al., 2003).

In spite of the high cost of developing the package, students taught simple pendulum, Hooke's law and momentum experiments are worth the money spent on the package (Bartolic-Zlomislic & Bates, 1999). The benefits of the package are therefore unquantifiable and incomparable with its cost.

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. This finding agrees with the earlier findings of Murniza, et al. (2010), Mahmoud and Zoltan (2009) who found that virtual laboratory instruction improves students' academic achievements in science-based subjects.

CONCLUSION

Result obtained from the data gathered indicated that physics students will be able to access virtual laboratory package in Nigerian secondary school having functional computer laboratories but flexibility of their access to the package on internet and mobile devices will be low since the package does not support usage on such platforms. Also, though it was expensive to develop virtual physics laboratory package yet, the package is still profitable considering its' unquantifiable benefits to students.

The major implication of this study for Open and Distance Learning is that the flexibility, accessibility and cost effectiveness of virtual laboratory package will enable learners acquire practical physics knowledge on any electronic devices without stress irrespective of time and space if the recommendations made are put into use.

RECOMMENDATIONS

- **Based on the major findings of this study, the following recommendations were made:**
- **Developers of learning packages such as virtual physics laboratory package should ensure high flexibility of the packages. This will enable and improve students' access to such packages on mobile devices and internet;**
- **Government and school administrators should assist schools financially by providing fund needed for developing contextually relevant learning packages and for training physics teachers on the development of such packages, as their benefits to students' learning of physics concepts are enormous;**
- **Physics teachers should expose students to virtual learning strategies to promote students' autonomy to knowledge acquisition, discovery learning and student-centered instructional approach; and**

- 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.

ACKNOWLEDGMENT: The authors wish to acknowledge the contributions of physics students, teachers and computer experts from Federal Government Colleges in Ikirun, Ijanikin, Ikole-Ekiti, Ogbomoso and Odoogbolu all in South West Nigeria who served as participants for this study.

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