Development of Virtual Classes and Laboratories with Remote Access

*[1]Mary A. Adedoyin, [1,2]Adetokunbo A. Adenowo, and [1]Fatia O. Egberongbe-Kukoyi
[1]Department of Electronic and Computer Engineering, Lagos State University, Nigeria
[2]Department of Computer Science, Lagos State University, Nigeria
mary.adedoyin@lasu.edu.ng | adetokyom@yahoo.com | egberongbekukoyifatiat@gmail.com

Received: 03-NOV-2024; Reviewed: 20-FEB-2024; Accepted: 18-MARCH-2024
https://dx.doi.org/10.4314/fuoyejet.v9i1.8

ORIGINAL RESEARCH

Abstract— When comparing a few decades ago to now, the educational system has undergone various technological revolutions, particularly with the usage of Virtual Learning Environments (VLEs), which have changed the process of teaching and learning. VLEs with internet services play a major role in the storage of information and its dissemination. With the use of VLEs, there emerges the challenge of bringing practical classes online, engaging the students in practical sessions as it is in traditional laboratories. Though, there have been various simulators but they are not geared towards educational sessions but practically for industrial use and are not curriculum-based, this has been a major concern in engaging the students practically at a distance level according to the instructor's plan. Hence, in this work, a robust VLE has been designed and implemented. The system has an evaluated model that was developed with MySQL and PHP, which served as the database and server-side programming, respectively. The proposed VLE offers an interactive web-enabled approach for online learning and practice, practical recordings are uploaded, and practical simulations are handled. Qualitative assessments were carried out on the gathered data from the 100 respondents through the use of the questionnaire. Performance metrics such as response time, latency, availability, reliability and scalability were used to conduct a comparative analysis between the existing VLEs and the developed VLE. The findings of the study showed that the utilisation of the proposed VLE has the potential to cause a positive transformation and a paradigm shift in educational institutions.

Keywords— Online practical, remote access, virtual learning environment, videos, database

1 Introduction

The world of the 21st century is greatly experiencing changes in the aspect of technology as a result of socio-economic demands and the need to have quick and better communication and delivery of services in various divisions of life such as economy, media, religion, transportation and education, among others. The integration of innovative and technological initiatives in the learning activities equips learners with 21st Century Skills such as creativity, collaboration and critical thinking by adopting the content knowledge concept and pedagogical techniques to improve their higher-order thinking skills (Jain & Kaur, 2022). Education as a major tool of the transformation of the human mind has gone beyond the four walls of learning as virtual environments are created (Avidov-Ungar & Eshet-Alkakay, 2011).

In the world of education, there are various virtual environments created specifically for learning, these environments are called Virtual Learning Environments (VLEs) while some social media platforms like WhatsApp and Telegram are adaptively used to foster learning between the instructors and the students. VLE is a web-based network used by educational institutions for the digital components of courses of study. VLEs with remote access help learners to acquire access and knowledge in different disciplines through the resources provided by the instructors on the computer networks using various developed applications (Hristov *et al.*, 2013).

The resources provided via these VLEs can be accessed by the learner anytime and anywhere. It has voice explanations and video lessons from the instructors, which are made available to the learners at any point in time. The majority of the learners had improved in their learning as even students with low self-esteem are not intimidated by the students around them when there is a need for them to ask questions on the areas they do not understand as they privately chat with the instructor for further explanations on the lessons they were taught. From the VLEs, the instructor can give a quick assessment to the learners to ascertain the understanding of the teachings that were made during the online class period and get quick feedback at a percentage level to understand the number of students who are following the teachings and possibly the areas where they are lacking in the teachings for reinforcements.

Also, students can assess their results of learning from the VLE. The online results help the learners to know the level at which they are performing in their various disciplines and the availability of resources helps the students as they do not need to seek for the library before they can read books that will aid their learning in their various disciplines. This system of learning has helped many students to acquire degrees in institutions where they had gone to their physical buildings once or twice or had never even seen the physical location. More students had the opportunity to enrol in the institution of learning as the internet provides a large form of networks where various information is to be shared and spread from one

*Corresponding Author

Section B- ELECTRICAL/COMPUTER ENGINEERING & COMPUTING SCIENCES
Can be cited as:
Adedoyin M.A., Adenowo A.A., and Egberongbe-Kukoyi F.O. (2024). Development of Virtual Classes and Laboratories with Remote Access, FUOYE Journal of Engineering and Technology (FUOYE**JET**), **9(1), 49-55.**
https://dx.doi.org/10.4314/fuoyejet.v9i1.8

person to another. The VLE also reduces the risk involved in students travelling for long distances to attend classes and the cost implication in accommodating a large number of students in classrooms and hostels for learning and resting respectively. The VLE is designed, and implemented in such a way that any user must register on it before he/she can participate in the activities that go on in the environment. The information of the students and lecturers can be extracted from the institution database and this information can be used as unique details for every staff member and student to be able to login to the VLE; information like matriculation numbers and staff identity numbers (ID) can be used as a tally to gain access (Unwin *et al.*, 2010).

The advent of the widespread disease called "CORONAVIRUS" in the year 2020 all over the world, which resulted in all students staying at home compulsorily to avoid the spread of the virus has really shown the educational system the need for learning to take place through another avenue (Allen & Barker, 2020). Furthermore, the number of students who need to be enrolled in the institution of learning within a year is more than the available physical structure of the institution, hence, there is a need to develop VLEs to address these above-mentioned challenges. In conclusion, there have been so many VLEs created to enhance education, but concerning the expediency of VLE to enhance learning activities; they have not been able to fulfill the objectives of all subjects especially the practical aspect of the subjects which are carried out in workshops and laboratories. How can laboratory/workshop practices be integrated into the design and implementation of VLEs? What are the challenges faced in incorporating laboratory/workshop practices in the VLEs design? This is what gave rise to this work as there is a need to find innovative solutions to these problems so as to see VLE as a great replica and well-improved system of the traditional school settings and enhance laboratory practices that take place in traditional laboratories into the environment.

2 Related Works

The world and its mode of operations are changing because the economic, social and technological forces are influencing them tremendously. These forces are causing dynamic changes in the way institutions educate and learn. Moore, Dickson-Deane & Galyen (2011) noted that the desire for flexible access to life-long learning as well as the necessity for varied learning models due to the skills gap and demographic shifts had had an impact on teaching and learning. Online learning, electronic learning (e-learning), virtual learning, web-based learning, and distant learning are some of the terminologies used to describe how social and technological forces have had an impact on the learning and teaching processes. Presently, e-learning is entering a new phase as a result of advances in technology, ideas, and devices. In 1996, CECIL, the first web-based Learning Management System (LMS), was created. An LMS is frequently described as a piece of software used to document, coordinate, and deliver different e-learning courses (Wang *et al.*, 2020; Sheridan *et al.*, 2002). The host can supply a variety of learning content, including reading materials, video and audio, chats, online conferences, tests, grading, blogs, learning games, etc., using the LMS, which are primarily web-based software. VLEs with LMS become useful in improving and reinforcing the method of learning within the 21st century. A VLE can assist the learners' special needs because it can afford the learners to access the training contents anywhere and at any time. The learners hold classes in the comfort of their homes with their instructors or they download the video of class content, audio or e-books later once they are online. Also, VLEs give lecturers the ability to monitor student learning and provide the means to record transitions between learning tasks (Mhlongo *et al.*, 2023; Mackay & Fisher, 2013).

Science laboratories and technical workshops have been placed where scientists are being built and technicians are made respectively, Instructional laboratories have been accepted as essential for the training and education of scientists and the promotion of science literacy generally (Sus *et al.*, 2020). The activities that happen during the laboratories/workshops can last for four hours and more. There are several electronic laboratories like chemistry labs, electrical/electronic labs, biology labs, physics labs, etc. which are developed with different sets of activities and students' responsibilities. There are several features related to these laboratories and workshops like connecting electronic components, makings of bricks, mixing of chemicals etc., though there have not been universally acceptable e-laboratories/workshops but these virtual laboratories are ready to present practical features to enhance learning among students.

A virtual experiment is a scientific and educational experiment conducted in a simulated or digital environment rather than in a physical laboratory setting with stage instructions. These experiments are often conducted using computer software, simulations, or virtual reality technology. Each virtual experiment has basic concepts, introductory information/background reading, step-by-step guidance, assignments, quizzes, logs/worksheets assessment and report writing. The virtual laboratories comprise a number of associated virtual experiments that integrate simulations and educational tools. Virtual labs have many benefits to offer the teaching and learning process, including lower costs for acquiring physical materials, lower risks for students in labs and workshops, greater accessibility for students, ability to present training content on a larger scale, ability to record results automatically by software and facilitate easy experiment reconfiguration.

The study by Mark Ching-pong Poo *et al.* (2023) presents a comprehensive summary of the implementation status and adoption levels of a VLE with remote laboratories for educational institutions during the COVID-19 pandemic. Practical insights and recommendations were offered.

http://.doi.org/10.46792/fuoyejet.v9i1.1133 engineering.fuoye.edu.ng/journal

Also, best practices aimed at improving the overall quality of learning experiences for students engaged in remote or online education settings were provided. Bohdan Susa *et al.* (2020) discussed VLE implementation model for robust online education systems to support and facilitate the seamless continuity of the educational process at educational institutions and schools. The authors addressed the inherent challenges associated with the development of specialised software solutions for VLEs, emphasizing the importance of establishing seamless integration between VLEs and LMS to enable effective learning processes. Furthermore, Ayse Yayla *et al.* (2020) developed an innovative VLE with remote laboratory application explicitly designed to increase the accessibility and electronic circuit design and analysis by adopting the speech recognition technology. This application enabled students to analyse and interact with electronic circuits in a hands-free manner by using speaking commands. The core functionality of speech recognition was facilitated through the integration of the Google Web Speech API, while the user interface was developed using Adobe Flash Professional. The application itself was developed using the C# programming language with the experimental hardware setup, comprising components such as a signal generator, a Raspberry Pi 2 equipped with a camera module and an oscilloscope. Upon successful completion of the predefined experimental procedures by a student, the application would automatically generate and send an email to the instructor.

Robles-Gómez *et al.* (2020) introduced a cloud-hosted VLE with remote laboratory that creates simulated environments by combining virtualisation and cloud computing technologies. The curricula of cybersecurity courses as a supplementary online resource were integrated into the VLE, degrees of satisfaction and technology acceptance among the students who utilised it were analysed. In a similar vein, Also, Ruben Morales-Menendez *et al.* (2019) developed a VLE with remote laboratory for teaching courses related to industrial automation processes and systems. However, most of the existing VLES are not geared towards educational sessions but practically for industrial use and are not curriculum-based. This has been a major concern in engaging the students practically at a distance level according to the instructor’s plan. Hence, in this work, a robust VLE has been designed in such a way that the remote laboratories are incorporated into the system based on specific courses’ curriculum for better interaction between the instructors and the learners, proper monitoring activities of the practical works and feedback from the process of learning and videos of practical session from the instructors are posted on the VLE for the learners to go over at their own pace and time coupled with the online laboratory activities.

3 Materials and Method

In this work, a qualitative method was adopted to carry out assessments on the gathered data from the 100 respondents through the use of the questionnaire. Performance metrics such as response time, latency, availability, reliability and scalability were used to conduct a comparative analysis between the existing VLEs and the developed VLE. The research design aims to gather data on the existing VLEs.

3.1 System Architecture

The proposed VLE gives room for students to obtain training online using the audio and video equipment incorporated into the VLE. After students have been duly registered, they are given a username and password which enable them to access the VLE platform where they can engage with various lecturers or instructors and the materials provided for training. Through collaborative software, the instructor's voice, PowerPoint slides, and slide annotations were broadcast in real-time from the physical classroom to online students, enabling simultaneous training delivery. This was done using collaborative software. Using an instant messenger built into the VLE, an in-class teaching assistant brought the online students into the classroom. The teaching assistant using the text tool, responded to their questions immediately or, if necessary, sent their real-time inquiries to the lecturer. There is a section on the VLEs where the video lessons are saved, it provides students who have difficulties the ability to view earlier classes or training that they missed. The forum on the course website and email were the main forms of communication for students who watched the training asynchronously with their teaching assistant.

The course materials of the instructors are converted from the text format to digital format using different Content Management System (CMS) and are made available within the VLE, where they will be downloaded when the learners connect to the VLE via the web service. Also, practical works are administered by the course instructors from the remote laboratories on the VLE and these processes are made available for the learners to observe and imitate from the VLE. The proposed VLE for the virtual lab with remote access has been developed using a number of online tools, to enhance practical sessions for the learners. Online laboratory demonstrations are made easier with the help of this collaborative tool, such that videos of laboratory processes of the instructor are seen and a portion of the online laboratory where specimens, devices and tools are used to carry out practices. 3D virtual models via the online collaborative application are used to modify photos on personal computers (rotate, pan, zoom, label, delete structures, etc.), connect circuits, mix various chemicals together, and in addition, the students can also view the instructors’ screen as he/she carries them through the practical session. Access to the archival demos is available.

A Remote Laboratory Management System (RMLS) is designed to solve the problems encountered with laboratory activities via the existing VLE designs to promote learning activities beyond just the training activities. The RMLS design works like a specialised workflow management system to improve the efficiency of operations and enhance the overall experience for students and instructors (Adedapo, 2023). It is used for

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the creation of a VLE to manage user engagement with the contents and assessment; manage learning content using a web framework and a backend server to communicate with the computer's operating system. The RMLS application's access management system comprises a web interface that must be logged into using the user's credentials that have been provided before access and permissions to the platform can be granted. The RLMS as a module of the SARL System, is shown in Fig. 1 while Fig. 2 displays the layout of VLE and RLMS interconnectivity with the user. According to Fig. 2, the Smart Adapter retrieves the activities that take place in the laboratory and assessment content from the VLE, the reliability module detects failures and provides feedback on those failures to the laboratory manager, and they are connected with one or more online laboratory stations to create a learning environment. The security/privacy module is connected with all the other modules providing services such as identity validation, detection of anomalies in the system (attacks, malicious code insertion, etc.) and encryption. The design architecture consists of physical equipment, an experiment controller, RMLS framework and application layers. The infrastructure was set up using AWS in order to implement the RLMS and LMS frameworks.

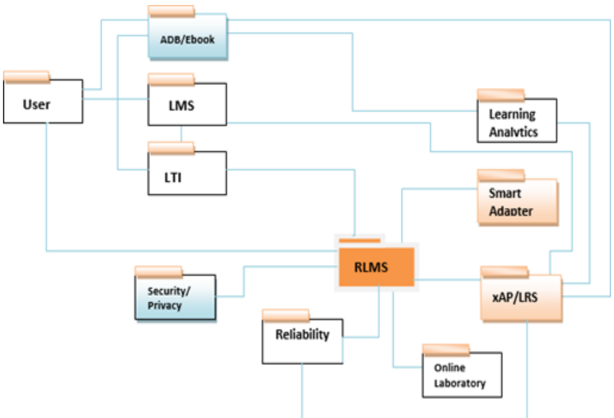

Fig. 1. RLMS as a Module of the SARL System

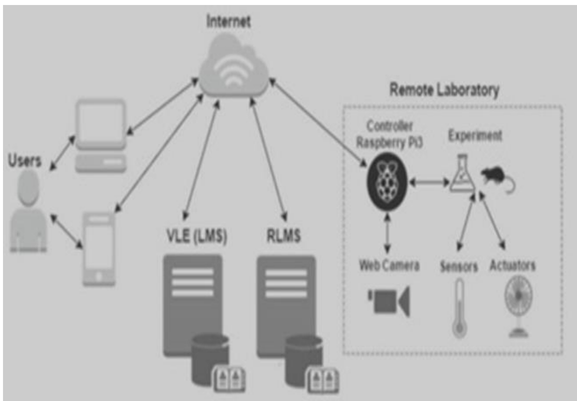

Fig. 2. Layout of VLE & RLMS interconnectivity with the User

3.2 System Requirements

The basic prerequisites to implement the VLE are 1.8 GHz Core I3 Processor with 2 GB of memory, 250 GB hard disk space, a graphics card with an 800 x 600pixel screen and 32bit quality, sound Card and Multimedia speakers, 802.11b/g wireless network card for wireless LAN, CD/DVD rewritable drive with a modem, LAN card with 10/100 Mbps Ethernet and Webcam system. 2.2.8 Apache Wamp Server, broadband internet connection such as Cable or ADSL for real-time video and audio monitoring of the experiments carried out, technologies such as Javascript, AJAX, Flashplayer are required for the developments of the VLE.

3.3 System Technology

Programming technology, Web technology, database technology, Javascript, AJAX and Flashplayer are all integrated during the implementation of the VLE System in conjunction with the RLMS using open source software (Apache, MySQL, and PHP) running on Windows 10 as the operating system. Some of these codes are included in the Appendix. The technological tools are chosen due to the several operations of this design as the laboratory process would sometimes requires high defined video card for the camera process of the practical works with a big broadband width of internet connections. This system uses Python to interface with the physical experiment, camera, sensors, and other commands.

The Moodle LMS was selected as the platform. This open-source platform for educators has a modular architecture based on plugins that may be altered to create any specific functionality. The establishment of the Learning Tools Interoperability (LTI) link between the RLMS and the LMS as depicted in the design is possible using this Platform's flexible open-source Moodle LMS version 3.0.

3.4 System Implementation

The VLE was developed using technologies such as JavaScript. PHP 5.2.5, a server-side scripting language known for its flexibility, many built-in functions, and relatively easy learning curve, served as the core application for developing the dynamic VLE. MySQL 5.0.51 was employed for constructing the database, enabling seamless collaboration between PHP and Apache to access and present data in a readable format for web browsers. This robust database management system was adopted to provide data over the internet due to its ability to handle heavy workloads and advanced security measures. The implementation followed an Apache and MySQL design structure, incorporating the VLE to manage user access to content and assessments, the RLMS user manager, and a backend server to facilitate communication with the computer board's operating system, as illustrated in the interface shown in Fig 3. The design architecture consists of physical equipment, experiment controller, RMLS framework and applications.

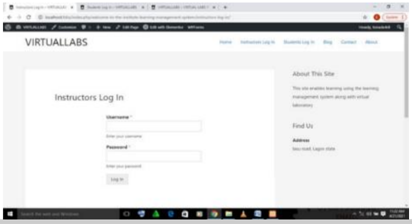

Fig. 3. Design Architecture of RLMS

Amazon Web Services (AWS) was used because of its robust security measures to safeguard the RMLS instance's login information. The instance data is redundantly stored across multiple physical locations using Amazon Elastic Block Storage (EBS). Security groups act as firewalls, allowing the instance to specify protocols, ports, and source IP ranges that can access it. Additionally, static IPv4 addresses, known as Elastic IP addresses, are utilised for dynamic cloud computing.
AWS securely stores the public key, while the RMLS instance stores the private key in a protected location. The operating system installed was Ubuntu Server 16.04 LTS (HVM), chosen for its compatibility with all types of storage, including SSD volume types. The key features of the RMLS are as follows:

1. Communication Resources: The web server has to be properly set up and configured before beginning the VLE and RLMS implementation. To connect with the servers, a backend programming language is offered. Apache server, MySQL, and PHP are the resources deployed for this implementation in order to handle and control data information.
2. Apache Implementation: This feature is an HTTP (Web) server that enables communication and ensures the administration of all data requests between the web server host and the client.
3. PHP Implementation: The PHP program is what enables the developed programs to initiate and terminate all server-side processing instructions from the web browser.
4. Database implementation: A database is an organized collection of data that enables the tracking of user interactions and data entered into the RMLS system. For this model, MySQL was the installed database system.
5. Home Page: The home page of the virtual lab is shown in Fig. 4, which was developed using a PHP form. It includes a message for the virtual lab.

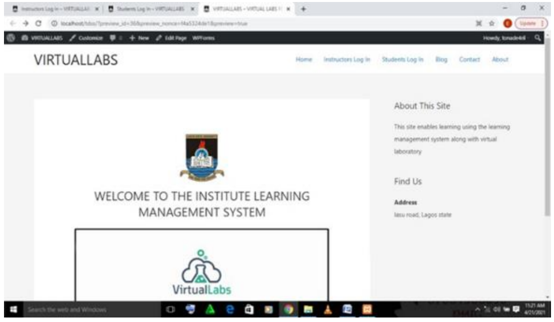

Fig. 4. Home Page of the Virtual lab

6. Instructor login: In Fig. 5, the instructor's login page is displayed. Two textboxes and a login button are included on this PHP form page for

Fig. 5. Instructor' Login page

data entry. For enrolled lecturer, it captures their instructor ID and password, enabling them to log in and add or modify instructional materials.
7. Student login: In Fig. 6, the student's login page is displayed. The input fields consist of two textboxes and a login button on a PHP form. It allows enrolled students to login and see instructional resources by collecting their student ID and password.

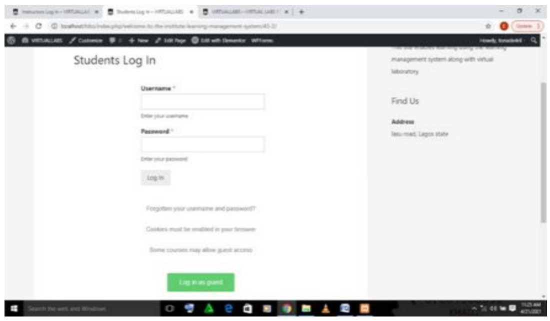

Fig 6. Students' Login page

8. Student Account Page: In Fig. 7, the student's account page is displayed. The name of student is prominently displayed above the website in a PHP form. The list of courses that the students plan to learn is shown in the course overview further down the page.

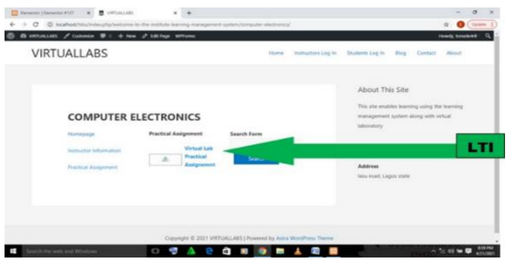

Fig. 7. Students' Account page

9. Course Page View: The course page view is shown in Fig. 8 as a PHP form. This is where the details of the coursework and assignments with practical activities for the courses are posted. A practical assignment (Demo) was posted for the students to access as provided by the instructor. This practical assignment is linked using LTI.

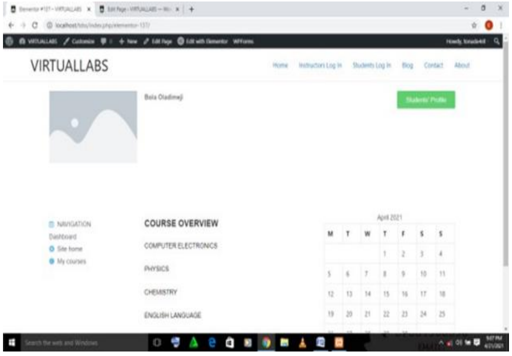

Fig. 8. Course Page View

10. Practical Page View: The practical Page view is shown below in Fig. 9 as an electronic lab example in PHP format. This is the page that displays the experiment set up and the practical exercise provided by the instructor so that the students can follow.

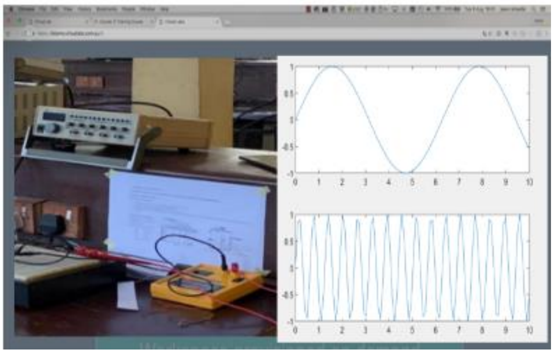

Fig. 9. Practical Page view

4 Result and Discussion

4.1 VLE Testing

The VLE testing sample was 100 respondents in the Faculty of Engineering through the use of a responsive sampling technique. The students were located in different locations on campus and out of campus. Each question consists of a two-point Liker-type scale: 1) Agree and 2) Disagree. The results of this testing are shown in Table 1. The performance metrics such as response time, latency, availability, reliability and scalability were used to conduct a comparative analysis between the existing VLEs and the developed VLE. The results of this testing are shown in Table 2. Also, the evaluation process consists of the following steps:

1. Usability Testing: This involves evaluating the ease of use and user experience of the virtual classes and laboratories. This evaluation was conducted through user testing sessions where users interact with the platform and provide feedback on its usability, navigation, interface design, and overall user experience.
2. Functionality Testing: This evaluation involves testing each component, such as virtual simulations, interactive modules, and remote access capabilities, to verify that they function correctly and meet the specified requirements.
3. Performance Testing: This testing assesses the system's performance under various conditions, such as bandwidths, and hardware configurations.
4. Accessibility Evaluation: This evaluation involves testing the platform's compatibility with screen readers, keyboard navigation, and alternative input methods to ensure equal access for all users.
5. Security Assessment: This evaluation includes testing for data encryption, authentication mechanisms, authorisation controls, secure data transmission, and protection against cyber threats such as hacking and data breaches.
6. Content Evaluation: Content evaluation assesses the quality, accuracy, and relevance of the educational content provided within the virtual classes and laboratories. This evaluation ensures that the content aligns with curriculum objectives, educational standards, and best practices in the respective fields of study.
7. Feedback and Iterative Improvement: Collecting feedback through surveys, user reviews, and performance analytics helped to identify areas for improvement and make iterative enhancements to enhance the platform's effectiveness and user satisfaction.

4.2 Result

The summary of VLE's ease of use is presented in Table 1 and the comparative analysis of the performance evaluation of the existing and proposed VLEs is presented in Table 2. The findings of the study showed that the utilization of the proposed VLEs has a flourishing potential to cause a positive transformation and a paradigm shift in educational institutions.

Table 1. Summary of VLE's ease of use

S/N	Questions	Agree	Disagree
1	The navigation menus are easy to understand and use.	98	2
2	The process of accessing course materials or experiments within the VLE is seamless.	99	1
3	The platform is compatible with various devices and operating systems.	98	2
4	I am able to quickly locate learning materials or specific experiments.	100	0
5	There are clear instructions provided for conducting experiments and completing tasks within the virtual environment.	100	0
6	The platform is responsive and fast, without significant lag or delays.	96	4
7	There are accessible support resources available to assist me.	98	2
8	I can easily collaborate with my peers or instructors within the virtual laboratory or classroom.	95	5
9	I can easily track my progress and achievements within the platform.	97	3
10	There are interactive features that enhance engagement and facilitate learning.	98	2
11	The VLE effectively simulate real-world laboratory experiences and classroom interactions.	98	2
12	There are tools available for instructors to monitor and assess student performance.	98	2
13	I can remotely take experiments at any time and place I like	100	0
14	I am satisfied working with this VLE	99	1

Table 2. Comparative Analysis of the Performance Evaluation of the Existing and Proposed VLEs

Performance Metrics	Response Time	Latency	Availability	Reliability	Scalability
Existing VLE	Moderate	Moderate	Moderate	Moderate	Low
Proposed VLE	High	Low	High	High	High

5 Conclusion

This work involves the study and overview of VLE and the evolving trends of the implementation of remote laboratories along with the courses during the teaching and learning process. Also, it improves the practical activities for students with active, collaborative, and personalised learning as key principles based on the student-centred business philosophy. The development of a VLE model led to its eventual implementation as a web-based system employing the Apache web server, PHP for server-side scripting, HTML for client-side scripting, and MySQL for relational databases. The presented formal description of the VLE system incorporates remote laboratories; a great innovation that enhances the practical aspect of various courses beyond the four walls of the institution and improves the pedagogically sound approach to adaptively composing and personalising the access of learning contents in tertiary institutions. VLE model presented the main components of the model performing several functions of both the courses' learning materials and the online practical materials to meet individual learners' learning requirements based on the type of courses they offer. Finally, the architectural design was implemented using Apache, WampServer, MySQL, and PHP web technology tools.

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Appendix

Codes for creating a password-protected login page with Apache 2.2.8. This involves using *.htaccess* and *.htpasswd* files.

Step 1: Create an .htpasswd file

This file contains usernames and encrypted passwords.

htpasswd -c /path/to/.htpasswd username

This command will prompt a user to enter a password for the specified username and create the *.htpasswd* file if it doesn't exist. If the file already exists, omit the -c flag.

Step 2: Create the *.htaccess* file

This file contains directives that Apache will use to control access to the site or specific directories.

```
AuthType Basic
AuthName "Restricted Area"
AuthUserFile /path/to/.htpasswd
Require valid-user
```

Replace /path/to/.htpasswd with the actual path to the *.htpasswd* file.

Step 3: Place the *.htaccess* file

Place the *.htaccess* file in the directory to be protected. If the entire site is to be protected, the file will be placed in the root directory.

Step 4: Restart Apache

After making these changes, Apache needs to be restarted for the changes to take effect.

Brief explanation of the directives used:

AuthType Basic: This specifies the authentication mechanism to use (in this case, basic authentication).

AuthName: This sets the authentication realm, a description displayed to users when prompted for credentials.

AuthUserFile: This specifies the path to the **.htpasswd** file containing usernames and encrypted passwords.

Require valid-user: Requires any valid user listed in the **.htpasswd** file to access the protected resource.