



## Development and Validation of Virtual Laboratory Package for Effective Teaching and Learning of Biology Practicals in Secondary Schools in Nigeria

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### ABSTRACT

*This study developed and validated a Virtual Laboratory Package (VLP) for effective teaching and learning of Biology practicals in Secondary Schools in Nigeria. A Research and Development (R & D) design was used and the population entails all the secondary school Biology teachers and students in Nigeria. 12 Biology teachers and 216 students participated in the study. The participants were selected through a multistage sampling technique across the six geopolitical zones in the country. A comprehensive desk review of the Biology curriculum was used in screening the laboratory activities included in the VLP model and a round table discussion with Biology teachers was carried out for harmonizing the activities used in the VLP model. Python programming language (Django framework) was used for the logic while Hypertext Mark-up Language (HTML) and Cascading Style Sheet (CSS) were used for the user interface. Data was collected through three instruments namely; VLP Content Validation Questionnaire (VLCVQ), VLP Functionality Questionnaire (VLPFQ) and VLP Usability Questionnaire (VLUQ). The data were analysed through charts, percentages, mean and standard deviation. The VLP was developed and found functional, suitable and user-friendly for effective teaching of Biology practicals.*

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### INTRODUCTION

The problem of the dearth of laboratory equipment, increase in class size, health hazards and consequent unsatisfactory achievement in science among secondary school students in Nigeria are some of the catalysts that make researchers and educationists search for alternative approaches that can enhance teaching and learning. This is against the conventional face-to-face approach that has proved to be ineffective due to the inadequacy of requisite equipment, reagents and other factors (Ngozi & Halima, 2015; Chukwunke, 2021). The use of computer, intermate and virtual learning platforms have become some of the alternatives through which some of the challenges surrounding the use of conventional methods might be overcome.

Moreover, the application of computers and other devices in teaching and learning is gaining prominence with advancements in technology and the need for self-driven learning.

Virtual learning provides a revolutionary approach that offers alternative means of delivering learning content to students especially in a situation where face-to-face contact is difficult to establish due to health hazards, scarcity of classrooms, distance learning and the need for augmenting classroom instructions with virtual experiences and self-directed learning.

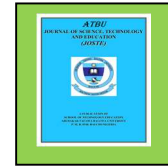
The COVID-19 pandemic which ravaged the world some years back has propelled a shift in teaching paradigm from conventional classrooms to synchronous and asynchronous virtual and online learning platforms. Virtual

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Laboratory Package (VLP) can provide programmed instruction to learners by simulating a virtual practical skills acquisition reality. It combines rich interactive elements, including text, audio, video, and 3D animations, to facilitate personalized learning of subjects that are otherwise difficult to understand. Katcha & Wushishi (2015) reported that the laboratory is at the center of scientific and related studies, so long as science and subjects remain both products and processes. For science to be taught properly and effectively, laboratories must be an integral part of the science subjects' curriculum; however, it is disappointing to note that student achievement in science at internal and external examinations has remained considerably poor despite the relative importance of the subjects (West African Examination Council [WAEC], 2020).

Factors identified to affect the student's achievement include laboratory inadequacy, student attitude toward the subjects, teacher factor, societal factor, governmental infrastructural problem, language problem, examination body-related variables, curriculum-related variables, test-related variables, textbook-related variables, home-related variables, and inadequate exposure to laboratory work (Fatokun, 2012). Lawrence and Aava (2011) maintained that students' poor achievement can be attributed to a lack of laboratory apparatus. More so, rapid science and technological advancement and the shocking emergence of the COVID-19 pandemic are changing educational systems the world over to depend more on computer-based instructional delivery.

Therefore, this study developed and validated a virtual laboratory package to take care of practical aspects of biology through four model components involving students, tutoring, domains, and user interfaces. Therefore, this study developed and validated a virtual laboratory package to take care of practical aspects of biology through four model components involving students, tutoring, domains, and user interfaces. The student, tutoring, and user interface components are programmed computer instructions that are concerned with how to teach the learner. The domain model is where the

course contents, such as cognitive and psychomotor components of biology, are to be taught to the learner and integrated. The study was structured to critically and systematically determine the contents of the student, tutoring, user-interface, and domain models for inclusion in the VLP, the suitability of the models in meeting the software development specifications in terms of usability, the suitability of the complete VLP in meeting the software development specifications in terms of usability, and the efficacy of the package in teaching cognitive and psychomotor skills in biology at the senior secondary school level in Nigeria. The focal point of the study is pinned on Mayer's (2011) cognitive theory of multimedia learning, which emphasizes the need for auditory and visual channels of information processing that are organized to enhance systemic and meaningful learning through multimedia. This implies the VLP will be modeled, designed, and developed to provide coherent verbal and pictorial information for effective teaching of biology. The VLP enhanced the cognitive achievement and psychomotor skills of the students in conducting practical.

Various simulation and animation packages on the theoretical aspects of content delivery have been developed by various researchers (Merchant *et al.*, 2014). By helping students develop an understanding of concepts and processes, through inquiry-based learning and engagement in realistic investigations, with continuous feedback, virtual learning simulations can foster learning in a new and innovative way (Honey & Hilton, 2011). Furtak, *et al.*, (2012) specifically argue that virtual learning simulations provide an excellent framework for engaging in inquiry-based learning because they enable students to gain conceptual knowledge while independently investigating a scientific issue with the relevant methodology in the field.

Several related studies have established the effectiveness of using a virtual learning platform in improving students' cognitive and psychomotor achievement and other learning outcomes. However, some studies reported no significant effect of virtual learning platforms when compared with traditional methods. Therefore,

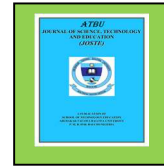
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there is no consensus on the efficacy of virtual learning packages in enhancing students' cognitive achievement. For instance, Moazami, Bahrapour, Azar, Jahedi, and Moattari (2014) conducted a study on students' performance in virtual and traditional learning methods. The study revealed that virtual learning was more effective than traditional learning methods.

Soltanimehr, Bahrapour, Imani, Rahimi, Almasi, and Moattari (2019), in a related study on the effect of virtual versus traditional education, reported that virtual learning was superior to traditional lecture-based methods in improving students' knowledge acquisition. Besides, the studies conducted by Nkemakolam, Chinelo, and Jane (2018) revealed that computer simulation was significantly more effective in enhancing students' achievement than the traditional method. Tyav, Adadu, and Onyilo (2015), in a study on the effect of simulation on motor vehicle mechanics work students' achievement, reported that those taught with simulation achieved higher scores in both post-test and retention tests than those taught with the traditional method. Moreover, similar findings were also reported by Chumba, Omwenga, and Atemi (2020), Zhang et al. (2021), Chang and Hwang (2021), and Huang, Hwang, and Chang (2021). Other studies, such as those of Monaghesh, Negahdari, and Samad-Soltani (2023), Zhang et al. (2021), Chang and Hwang (2021), and Huang, Hwang, and Chang (2021), reported a statistically significant effect of virtual reality intervention on the psychomotor aspect of learning.

Despite these positive outcomes, Chen et al. (2020) examined that virtual reality can effectively improve knowledge acquisition, but it was not more effective than other teaching methods in areas of skills, satisfaction, and confidence. Similarly, Nassar, Al-Manaseer, Knowlton, and Tuma (2017), Middleton, Alvand, Roberts, Hargrove, Kirby, and Rees (2017), and Udogu and Igwe (2021) examined that students taught through real-life experience learn insignificantly better than those taught through computer simulation teaching techniques. This result agreed with that of William, Frederick,

Christian, Ruth, Peter, and Yen-ing (2015). Similarly, Hakami (2021) and Abarghouie, Omid, and Ghadami (2020) reported no statistically significant difference between the groups taught through virtual and traditional learning methods.

Therefore, the effectiveness of virtual learning platforms over traditional methods may not be unconnected with the ease of use and interactivity of such platforms, where students engage in virtual hands-on activities in a user-friendly manner. Most of the studies conducted attested to its effectiveness in enhancing cognitive achievement and the acquisition of psychomotor skills. Some of the studies that reported a lack of significant results recommended the use of the platform because it enhances students' learning better than the traditional method.

### **Objectives of the Study**

The aim of this study was to develop and validate a Virtual Laboratory Package for teaching and learning Biology practicals in secondary schools in Nigeria. The specific objectives are to:

1. Develop the Models of the VLP for Student, Tutoring, User-Interface and Domain for teaching and learning Biology practical in senior secondary schools in Nigeria.
2. Validate the Student, Tutoring, User-Interface and Domain Models of the VLP to meet software development specifications in terms of usability for teaching and learning of Biology practical in senior secondary schools in Nigeria

### **Research Questions**

1. What are the appropriate contents of the Student, Tutoring, User-Interface and Domain for teaching and learning of Biology practical in senior secondary schools in Nigeria?
2. What is the functionality, Content Validity and Usability of the VLP model?

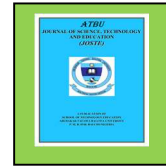
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## METHODOLOGY

The study adopted Research and Development (R & D) design. The R & D method according to Gall et al. (2007) is concerned with the development of educational products and consists of ten stages. The 1<sup>st</sup> to 6<sup>th</sup> stages of the R & D method guided the researchers in ascertaining the instructional goals, students' characteristics, entry-level skills and expectations, assessment instruments and instructional strategies in the VLP to perform the intended instruction on Biology practical. This involved a desk review to extract the practical contents from the National Educational Research and Development Council's (NERDC) biology curriculum. Moreover, a roundtable discussion and interview to sort out the six most difficult practicals for inclusion in the VLP were conducted.

The module design phase in this study, which is the 7th stage in the R&D method, was considered the phase of the VLP prototype development using the V-Model of Software Development Life Cycle (SDLC). As such, Hypertext Markup Language (HTML) and Cascading Style Sheets (CSS) were used for the user interface design, while Python (the Django framework) was used for the logic and database. The criteria for selecting Python were based on: multimedia capability, data handling capability, ease of use, and level of configuration with little or no difficulty during installation that met the software requirements specifications (SRS). The integration of every part of the VLP prototype was then tested to ensure that it worked properly according to the SRS acceptable standard by computer experts and educational technology experts using the VLP Functionality Questionnaire (VLFQ). The prototype was modified and refined at various stages to correct or include some functions that were not originally included in the design specifications. For instance, the students' help line was debugged and included due to an initial malfunction, as suggested by one of the validators during the validation process. The main menu of the VLP consisted of students' registration and a list of six practical lessons.

The 8th stage of the R&D method, which is on formative evaluation, involved the testing of

the developed VLP prototype in government science schools, two from each of the six geopolitical regions in Nigeria, using 18 biology students from each school. The students used the VLP and rated it using the VLP Usability Questionnaire. The ninth and tenth stages involved revising the VLP package based on the results from the formative evaluation and expert validation at various stages of the VLP development into an operational product. The population of the study comprised all secondary school biology teachers and students in Nigeria. 12 biology teachers with more than ten years of teaching experience (1 from each of the 12 science schools purposely chosen across the six geopolitical zones) and 216 biology students (18 from each of the 12 science schools). Only schools that had functional computer labs were used for the study.

The instruments for data collection were the VLP Content Validation Questionnaire (VLCVQ), the Virtual Laboratory Functionality Questionnaire (VLFQ), and the Virtual Laboratory Usability Questionnaire (VLUQ). These instruments were validated by experts in computer science, educational technology, and biology education to ascertain their validity and content. The reliability indices of the VLCVQ, VLFQ, and VLUQ were computed using Cronbach's alpha, yielding indices of 0.85, 0.83, and 0.81, respectively. The data collected in this project was analyzed both at the formative and summative levels. At the formative level, the qualitative data collected from the desk review, round table discussion, and interview were analyzed using thematic analysis and used to develop the VLP model. The quantitative data collected from the survey questionnaires were analyzed using percentages, counts, charts, means, and standard deviations..

## RESULTS

The results of the study are presented based on the research questions.

### **Research Question One**

What are the appropriate contents of the Student, Tutoring, User-Interface and Domain for

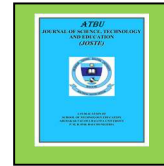
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teaching and learning of Biology practical in senior secondary schools in Nigeria?

The four (4) Models of the VLP were developed in line with the stages of the R & D model, the needs or expectations of the VLP to perform the intended instruction were carefully sorted out to produce a document known as Software Requirement Specification (SRS). The SRS document tells us 'what' software does and as such becomes the input of this software requirement analysis stage, which tells us 'how' a software system should work. The expectations of the VLP for effective teaching and learning of Biology practicals were carefully sorted as follows: The VLP was expected to;

1. provide the benefit of one-on-one instruction of Biology practical;
2. store students' information such as name, level, registration number and year;
3. track the user's learning history and behaviour;
4. force the learner to follow a strict sequence of lessons in learning Biology practical;
5. provide a clear demonstration of the virtual laboratory/workshop for effective learning of Biology practicals;
6. Give students exercises at the end of each learning session;
7. provide timely feedback on attempted exercises and store students' performance;
8. Give clear instructions using demonstration videos and help-line on how to use the software;
9. Students' energy should mainly be dedicated or converged to the contents of the subject matter and not how to use the system;
10. If a student quit the program before completing an instructional unit, it should be possible to re-enter at the point where he or she gave up.

### **Module design**

In developing the VLP includes, the target user, the language level, the purpose of the

VLP and the pedagogical approach and appropriate use of technology were thoroughly considered. The Module design phase in this study was considered as the phase of the VLP prototype development. This was initiated within the following framework of three sub-tasks provided: (1) Structure of the knowledge base for the VLP, (2) Selection of computer language used in creating the expert system; and (3) Inference techniques (that is the method used to process the system).

(1) Structure of the knowledge base for the tutor: The strategy used by the researchers was to develop the Student, Tutoring, User Interface and Domain Models to teach the contents of the Biology practical as follows:

- (a) Student's Model: The student model stores and updates data about the student's performance in the subject domain. It is the device that understands the amount of knowledge that the student has. The student model may keep any number of students' characteristics, depending on the system requirements. In the context of this study, three basic categories of the students' characteristics were used.
  - (i) Personal data: Personal characteristics of a student which include his name, password, e-mail address, mobile phone number, course of study, year of study, beginner or old student and date of registration). This information represents the static part of the student model and was collected during the student's first learning session with the system, through the registration dialogue boxes.
  - (ii) Performance data and individual preferences: Cognitive and individual characteristics of a student. This part of the student model represents a mixture of static and dynamic data. Static data represent the desired detail level or the experience level of each student. Dynamic data is derived from the learning sessions and changes as the student progresses in the learning of the Biology practical. The performance data, both static and dynamic, is quintessential for one of the system's primary functions – adaptive

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presentation of the teaching material. This data represents the system's interpretations of the student's traits. The quality of these believes directly affect the quality of the content-adaptation process.

- (iii) Learning history: Data related to the student's interactions with the system during learning sessions. This part of the student model keeps track of what the student has done during the learning process. In particular, it keeps data about each student's learning sessions with the system, such as the date, time spent on solving exercises and the student's success in each exercise attempted. The system uses this data to provide the student with feedback about what he has done well and where he failed.
- (b) Domain Model: The domain model here represents the domain knowledge (set of concepts, practical training, texts, diagrams, motion pictures, audios, and video clips on biology practical). It was designed as a network of concepts. The concepts were presented in the context of the virtual reality of lessons.
- (c) Tutoring Model: The tutoring model in the system controls the presentation of the instructional knowledge by selecting and sequencing the domain knowledge of the concepts of biology to be learned using suitable learning strategies. The tutoring model can select the sessions to be displayed based on the output of the student model for that particular student. The tutoring model was designed using a drill-and-practice learning process after taking into account various pedagogical principles for learning biology.
- (d) The User Interface Model: A User Interface Model was designed to provide an interface between the student and the VLP by clicking and reading from the screen. This is so because most programs use non-vocal techniques which include typing and clicking on buttons as well as reading from the screen.

The four models of the VLP were designed to work with a smooth interface to deliver the contents of the subject matter to the student in a dynamic and personalized style.

- (2) Selection of Computer Language that was used in Creating the Expert System: The development of the VLP focused on using the programming language that can accommodate a combination of virtual elements in line with the software requirements specifications (SRS). As such, Hypertext Mark-up Language (HTML) and Cascading Style Sheets (CSS) were used for the user interface design, while Python (Django framework) was used for the logic and database. The criteria for selecting Python was based on: multimedia capability, data handling capability, ease of use and level of configuration with little or no difficulty on installation that met the software requirements specifications of the VLP.

- (3) Inference Technique: In developing the expert system for the VLP, the researchers wrote the Models of VLP as a system of "IF Then" production rules because it is the most suitable for the inference process of this system. A rule means a structure which has an 'IF' component and a 'THEN' component. The statement after the word 'IF' represents some pattern which may be observed. The statement or set of statements, after the word 'THEN' represents some conclusion that can be drawn by the VLP, or some action that the VLP should take. For instance, 'IF' the learner scores place a beaker correctly, 'THEN' allow him to proceed to the next session. This type of rule is often referred to as a production rule. A set of production rules, together with software that can reason with them, is known as an Inference Technique or production system.

#### (4) VLP Installation and Operation

The Virtual Laboratory Package at least 1 GHz and above processor, 1 GGB of RAM, 64/32 bits system type.

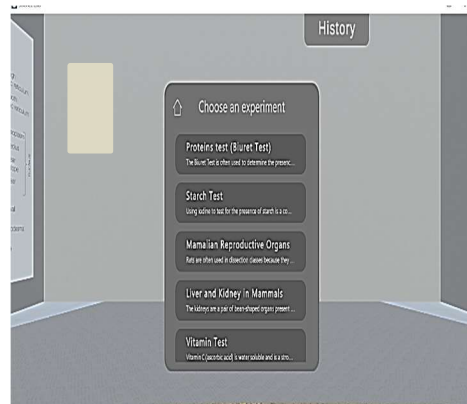


Figure 1: Revised VLP Folder

1. Python-2.7.15.amd64 (for 64-bit OS) was copied and installed;
2. Python-2.7.15.amd32 (for 32-bit OS) was copied and installed;
3. The VLP software can be copied and installed into the system;
4. The 'Revised VLP' folder should be double-clicked (See Figure 1)
5. Then, the 'setup' icon in Figure 1 was double-clicked;
6. The instructions displayed by the installation dialogue box were followed by clicking the 'next' instruction until the 'finish' stage was reached.
7. The Schoovir icon is then double-clicked to launch the installed Science Lab or 'Technical La' to run the Technical workshop software

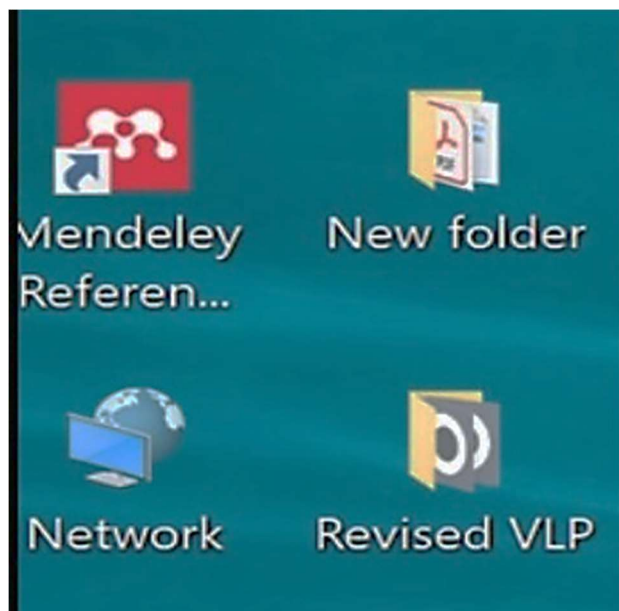


Figure 2: The VLP Main Menu

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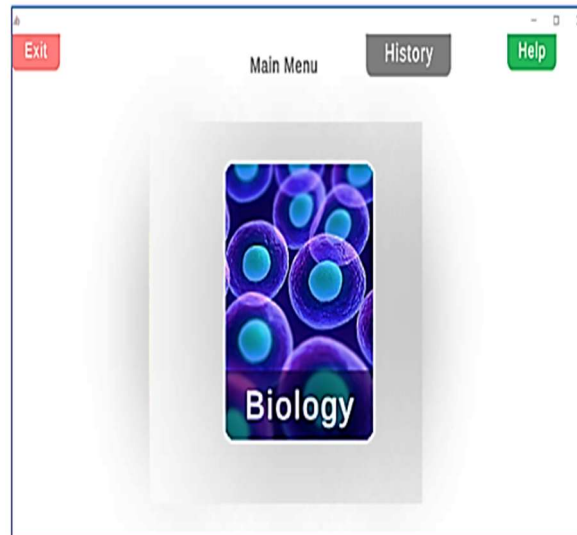


Figure 3: The VLP Practical Selection Menu



Figure 4: Biology Practical on Mammalian Reproductive Organs

### Research Question Two

What is the functionality, Content Validity and Usability of the 4-model VLP?

The validation of the VLP was done in stages to ensure effective system delivery in the teaching and learning of Biology practical. The first validation known as Functionality Test was done by software experts to ensure that the VLP

development is in line with the SRS. The second aspect of the validation was to scrutinize the contents of the domain model (subject matter to be taught) to ensure that the Biology practical are in line with the approved syllabus. More so, the Usability of the VLP was tested by the end users who are Biology students and teachers at secondary school level in Nigeria.

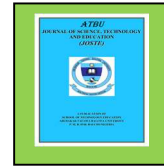
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### Functionality Test

The software experts checked all the functions of the VLP and ascertained that it was

able to perform the expected tasks as stipulated in the SRS document as follows:

**Table 1:** Functionality Analysis of the VLP by Software Experts

SN	Expectation/Requirement	Score (%)	Remark
1.	Provides the benefit of one-on-one instruction of Biology practical	98	Satisfactory
2.	Store students' information such as name, level, registration number and year	99	Satisfactory
3.	Track the user's learning history and behaviour	97	Satisfactory
4.	Force the learner to follow a strict sequence of lessons in learning of Biology practical.	98	Satisfactory
5.	Provide clear demonstration of the virtual laboratory/workshop for effective learning of Biology practical.	99	Satisfactory
6.	Give students exercises at the end of each learning session	96	Satisfactory
7.	Provide timely feedback on attempted exercises and store student's performance	97	Satisfactory
8.	Give clear instructions using demonstration videos and help-line on how to use the software	95	Satisfactory
9.	Students' energy should mainly be dedicated or converged to the contents of the subject matter and not how to use the system	97	Satisfactory
10.	If a student quit the program before completing an instructional unit, it should be possible to re-enter at the point where he or she gave up	99	Satisfactory

Data presented and analyzed in Table 1 shows that the VLP software had very high system functionality output of 96-99%. This means that the package performed all the expected functions based on the requirement engineering that was conceived SRS document.

### Content Validation

To establish content and face validity of the virtual laboratory package a pilot study was conducted across the six geopolitical zones of the country. Six subject specialists in Biology were trained on how to use the software and

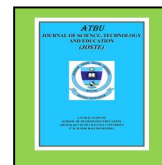
subsequently conducted all the practical. A designed validation guide instrument titled Virtual Laboratory Package Content Validation Questionnaire (VLPCVQ) was then administered to the participants and the data collected was analysed using count, percentage, mean and standard deviation. A mean of 2 and above indicates positive response while a lesser mean indicates negative response. The percentages were used in determining the degree of the respondents' responses. The results of the analysis were in Table 2 below.

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**Table 2:** Teachers Validation Results of the Developed Biology VLP

S/N	Statement	N	1	Scale 2	3	Total	$\bar{X}$	SD	Remark
1.	Adequacy of the practical in relation to the National Educational Research and Development Council Biology curriculum.	12	2(16.7%)	4(33.3%)	6(50%)	12(100%)	2.33	0.82	Very Adequate
2.	Adequacy of the practical in relation to the scheme of work.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Adequate
3.	How the practical in the VLP reflect the actual Biology practical conducted in senior secondary school?	12	0(0%)	4(33.3%)	8(66.7%)	12(100%)	2.67	0.52	Highly reflected
4.	Is there any Biology practical in the software that is not conducted in your school?	12	10(83.3%)	2(16.7%)		12(100%)	1.17	0.41	No
5.	Appropriateness of the arrangement of the Biology practical in order of simplicity and relevance.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Appropriate
6.	Relevance of the practical in achieving the learning outcomes.	12	0(0%)	0(0%)	12(100%)	12(100%)	3.00	0.00	Very Relevant
7.	Adequacy of the practical in achieving the learning outcomes.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Adequate
8.	Suitability of the items required for conducting the practical.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Suitable
9.	Adequacy of the items required for conducting the practical.	12	0(0%)	4(33.3%)	8(66.7%)	12(100%)	2.67	0.52	Very Adequate
10.	Suitability of the apparatus for conducting the practical.	12	0(0%)	4(33.3%)	8(66.7%)	12(100%)	2.67	0.52	Very Suitable
11.	Adequacy of the apparatus for conducting the practical.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Adequate
12.	Accuracy of the steps involves in conducting the practical.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Accurate

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S/N	Statement	N	1	Scale 2	3	Total	$\bar{X}$	SD	Remark
13.	Appropriateness of the stated procedure in conducting the practical in relation to the students' ability level.	12	0(0%)	0(0%)	12(100%)	12(100%)	3.00	0.00	Very Appropriate
14.	Accuracy of the result(s)/outcome(s) of the practical.	12	0(0%)	0(0%)	12(100%)	12(100%)	3.00	0.00	Very Accurate
15.	Appropriateness of the evaluation questions in assessing the learning outcomes.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Appropriate
16.	Adequacy of the evaluation questions in covering the learning outcomes.	12	0(0%)	2(16.7%)	10(83.3%)	12(100%)	2.83	0.41	Very Adequate
17.	Clarity of the evaluation questions in line with the students' ability level.	12	0(0%)	0(0%)	12(100%)	12(100%)	3.00	0.00	Very Clear
Overall Responses		12	2(1.0%)	32(16.7%)	158(82.3%)	192(100%)	2.81	0.42	Highly Valid

Results in Table 2 show that all the statements raised about the content and face validity of the Biology Virtual Laboratory Package received high ratings from the participants, and the overall assessment of 158 (82.3%) of the participants' responses indicates that the software is highly valid (Figure 5). However, the major

recommendations given by the participants are; (1) More practicals should be added (2) More operations and hands-on activity should be added (3) Some grammatical errors exist in some of the practical which need to be corrected (4) A preamble inform of theoretical aspect of the practical should also be provided.

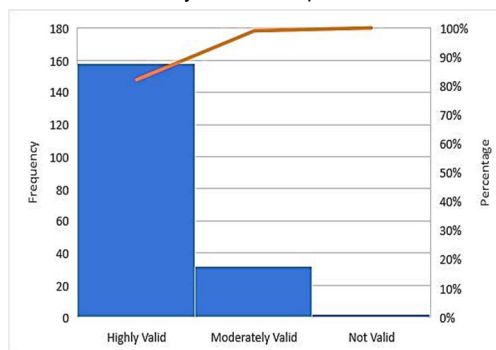


Figure 5: Overall Validity Assessment of Biology Virtual Laboratory Package

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### Students Usability Validation Results

Usability testing was used to verify the usefulness and efficiency of the virtual laboratory application. The usability testing was conducted on three major constructs: “Effectiveness”, “User-friendliness” and “Ease of Use”. These tests were conducted in order to verify the effectiveness, ease of use and friendliness of the user interface design of the virtual lab application to the target users. In essence, a VLP Usability Questionnaire (VLUQ) was used for this purpose. During the test,

users followed the actions listed in a specified. After performing the task, the users completed a questionnaire based on their experience of the test.

### Effectiveness Evaluation

This evaluation was done by students and the data was analysed using mean (average rating) as presented in Table 3, 4 and 5 as follows

**Table 3:** Mean Rating of Biology Students on the Effectiveness of the VLP

SN	Questions	$\bar{X}$
1	How good is the virtual lab at helping students to identify the available practicals?	4.47
2	How effective is the virtual lab in helping the students to conduct practicals?	4.32
3	How good is the virtual lab at helping students to identify the available apparatus?	4.39
4	How good is the virtual lab at helping students to identify the procedure of conducting an experiment?	4.40

Data presented and analyzed in Table 3 and Figure 6 in relation to Effectiveness Evaluation, shows that the average rating for the four questions is in the range of 4.4 – 4.47 on a

scale of 1 – 5, with 5 being the highest preferred rating. This shows the virtual lab application is effective.

### a. User Friendliness Evaluation

**Table 4:** Mean Rating of Biology Students on the User Friendliness of the VLP

SN	Question	$\bar{X}$
1	How helpful is the design of the home page in finding the desired practical?	4.27
2	How helpful is the practical page in helping students to identify all the apparatus?	4.39
3	How helpful is the practical page in helping students to identify the procedure?	4.40
4	How clear are the texts or images on items in explaining the functions of the items?	4.34
5	Is the size of the texts and images big enough so that it is easy to be seen and read by a user?	4.45
6	Is the system running smoothly and responsive to user action (e.g. page changes after the user clicks on a button)?	4.10

Data presented and analyzed in Table 4 and Figure 7 above in relation to User Friendliness Evaluation, the average rating for the four questions is in the range of 4.11 – 4.45 on a scale

of 1 – 5, with 5 being the highest preferred rating. This shows the virtual lab application is user-friendly.

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## Ease of Use Evaluation

**Table 5:** Mean Rating of Biology Students on the Ease of Use of the VLP

SN	Question	$\bar{X}$
1	I think that I would like to use this system frequently	4.57
2	I found the system unnecessarily complex	2.72
3	I thought the system was easy to use	4.03
4	I think that I would need the support of a technical person to be able to use this system	3.59
5	I found the various functions in this system were well-integrated	4.37
6	I thought there was too much inconsistency in this system	2.46
7	I would imagine that most people would learn to use this system very quickly	4.44
8	I found the system very cumbersome to use	2.93
9	I felt very confident using the system	4.40
10	I needed to learn a lot of things before I could get going with this system	3.61

Figure 8: Chart on Ease-of-Use Evaluation

Data presented and analyzed in Table 5 and Figure 8 in relation to the Ease-of-Use Evaluation, there are six positively worded questions and have an average rating in the range of 4.41 – 4.57 on a scale of 1 – 5, with 5 being the preferred rating. This shows the virtual lab application has a good ease of use evaluation score. On the other hand, the negatively worded questions have an average rating in the range of 2.72 – 3.59 on a scale of 1 – 5 with 1 being the preferred score.

### SUMMARY OF MAJOR FINDINGS

The following findings emerged from data analysis:

1. The Student, Tutoring and User Interface Models of the VLP for effective teaching and learning of Biology practical was developed and contained: Student Model: (a) Recognition of individual students by the VLP; and (b) Provision of user 'log-in and out' interface in the VLP. Tutoring Model: (a) Controlling the presentation of the instructional knowledge; (b) Adaptive presentation of lessons on Biology practical; and (c) Consistency of the format of presentation of lessons. User Interface Model: (a) Time taken in providing feedback to options selected by students; (b) Clarity and ease of operation and selection of menus in the VLP; (c)

Ease of interaction between students and other aspects of the VLP.

2. The developed VLP for effective teaching and learning of Biology practicals is suitable and usable in terms of "Effectiveness", "User-friendliness" and "Ease of Use."

### DISCUSSION OF FINDINGS

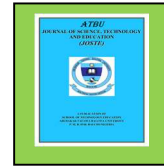
The finding on the successful development of the Student, Tutoring and User Interface Models of the VLP for effective teaching and learning of Biology practical is concurrent with that of Oloyede and Adekunle (2009) who developed a computer package on electrochemistry (ECIP) for secondary schools in Nigeria and found that the design of the ECIP conformed to the acceptable standards of Educational Technologists in terms of legibility, simulation and navigation. Similarly, the study also found out that The developed VLP for effective teaching and learning of Biology practicals is suitable and usable in terms of "Effectiveness", "User-friendliness" and "Ease of Use. This validation result is similar to that of Yuniarti, Yeni and Yokhebed (2017) who conducted a study on the Development of a Virtual Laboratory Based on Interactive Multimedia on Planting and Painting Bacteria. Similarly, the finding is congruent with that of Serevina, and Kirana (2019) in a study on

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the Development of virtual laboratory assisted by Flash and PhET to support distance learning. Moreover, Sasmito and Sekarsari's (2022) finding on enhancing students' understanding and motivation during the COVID-19 pandemic via the development of a virtual laboratory is also in agreement with this finding.

The VLP was found valid by both Biology students and teachers because the validators believed that the software provides simple, user-friendly, appropriate and accurate steps for conducting Biology practicals. The software was also examined to be interactive, relevant and adequate for achieving psychomotor and cognitive learning outcomes. The developed VLP is suitable and usable in terms of "Effectiveness", "User-friendliness" and "Ease of Use".

#### CONCLUSION

The research sought to develop virtual laboratory software for teaching and learning of Biology practical in Nigeria. The appropriate contents of the Student, Tutoring and User Interface Models of the VLP have been fully developed and found to have a high rate of functionality. The software was found to be valid and user-friendly for teaching and learning Biology practicals in Nigeria.

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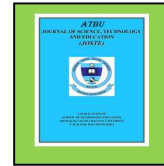
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