Phases Involved and Model Derived from the Development and Evaluation of Virtual Laboratory Package on Selected Nigerian Secondary School Physics Concepts

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Abstract

This study reveals the phases and model involved in the development and evaluation of virtual laboratory package on three selected Nigerian secondary school physics concepts. Specifically, the package is meant for conducting simple pendulum, Hooke's Law and momentum experiments. Development and evaluation research of the model type was employed for the study and qualitative method was used for the analysis. Three research questions were raised and answered. Adobe Flash CS6, Actions script 3.0, Adobe Fireworks CS6 and Box2D were the major tools used in the development of the package, validation of the package was done three times by physics experts, educational technology experts and computer experts, and 10 phases were required in the development of the package while a model named Model for the Development and Evaluation of Virtual Laboratory Package (MDEVLP) was derived. The package is therefore recommended for use in teaching and learning of the selected physics concept in order to improve students' performance, interest and retention of the subject.

Keywords: Virtual Laboratory Package, Model, Development, ACTIONS Model, Physics Experiment, Evaluation

Introduction

The technological development of any nation lies in the study of science. Science is the foundation upon which the present day technological breakthrough and innovations are built. Science comprises of basic disciplines such as physics, chemistry, biology and mathematics. Essentially, science and technology would be incomplete without physics (Michael, 2006). The importance of physics to mankind cannot be underestimated as almost every human activity and virtually every profession involves some element of physics (Gambari, 2010; NERC, 2009; Javed, 2005).

In spite of the importance of physics to technological development and as a requirement for many specialized science and technology-based courses in institutions of higher learning, Falode (2014) observed and reported that students' performance in the subject at the Senior School Certificate Examination (SSCE) in Nigeria has never been excellent. For instance, Table 1 and Figure 1 show students' performance in SSCE physics conducted by West Africa Examinations Council in Nigeria from 2007 to 2011.

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)

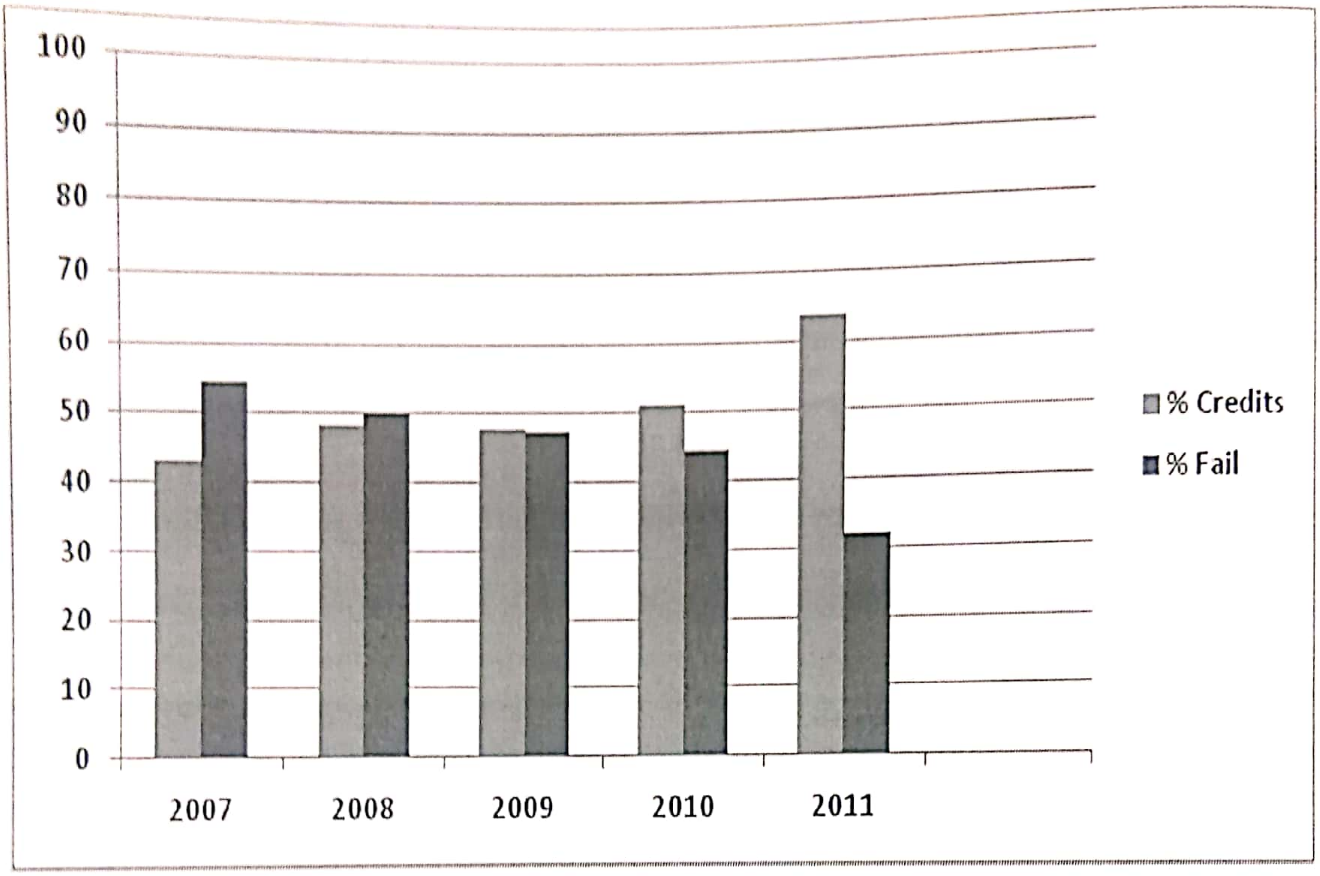


Figure 1: Students' performance in SSCE physics between 2007-2011
Source: WAEC Chief Examiner's report (2007-2011)

Table 1 andFigure 1 revealed that on average between 2007-2011, only 50.90% obtained at least credit pass in physics while the remaining 49.10% failed the subject. Falode (2014), Yusuf (2004), Shalw (2003), Matthew (2002) and Bajah (2000) attributed poor performance of students in science, particularly in physics to non-availability of standard laboratory and poor utilization of instructional materials.

Mechanics is a major branch of physics because principles, theories, and laws contained in mechanics are used to design electric dynamos and motors, radar installations, artificial satellites, spacecrafts, ships, nuclear power generators and lots of others, which have all helped to make life easier for people (Gambari, 2010). The importance attributed to mechanics as underscored by WAEC Chief Examiner's Reports (2002, 2003, 2004 & 2005) revealed that more than 30 percent of SSCE physics questions conducted by West African Examinations Council were from mechanics (Rafiu & Adetona, 2006). 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 is not unconnected to inability of students to understand contents while studying independently and poor skills in physics laboratory exercise (Aina, 2012; WAEC Chief Examiners' report, 2007).

Since physics, an activity-oriented subject has remained one of the most difficult subjects in the school curriculum, guided discovery method which is resource-based should be employed to effectively teach the subject (NERDC, 2005; NTI, 2007). Ogunleye (2000) and Omosewo (1991) also suggested that physics teachers should be able to organize their students to learn physics through activities in the laboratory using appropriate learning resources capable of generating and sustaining the interest of students in physics.In instances, where theses laboratory resources are unavailable or insufficient, computer simulation tools can be used.

Computer simulation is a computer-generated version of real-world objects or processes. It can take many different forms, ranging from computer renderings of 2-dimensional geometric shapes to highly interactive computerized laboratory experiments (Gambari, Falode, Fagbemi & Idris, 2012). Through computer simulation, virtual laboratory can be set up.That is, through simulation, virtual laboratory, a computer-based learning environment where learner is able to simulate experiments completed in traditional laboratory through the use of computer can be developed(Onyesolu & Eze, 2011).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). The most intricate virtual laboratory includes highly interactive simulations of laboratory exercises (Scheckler, 2003).

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; Nunn, 2009). An example of a virtual laboratory is a collection of digital simulations supported by discussion fora, video demonstrations, hyperlinked glossaries, and e-mail lists organized in a World-Wide-Web format or on a CD in a shell produced by an authoring language (Scheckler, 2003).

Harms (2000) classified virtual laboratory into five based on different sorts of simulations. They are: classical simulations which contain certain elements of laboratory experiments and are available locally (*Simulations*);classical simulations which contain certain elements of laboratory experiments and are accessible on the web and are available as JAVA-Applets (*Cyber Labs*); simulations which attempt to represent laboratory experiments as closely as possible (*Virtual Labs*); simulations of lab experiments using virtual reality techniques (*VR Labs*); and real experiments which are controlled via the internet (*Remote Labs*).

Empirical studies on the effects of virtual laboratory on students' academic performance revealed the effectiveness of virtual laboratory in teaching and learning process, especially in science subjects (*Abdullah & Shariff, 2008;* Efe & Efe, 2011; Kevin & Rod, 2012; Mahmoud & Zoltan, 2009; Murniza, Halimah & Azlina, 2010; 2009; Tuysuz, 2010). They therefore recommended the use of virtual laboratory as a supplement to classroom instruction.

Virtual laboratory instruction should be developed based on learners' needs following constructivism theory of learning. Cooperstein and Kocevar-Weidinger (2004) opined that in constructive learning, the standard classroom procedure is turned upside down because there are no lectures, no demonstrations, and no presentations. That is, from the beginning, students engage in activities through which they develop skills and acquire concepts. Constructivism in most cases begins with a case or a problem and as learners solve the problem, the intervention of the teacher, facilitator or instructor is only to guide students in the appropriate direction and not to directly impart knowledge.

In line with constructivism, several instructional design models which share common features exist for developing learning packages such as virtual laboratory package. Models like Evolutionary model, the Rapid Prototyping Design (RPD) model, Spitzer instructional development cycle and the ISD ADDIE model share these features and are frequently being used. For the purpose of this study, development and evaluation model which revealed stages of developing the virtual laboratory package as well as Bates' (1995) ACTIONS evaluation model was employed. ACTIONS is an acronym where A represents Accessibility, C for Cost Effectiveness, T for Teaching and learning function, I for Interactivity, O for Organizational issues, N for Novelty, and S represents Speed features.

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. Virtual physics laboratory will help to supplement conventional laboratory learning because it affords learners opportunities to perform experiments and do practical physics revision anywhere and at any time so far the user has access to computer with installed virtual physics laboratory package. Hence, this study was carried out to describe the phases and model involved in the development and evaluation of virtual laboratory package on three (Simple pendulum, Hooke's law and momentum experiments) selected Nigerian secondary school physicsconcepts.

Purpose of the Study

This study was carried out to develop, validate and evaluatea virtual laboratory package on three selected physics concepts for Nigerian secondary schools. Specifically, the research was carried out to determine:

1. the tools used in the development of the virtual laboratory package;
2. the stages involved in the validation of the virtual laboratory package; and
3. the phases involved in the development and evaluation of the virtual laboratory package.

Research Questions

The study provided answers to the following research questions:

1. What are the tools used in the development of virtual laboratory package on selected Nigerian secondary school physics concepts?
2. What are the stages involved in the validation of virtual laboratory package on selected Nigerian secondary school physics concepts?
3. What are the phases involved in the development and evaluation of virtual laboratory package on selected Nigerian secondary school physics concepts?

Research Type

The study was a design, development and evaluation research of the model type which revealed stages of developing the virtual laboratory package as well as Bates' (1995) ACTIONS evaluation model was employed. Qualitative method was used for analysis.

Tools used in the Development of Virtual Laboratory Package

The virtual laboratory package for conducting three senior secondary school physics experiments (simple pendulum experiment, Hooke's law experiment and momentum experiment) 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 entrance menu of the package consisted of introduction/student's registration edifice. 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 intended experiments using the simulation tools provided.

Validation of Virtual Laboratory Package

The validation of the virtual laboratory package on the three selected physics concepts was done three times.

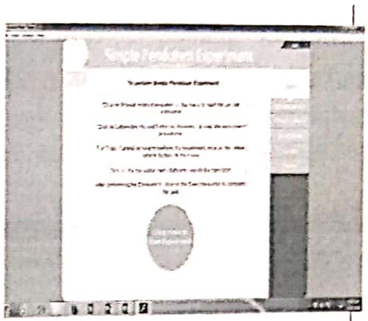
First Validation: After the researchers have completed the initial development of the package, itwas validated by four computer programmers, two physics teachers, and four educational technology specialists in two secondary schools and Federal University of Technology, Minna, Nigeria. These experts observed some weaknesses in the package which could affect its suitability, effectiveness, selection and utilization by teachers and physics students in the teaching and learning of the selected physics contents. They observed that no virtual tool was labeled, values which were supposed to be adjustable by learners were digitally fixed and un-adjustable, arrows were wrongly directed, wrong icons were used, content of the experiment sheets were inadequate, it was not possible for learners to open multiple pages or maximize/minimize a page and there was no title of experiment to be performed on the working interface. Hence, they suggested the need to improve on the package to make it suitable for selection and utilization in teaching and learning of physics.

Second Validation: Based on experts' suggestion after first validation process, the installation settings of the package were adjusted, tools were re-labeled, arrows were re-directed, working interface was widened, parameters and tools were made more flexible. The package was thereafter subject to a team of experts including a physics expert and five educational technology experts in University of Ilorin, Nigeria. These experts suggested that the contents in the laboratory manual should be updated, navigation buttons should be added, welcome page should be added, class exercises should be added and some icons should be changed.

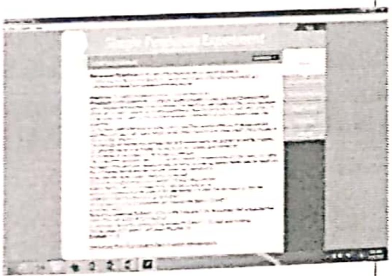
Third Validation: Based on experts' suggestion during the second validation process, navigating buttons were included, the menu icons were changed, the virtual tools were changed, the content in the laboratory manual were updated, class exercises were added, introductory page was provided for each of the experiment and the flexibility and friendliness of the package was improved upon to allow learners input values of their choice, minimize, maximize and exit pages. The experts that were involved in the second validation process were asked to validate the package again. At, this point, they certified the package suitable in conduct the three physics experiments.

Log-in Page

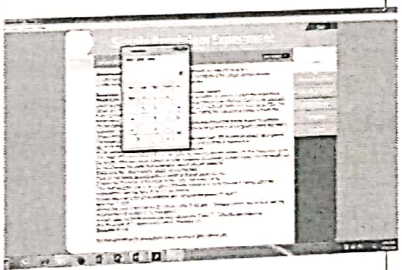
Task Selection Page



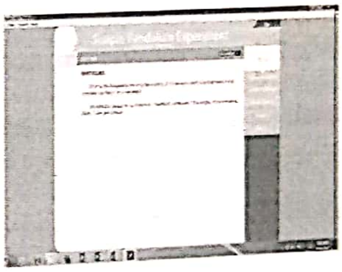
Experiment Manual Page



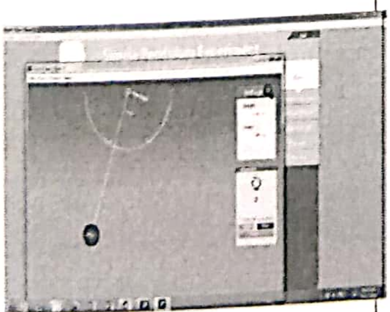
Laboratory Instruction



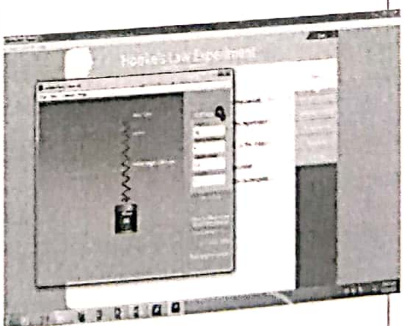
Experiment Sheet with Calculator



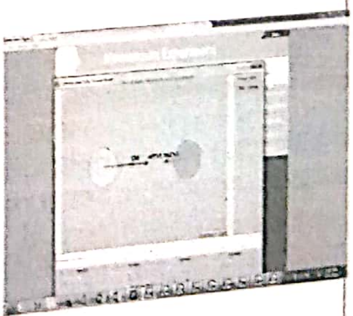
Exercise



Simple Pendulum Experiment



Hooke's Law Experiment



Momentum Experiment

Figure 1: Screenshot of the developed Virtual Laboratory Package

Stages Involved in the Development and Evaluation of Virtual Laboratory Package

The development and evaluation of virtual laboratory package on selected Nigerian secondary school physics concepts was carried out under 10 major phases. Phase I, II and III addressed the processes involved in the development of the package while Phase IV to X addressed the evaluation carried out with respect to Bates' (1995) ACTIONS model. The phases are:

Phase I: At this phase, the need for developing the virtual physics laboratory package on the concepts of Hooke's law, momentum and simple pendulum concepts were identified and analyzed by physics and educational technology experts.

Phase II: At this phase, a total of four experts including a computer programmer, an audio-visual specialist, educational technology expert and a physics expert were involved in the development of the package.They developed the package based on the needs identified and analyzed.

Phase III: At this phase, the developed package was validated by the experts involved in the determination and identification of needs at Phase I.

Phase IV: At this phase, physics teachers and computer experts evaluated the package in terms of its accessibility to Nigerian secondary school physics students, as well as the flexibility of its accessibility to students on different platforms, such as mobile devices and internet.

Phase V: At this phase, the researchers evaluated the virtual physics laboratory package to determine its cost effectiveness in the teaching and learning of simple pendulum, Hooke's law and momentum experiments.

Phase VI: At this phase, secondary school physics teachers evaluated the teaching and learning functions of the package to determine whether it satisfies the objectives and procedures for learning the selected physics concepts. In addition, the effectiveness of the package was determined by male and female secondary school physics students who were taught the selected concepts using the package.

Phase VII: At this phase, instructional design experts evaluated the package to determine whether it is interactive and friendly to secondary school physics students.

Phase VIII: At this phase, physics teachers evaluated the virtual physics laboratory package to determine the requirements within Nigerian secondary schools that will enhance the use of the package in the teaching and learning of the selected physics concepts as well as the barriers to effective use of the package within the school.

Phase IX: At this phase, computer experts evaluated the package to determine its newness to secondary school physics students and teachers in Nigerian secondary schools. They also evaluated the package to determine the technical capabilities that come with new technologies.

Phase X: At this phase, computer experts evaluated the package to determine the swiftness of developing and updating it when the need arises.

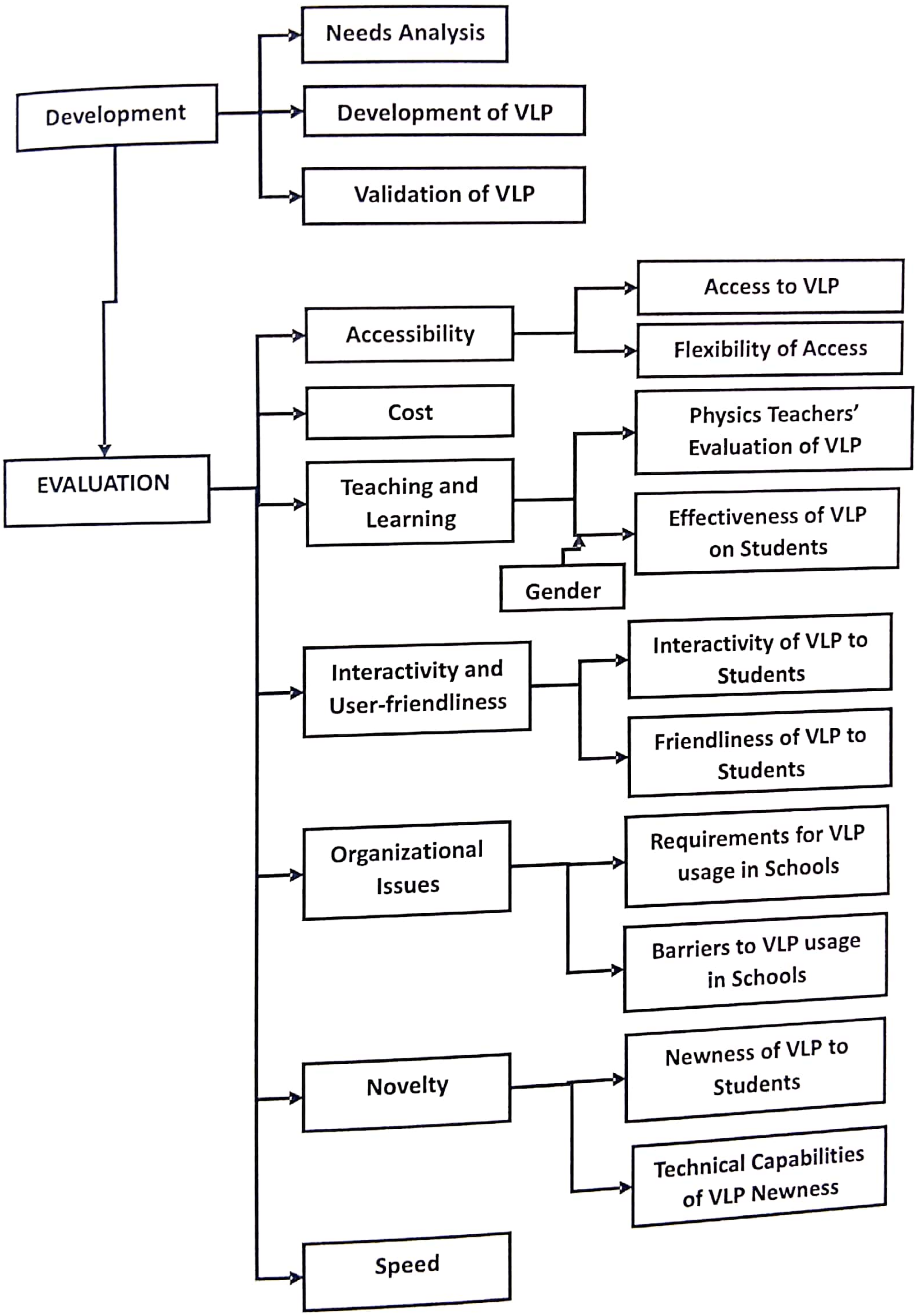


Figure 2: Model for the Development and Evaluation of Virtual Laboratory Package on Selected Nigerian Secondary School Physics Concepts

Conclusion

This study has revealed that development and evaluation of virtual laboratory package is best carried out in stages starting from analysis of needs, to design, development stage and evaluation stage, and that, a team of experts is usually required in such process. The developed package is capable of improving secondary school students' performance, interest and retention in physics if employed in teaching and learning of Simple Pendulum, Hooke's law and momentum experiments.

Recommendations

It is recommended that the developed virtual laboratory package should be used by secondary school physics students in conducting Simple Pendulum, Hooke's law and momentum experiments in other to improve their performance, interest and retention of physics. Also, the model that emanated from this study should be followed in the development and evaluation of other contents in Nigerian secondary school physics curriculum.

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