East African Journal of Information Technology
eajit.eanso.org
Volume 7, Issue 1, 2024
Print ISSN: 2707-5346 | Online ISSN: 2707-5354
Title DOI: https://doi.org/10.37284/2707-5354

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Design of a Virtual Laboratory for Secondary Schools

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Article DOI: https://doi.org/10.37284/eajit.7.1.2291

Date Published:

10 October 2024

Keywords:

Virtual, Laboratory, Secondary Schools, Physics, Practicals.

ABSTRACT

This Virtual physics laboratory is an important instrument used in science, engineering, and technology courses to improve learning and understanding of many theoretical topics. This study proposes the introduction of a Virtual lab and need for a Virtual lab as an alternate tool in place of the physical lab for learning and understanding. The report examined developed virtual labs, compared the physical lab to the virtual lab, and justified the need for virtual lab adoption. Virtual labs are interactive simulators that use frontend and backend technology. Through the development of a virtual laboratory, this initiative seeks to transform the teaching of physics in secondary schools. The virtual laboratory gives students an immersive environment to conduct experiments, illustrate concepts, and investigate physical phenomena by getting over resource constraints and safety concerns. The lab provides lifelike simulations of mechanics, electricity, magnetism, and optics by utilizing technologies like virtual reality and simulation software. Features like adjustable parameters and instant feedback enhance student engagement and learning. Through user testing and feedback iterations, the laboratory is refined to align with educational objectives. Evaluation metrics assess its effectiveness in improving student understanding, retention, and overall learning outcomes. By democratizing physics education, this project empowers students worldwide to explore the wonders of the physical world in a dynamic digital environment, transforming physics instruction along the way.

APA CITATION

Nkwande, M. J., Mwisomba, C., Karawa, C. & Salawa, J. S. (2024). Design of a Virtual Laboratory for Secondary Schools. *East African Journal of Information Technology*, *7*(1), 394-399. https://doi.org/10.37284/eajit.7.1.2291

CHICAGO CITATION

Nkwande, Maganga John, Candida Mwisomba, Cuthbert Karawa and Joseph Sospeter Salawa. 2024. "Design of a Virtual Laboratory for Secondary Schools". *East African Journal of Information Technology* 7 (1), 394-399. https://doi.org/10.37284/eajit.7.1.2291.

HARVARD CITATION

Nkwande, M. J., Mwisomba, C., Karawa, C. & Salawa, J. S. (2024) "Design of a Virtual Laboratory for Secondary Schools", *East African Journal of Information Technology*, 7(1), pp. 394-399. doi: 10.37284/eajit.7.1.2291.

IEEE CITATION

M. J., Nkwande, C., Mwisomba, C., Karawa & J. S. Salawa "Design of a Virtual Laboratory for Secondary Schools.", *EAJIT*, vol. 7, no. 1, pp. 394-399, Oct. 2024.

Article DOI: https://doi.org/10.37284/eajit.7.1.2291

MLA CITATION

Nkwande, Maganga John, Candida Mwisomba, Cuthbert Karawa & Joseph Sospeter Salawa "Design of a Virtual Laboratory for Secondary Schools". *East African Journal of Information Technology*, Vol. 7, no. 1, Oct. 2024, pp. 394-399, doi:10.37284/eajit.7.1.2291.

INTRODUCTION

Virtual labs are essentially visually appealing simulators that represent all of the components and setups of physical labs. Frontend and backend technologies are utilized to make any simulator appealing. In any simulator, frontend technologies are mostly utilized to provide everything that the user sees on a simulator page (*ChemLab A Virtual Chemistry Lab - Chemistry Lab Simulations - ChemLab by Model Science Software*, n.d.). Frontend technologies are responsible for the simulator's appearance and feel, as well as its responsive design.

Users can visit Virtual labs anytime and can do any experiment multiple times to clear his/her doubt as these labs can easily be accessible through the internet (Khairudin et al., 2019). Because of the attractive simulators, the curiosity of the users increases while performing any experiments virtually. Virtual labs help students not only to learn basics but also to understand advanced topics through virtual experimentation. With the help of the Virtual labs, a user can repeatedly perform any experiment without the time and place restrictions (Schnieder et al., 2022). Performing an experiment on a Virtual lab before the physical lab, allows students to make mistakes without fear of not getting the experiment done right. Virtual labs protect students and teachers from hazards, as there is no direct contact with chemicals and no handling of explosive devices or electricity. Virtual labs are not limited to any 50-minute class period (Gamage et al., 2020), users can perform experiments through Virtual labs before and after class from his/her home. Many users can access a single experiment at the same time. Virtual labs have been developed for different domains (Christopoulos et al., 2018). These are not bounded for any specific domain area. Virtual Labs are not the replacement of physical labs but they act as a supplementary learning for students and teachers. The practical work in laboratories for any student is as important as any theoretical class (Rizman Herga et al., 2016). Virtual labs provide an environment in which teaching and practicing any experiment is possible without any physical contact. It generates awareness among students about the equipment and procedure of those experiments which may not be easily explained in physical labs due to time and precautions issues (Oser & Fraser, 2015).

Physical vs Virtual labs

In Science and Technology, practical work is very important so laboratories are set up by the institutions for the same. Laboratories can be physical or virtual. Physical labs are also known as traditional labs. These labs are essentially an area that contains many specified equipment with many students performing experiments with their instructor in a real-time environment. The output of the experiment is then recorded and analysed in the form of a handwritten report.

Virtual labs are those labs that are developed virtually with the help of different programming languages in the form of responsive, attractive and user-friendly simulators (Chakravarti et al., 2021). There are many differences between the types of labs that are mentioned below. In physical labs there is highly paid equipment which are having high maintenance costs but in Virtual labs there are no such additional expenses, you only required a computer or a laptop with an internet connection (Mujkanovic et al., 2015).

In physical labs, there is a need for a teacher to explain the procedure or steps of an experiment but in Virtual labs, no need for a teacher for instructions is required as instructions are given in a very simple language. In physical labs, resources sharing is very complex and in Virtual labs it is very simple. A single experiment can be performed by few users only in physical labs while in Virtual labs multiple users can perform experiments at the same time (Baranov, 2016).

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NEED OF ADOPTION OF VIRTUAL LABS

Users found Virtual labs to be very exciting and enjoyable due to interactive simulators and different video links which are provided by the developer. The attractive visual effects in the Virtual labs make it more useful for users to grasp any concept quickly (Lindsay et al., 2007). The adoption of Virtual labs is the need of the hour because these labs use computer software only which is very cheap and easily accessible by the students and even the risk factor associated with these experiments are negligible. Those data can be easily examined by the students with the help of Virtual labs which are not concerned with their prior knowledge but these data are very difficult to examine through physical labs. Difficult experiments can be easily performed by the students with the help of Virtual labs because of its understandable design (Neumann & Woodfill, 1997). In physical labs if equipment is not available and even the existing equipment is not working properly then in that situation the teaching may be affected. Virtual labs do not have these kinds of problems as equipment is virtually available and because of this quality the operational cost of Virtual labs is also reduced (Tuysuz, 2010). If we develop a virtual experiment of any physical experiment then the lifetime of that experiment increases and we can perform that experiment virtually without any wear and tear of equipment. The quality of practical work in any field is increased through Virtual labs. Virtual technology acts as a boon to those who live in distant areas where fully equipped laboratories with expensive equipment are not available. These labs are available for worldwide users across the globe (Saliah-Hassane et al., 2000). Many experiments deal with high voltage devices, concentrated chemicals and huge machines that have risk factors involved with them and are eliminated by performing them virtually. It also increases the safety factor of the user. The other main importance of Virtual labs is that students can practice an experiment in advance before moving on to physical equipment due to the mistreatment and damage of equipment (Dziabenko et al., 2013).

CASE STUDIES

To show the real environment of physical labs in any Virtual labs, a method is used in which we are creating virtual copies of real labs. In this method, a photo of any lab is clicked by choosing an appropriate point initially. The equipment in the lab is positioned in such a way that all the equipment is clearly visible to the user and then marking of that equipment is done. The model of 3 dimensional is made for every equipment with the help of good quality pictures. These 3D models of each equipment are then transferred as images of 2D in the PNG format after choosing an appropriate viewpoint of the 3D model with some modifications.

SYSTEM DESIGN

Designing a virtual physics laboratory for secondary schools involves a meticulous approach to system architecture, user interface, and functional modules. The system architecture leverages a component-based design, integrating essential elements such as the user interface, physics engine, and database management. This architecture ensures that each part of the system operates cohesively, providing a seamless user experience. The user interface is crafted to be intuitive and educational, incorporating drag-and-drop features, interactive buttons, and detailed wireframes that facilitate easy navigation and engagement with the simulations. Additionally, the core functional modules, including the simulation module, experiment setup module, and data analysis tools, are designed to emulate real-life physics experiments, allowing students to interact with and learn complex physics concepts through practical, hands-on virtual experiments.

The expected system is supposed to work based on the figure represented by the following flow chart diagram.

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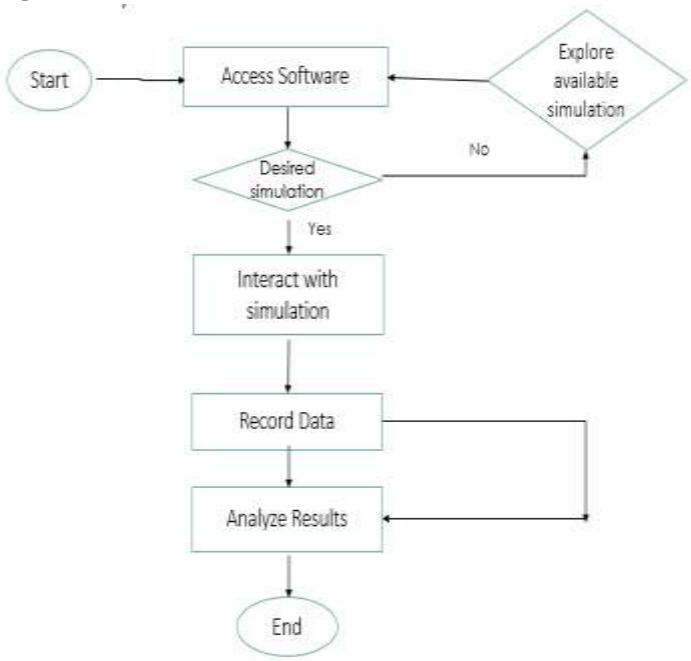
Figure 1. Flowchart



RESULTS AND DISCUSSIONS

It was observed that there were so many limitations associated with physical laboratories work. Physical labs have pre-defined schedules which limit the availability of time for performing experiments by students. If a user fails to complete the experiment on time which is assigned to him due to some reason, then the complete practical will be lost for him. Even some safety issues also arise along with equipment shortage in many physical labs that are set up by many institutions. To overcome those limitations technology plays a vital role with development of Virtual labs. The teaching and learning methods which are currently used can be enhanced with this technology that is Virtual labs. By Virtual labs, the visual concepts of the students are developed which motivates them to be actively involved in the laboratory works in class. It can act as an alternative for those institutions that are not able to provide fully equipped labs for practical and research work of students. Safe and attractive environment is provided by Virtual labs for better improvement of learning approaches. Virtual labs provide an opportunity for users to repeat an experiment multiple times and the experiments can be individually performed.

From the start of the development of this project, the following figure shows a sample of what an interface of the Physics laboratory would look like.

Plate 1. Lab Interface

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CONCLUSIONS

The lack of equipment', high maintenance cost of physical labs, safety issues and other such issues which are mentioned in this paper are sufficient to show that standard of the education in the field of practical teaching is decreasing (Špernjak & Šorgo, 2010). Virtual labs are complementary tools to support better learning in the field of practical work but we can use it as an alternative tool also for those practical's that are difficult to perform in traditional labs (Bell & Fogler, 1999). Through Virtual labs students can improve their skills as Virtual labs gives them the opportunity to learn through videos, practice single experiment again and again and solve interesting assignments. In this paper, we have reviewed what Virtual labs are, how they are made, what technologies are used in making Virtual labs, how coding helps in making interactive simulators which are nothing but exact replica of the physical labs (Bortnik et al., 2017). Their contributions in the different fields of learning for making the studying method more efficient have been shown (Dalgarno et al., 2012). The advantages of Virtual labs over traditional labs and the need for adoption of these labs are also included. The paper also shows multiple reasons support that Virtual lab not only increase the interest of the students but also allow them to learn at their own pace even early in the morning. Virtual labs are truly anytime, anyplace lab (Filanovich & Povzner, 2021).

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