

A Review on Virtual lab : A Simulator for Physical lab

Praveen Kumar Chakravarti¹, Meenakshi Pradhan², Naina Choudhary³, Nikhil Kumar Mishra⁴, Saurabh Arya⁵ and Jigyasa Sharma⁶

¹Assistant Professor, Department of Electronics and Communication Engineering, Meerut Institute of Engineering and Technology, Meerut, India

^{2,3,4,5,6}U.G. Student, Department of Electronics and Communication Engineering, Meerut Institute of Engineering and Technology, Meerut, India

Abstract

Laboratory is necessary tool used in science, engineering and technology courses for better learning and understanding of different theoretical concepts. This paper proposed introduction of Virtual lab and need of Virtual lab as an alternative tool in place of physical lab for learning and understanding. The paper reviewed developed virtual labs, comparison of Physical lab and Virtual lab and justification for need of adoption of Virtual lab. Virtual labs are interactive simulators which are developed with the help of frontend and backend technologies. These technologies are HTML, CSS, JavaScript, Java, etc. It concluded that Virtual labs could also be adopted as complementary tools to support better learning for theoretical concept practical work in the field of science, engineering and technology.

Keywords: *Virtual Labs, Physical Labs, Frontend, Backend, Simulator.*

1. Introduction

Virtual Labs are basically the attractive simulators that represent all the components and set-ups of physical labs. Frontend and backend technologies are used to make any simulator attractive. In any simulator frontend technologies are basically used to display everything in a presentable way that user see on a simulator page. Frontend technologies are responsible for the look and feel of the simulator and ensures a responsive design of simulator. To create the frontend, developers use the combination of HTML (used to create skeleton of web page), CSS (used for designing) and JavaScript (to make simulator interactive). Backend technologies are those which work at the backstage of simulator. These technologies primarily focused on the working of simulator. The working of these technologies cannot be directly seen by user. Backend technologies are needed to power the frontend. Backend uses languages like Java, Python, PHP, etc.

Frontend and backend technologies are very different from one another just like two sides of the same coin. They both are equally important and play a very important role in the development of simulator for any Virtual labs. The main frontend development languages together create everything that is visually presented on the simulator screen when user visit any Virtual lab. With the help of frontend technologies, developer forms the basis of what user can see and experience on simulator and on the other side backend is the brain of the simulator that is never visible to the user and all the processing and calculations are done with the help of backend technologies.

Frontend technologies are basically used for converting data to graphical interface through the use of HTML, CSS and JavaScript so that user can easily interact with that data. Backend is exactly the codes that are running on the server, when it receives any request from the user it contains the appropriate logic to send the data back to the user and it mainly focused on a simulator responsiveness and good speed [11].

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. 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. By performing an experiment on a Virtual lab before the physical lab, it 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 minutes class period, users can perform experiments through Virtual labs before and after class from his/her home [1].

Many users can access a single experiment at the same time. Virtual labs have been developed for different domains. 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 classes. Virtual labs provide an environment in which teaching and practicing of any experiment is possible without any physical contact. It generates awareness among students about equipment and procedure of those experiments which may not be easily explained in physical labs due to time and precautions issues [7].

Below are some of the reasons which support the development of Virtual labs and shows us the importance of Virtual labs over traditional labs-

- Due to unpredictable situations in any pandemic time students cannot perform any experiment in physical labs without being physically present in college as at that time students are restricted to their homes.
- In physical labs, many experiments cannot be performed due to time limitations, complexity, lack of infrastructure, difficulty or hazards but in Virtual labs these experiments are easily simulated.
- As there are many types of software which are paid due to this the labs which are based on them cannot be performed by students. To perform such experiments students, have to pay a handsome amount for that software.
- Any student wants to practice the experiment but a predefined schedule for every physical lab can restrict the student to do so.
- If already a person is working in the physical lab then the other user has to wait until the lab gets free but in case of Virtual lab multiple users can access the same experiment at the same time.
- The time that a user spends in going to physical labs to perform any experiment can be saved by the Virtual labs as these can be accessible from your home also and users can utilize that travelling time in learning that concept more effectively.
- While performing any experiment virtually you do not need any teacher as in Virtual labs all the instructions and guidelines are provided in a very simple language so that in case of absence of teacher also users can perform any experiment very easily [8].

To support the above statements, the developments of Virtual labs are very useful.

For the development of Virtual labs experiments some steps are followed which are shown in Fig. 1 and explained below-

- First the selection of experiments is necessary which is done as per the syllabus of the university. This is done so that each and every topic which is prescribed in the syllabus of university is covered through the Virtual labs.
- After the appropriate selection of the experiment, the set of rules are made for the experiment from different books and references before developing the Virtual lab for that experiment to avoid any scope of error.
- The visual description of an experiment includes all the elements that a user will see on the screen that is why the visual description needs to be very clear for the developer to develop any experiment virtually.
- Creation of storyboard means creating the story in which overall execution of the experiment in a simplified manner is shown.
- For Virtual lab experiments apart from simulation, explanation of theory section, procedure of the experiment and assignment related to the experiments were also uploaded to enhance the knowledge of the user.

Finally, the simulator is designed for the user to perform an experiment online.

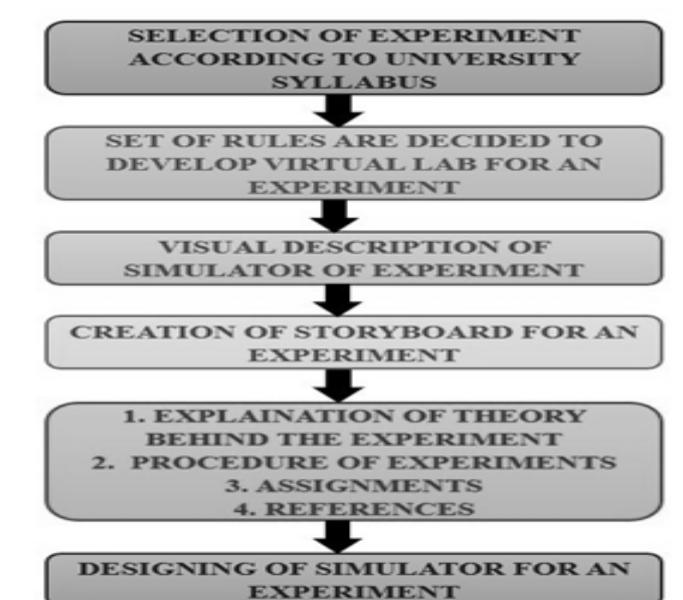


Fig. 1. Flowchart showing the steps for developing the Virtual lab experiment.

2. Physical Labs Vs Virtual Labs In Science And Technology

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 which are developed virtually with the help of different programming languages in the form of responsive, attractive and user-friendly simulators [9].

There are many differences between both the types of labs that are mentioned below. In physical labs there are 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 internet connection in it[10].

In physical labs, there is a need for a teacher for explaining the procedure or steps of 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 the 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 see Table.1 [11].

Table. 1. Table shows the difference between physical labs and virtual lab

Physical Labs	Virtual Labs
The cost of maintaining the equipments of physical labs is very high.	No cost is required for maintaining the virtual labs.
Predefined schedule for every physical lab limits the availability of time.	Virtual labs are available 24 x 7 times as per the need of users.
Need of Teacher: - teacher is require to explain the whole procedure of the experiment.	No need of teacher as instructions are provided in a very simple language.
Direct contact with chemicals and explosive devices can harm.	No direct contact is there with the harmful chemicals.
Resource sharing is complex.	Resource sharing is simple.
In physical labs, expensive or rare chemicals can be used by student only limited number of times for a single experiment.	In virtual labs, student can use expensive or rare chemicals n number of times for a single experiment.
The equipments used in physical labs are very expensive.	No additional cost only you need your computer with internet.
User need to note down every result by itself.	User can take a print out of recorded result.
At a time, only few users can perform a single experiment.	Multiple users can perform an experiment at a time.

3. 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 equipments are clearly visible to the user and then marking of those equipments 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. The development of tools of virtual reality should be properly selected. A proper planning is done. To generate Virtual copy of any equipment following series of steps are involved. First, the equipments are placed together so that a correct viewpoint can be selected to take the photograph. After identifying the proper distance, the high-quality pictures are to be taken. A 3D model which shows the shadow of each equipment is created. Now finally the 2D PNG image is formed from the 3D model after choosing an appropriate viewpoint. The PNG image scaling is to be done so that it can be fitted within the markings of equipment. By adopting correct methodology and following the steps properly, the several virtual equipments of same or different sizes can be easily moved in X or Y axis without affecting virtual reality. Some changes are required for movement of virtual components in the Y axis while having a sense to keep virtual reality in mind. This shows that real equipment Virtual copy can be made in 2D environment [2].

The existence of Virtual labs is very old around 20 years old but still many control education field people did not know about Virtual labs benefits. Control community people did not know about the current trends and popularity of the Virtual labs. If a student wants to learn from a physical lab, he/she can learn but some additional advantages are available if we talk about the Virtual labs. The advantages include that anyone from anywhere and anytime with safety measures can access Virtual labs and can get the recorded results also. Initially the control system study material was not properly available on the internet because documentation of the control system was not up to mark and the quality of the control system material was also not very good. After so many efforts, professional organisations of the control system developed WWW based tools for this in which they improved the documentation part of the control system material so that users can take the full advantage of Virtual labs in the field of control systems. Finally, after so many efforts made by the professional organisations for improving control system labs virtually, the educational material of control system labs now include so many exercises, case studies and tutorials of the control system. These developments in the field of Virtual labs will surely help students in getting proper understanding of concepts and also will enhance their ability in the control system field [3].

This paper shows that many laboratories have to be built to increase development. Due to which the students of electronics get a big achievement. A lot of research has shown that the creation of Virtual labs helps many students in development of skills and conduction of good trials. Virtual labs were created to check the study of today's time and to improve the understanding of the students. To make the students more effective in practical work it builds skills of handling and using circuits correctly. The results have shown that laboratories have been constructed to increase the achievements of the students in their fields. All engineering students read and learn about electronics circuits mentioned in courses. It enhances student development and it also provides a good opportunity to use and practice what they have learned so far in their classes. Many students need such laboratories to overcome many difficulties encountered in the results of their experiment so that they get the satisfaction of what they have done are right. The main objective of the creation of Virtual labs is that students should do the experiments correctly from electronics components. By using them for design of the circuits in a more advanced way. Whatever students do with circuits, it teaches them to understand the use of Virtual labs in the right way. All the data is recorded in the Virtual lab and students can easily get the result in a printed form. Students can know how to improve their skills of performing experiments properly with a Virtual lab. In order to promote the achievements of the use of electronic circuits, the Virtual labs have been constructed so that the development of the engineering picture can be done [4].

The Virtual lab is proposed for the student of electronic and instrumentation at university level. To enhance the quality, the Virtual lab was designed based on "Gagne's Nine Events of Instruction". It is cost effective and aims to improve student learning and teaching methodology. Many countries are working on improving the quality of education in order to produce skilled and innovative minds for the future, especially in the area of science and technology which in turn increase nation growth and play a vital role in country development. All over the world it is believed by the student that learning electronic and retaining its concept is not an easy task especially when it comes to apply those concepts practically. Research in the past year has been done on how to resolve challenges faced by a student during experimental work. As it found that after performing the experiments in the physical lab, students are still not able to understand what is the real outcome of experiments as they do not find it interesting as students cannot see what is actually happening behind, how current flows in a circuit. Have several unresolved queries like how they use that concept somewhere else. Even some are confused in between the basic terminology like what is inductor and what is inductance. The main objective behind creating the physical lab was to teach students how system parameters vary to different conditions, how they calculate accurately by estimating errors, still there are a lot of challenges which a student can only learn in a physical lab. In recent research, it is found that doing experiments virtually will help students to focus more on the experiments and can get a number of data for different readings in a short span. Instead of a physical lab where students have to perform in a group of 4 to 5 at a time. As we know lab equipment comes at a higher price which limits the ability of institutions to own and maintain it and only a few students can perform on it at a time. Performing an experiment on a Virtual lab makes it easy, now students can perform individually and at any time, and can get results just in a click by assembling blocks. Gagne's "Nine Events of Instruction" are as follow:

- Gaining attention
- Informing the learner of the objective
- Stimulating recall of prerequisite learning
- Presenting the stimulus material
- Providing learning guidance
- Eliciting the performance
- Providing feedback
- Assessing the performance
- Enhancing retention and transfer [5].

The paper provides us information regarding the ongoing projects of improving the laboratory education for students of engineering background. The context is chosen purely based on the online model. The labs which are virtual and remotely based are explained with a toolbox containing all the necessary tools. Many strategies have been developed by using such toolboxes. The toolbox is developed using many methods which are nevertheless evident. The combinations of practical education work with these planning's are being evaluated. The guidelines with suggestions are set for the users of educational institutions. These suggestions will act as feedback of the research for improving the labs accordingly. The output as feedback is taken by students in the questions and answers form. Thus, this is how the ongoing innovations regarding Virtual labs are being studied and analysed [6].

As we know that technology of virtual education is spreading widely all around the world and accepted by everyone. So, the analysis of role of Virtual labs in different fields is done. It is integrated with students' ability to learn and understand things properly. A survey was done after the use of Virtual labs by students in which it suggested that Virtual labs enhanced the guided methods of education. On comparison Virtual labs with conventional or traditional labs, this study gives the result that performance in students is improved. This analysis indicated about the learning process in a mixed environment in the classroom. The Virtual labs are also developed for students of elementary school. These little students easily do the stimulation on the devices or hardware such as the computer or laptop which they prefer. This gives them a perception about the things processes in the real world as the technologies are used for learning and teaching. This survey and study briefly tell us how Virtual labs are being used and developed for every student whether they belong to elementary, higher secondary or professional degrees [7].

The courses which we do online are increasing day by day. With this context, the online courses are providing different platforms for integrating the theory work with practical sessions. The areas of science and technology can have laboratories which are online available. The labs which are virtual or remote cannot be easily developed. As many problems occur during development which are resolved in this paper. Some pre planning is done for the designing of the architecture of labs. The solution implementation is done in EjsS with the help of Java in server and JavaScript on client sides will make the simulation of experiments on Virtual labs easy. Even the development and designing of labs get simple for developers in some ways. JavaScript is easy to use when all the basics of this is cleared to the developers. EjsS uses the Java model and has many advantages and can be explored in the future. The elements involved inside its parameters can be studied in future work. It can be concluded some qualitative comparison and analysis is to be done of original Java labs with versions of JavaScript labs. The positive feedback is given for JavaScript labs as they are more dynamic in nature. The future scope is the development of more advanced labs with more advanced architecture for research students [8].

4. Need Of Adoption Of Virtual Labs

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. 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 [9].

The adoption of Virtual labs is the need of the hour because these labs use computer software only which are 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 [12].

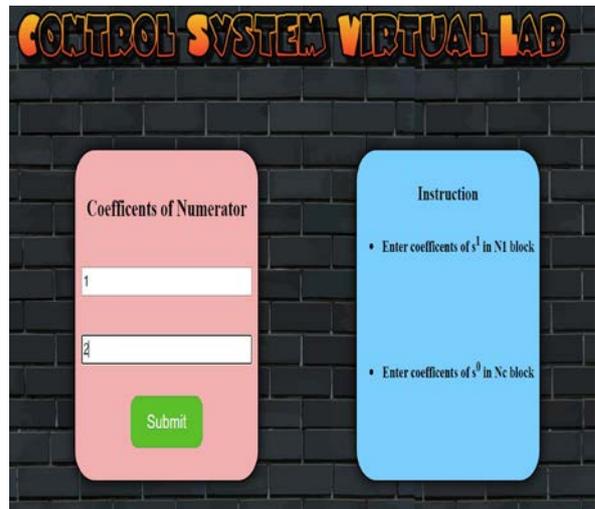
In physical labs if equipments are not available and even the existence equipments are not working properly then in that situation the teaching may affect. Virtual labs do not have these kinds of problems as equipments are virtually available and because of this quality the operational cost of Virtual labs is also reduced [13].

If we developed 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 equipments. 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 equipments are not available. These labs are available for worldwide users across the globe [19].

Many experiments deal with high voltage devices, concentrated chemicals and huge machines which have risk factors involved with them 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 physical equipment due to this the mistreating and damaging of equipment [20].



(a)



(b)

Fig. 2. (a) Sample of Physical lab (b) Sample of Virtual Lab

5. Conclusions

The lack of equipments, 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.

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 which are difficult to perform in traditional labs. Through Virtual labs students can improve their skills as Virtual labs gives them the opportunity to learn by videos, practicing single experiment again and again and by solving 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. There contributions in the different fields of learning for making the studying method more efficient has been showed. The advantages of Virtual labs over traditional labs and the need of adoption of these labs are also included. The paper also shows multiple reasons which 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 labs.

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