How Virtual Labs are Better than Traditional Labs

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ABSTRACT

Virtual reality has proved itself as a boon in many fields. Virtual Labs which is one of its application has showered the educational world with great benefits. It took a lot of hard work to develop virtual labs. It has not only improved the learning system but has also saved a lot of time and money. It has increased the engagement of students in practical applications. It has also increased scientific research rates. The evolution of virtual labs was supported by the advancement in ICT. Indian Government has started a Virtual Labs project which has participation of many prestigious engineering colleges of India. The work presented here models how virtual labs proved to be better than traditional labs in many aspects. A lot of research and reviews has been done in this technical report. This report is going to review various technologies and methods used to develop virtual labs with their pros and cons. Implementation and design of virtual labs has been reviewed in this report. Comparison of traditional labs and virtual has also been discussed in this report.

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1. Literature Review

1. Anita Diwakar, S. Poojary, S.B. Noronha [1] in their research paper have discussed about the various types of virtual labs used in education of engineering and broadly classified them into three major categories. They have also compared the advantages and disadvantages of virtual labs with the pros and cons of traditional laboratories to test the productiveness of virtual laboratories in education of engineering. They have also discussed about the various technological aspects using various free and open resources in the development of virtual labs.

2. Nurendra Choudhary [2] and his team have proposed a method in their research paper to make virtual labs accessible to all those people who lack access to internet. Their objective was to make availability and utilization of virtual labs without internet connectivity easier.

3. Shuang Wang and Huiyang Zhao [3] in their research paper proposed a scheme of designing and implementing a remote virtual lab. Their purpose was to achieve a productive solution to the problem of less quantity equipment in the school and colleges and providing less time for students to perform experiments with the help of implementation of remote virtual laboratory.

4. Lixia Zhang and Guangran Liu [4] in their research work researched about the three-dimensional images of virtual laboratory. Laboratory apparatus's model design adopts the concept of combination of geometry and images. Panoramic technology of cylinder is adopted to design the background of virtual laboratory. In their research paper, they adopted the projective geometry principle to adjust virtual apparatus direction and position. They adopted the gradation zone of illumination to integrate background and virtual apparatus. And finally, they created the suitable virtual environment.

5. Yuchuan Chen, Qingni Hu and Hong Shu [5] in their research paper put forward a different way to build the virtual reality system. A virtual lab for mechanical experiments based on Virtools technology is built. The system contains machining scenes and assembly scene. The system proposed by them can be used in colleges and potential dangers can be avoided.

6. Mrityunjay Kumar, Jessica Emory and Venkatesh Choppella [6] in their research paper examined virtual labs from a feasible point of view. They considered the productivity of user-interface elements as well as how they aid pedagogical usability. Their investigation revealed a lack of productivity focus in lab designs. They also proposed some suggestions to rapidly improve the productivity of these labs.

7. Rakhi Radhamani [7] and her team in their research paper explored an analysis of feedback of students after attending virtual lab sessions suggesting virtual labs improved learning and teaching experiences. They collected feedbacks from undergraduate and post-graduate level students of biotechnology. They collected data by organizing workshops. From their research and analysis, they concluded that virtual labs can be beneficial for institutions lacking sufficient facilities to provide better education. This can also be helpful for teachers as it reduces their efforts in teaching.

8. M. Travassos Valdez [8] and his team in their research paper demonstrated the application of desktop virtual reality prototype, 'VEMA' in engineering unit. They developed several interactive scenes to illustrate the idea using a measurements and instrumentation laboratory as virtual environment. Students can design complex circuits with the help of VEMA.

9. Mikel Perales, Luis Pedraza and Pablo Moreno-Ger [9] in their research paper explained about a continuing project on educational innovation focusses primarily on refining the practical knowledge students of engineering, in the condition of a purely online educational model. They have provided a set of guidelines and recommendations for educational practitioners as output of their research.

10. Garima Ahuja, Anubha Gupta, Harsh Wardhan and Venkatesh Choppella [10] in their research work examined the impression of Advanced VLSI Virtual Lab. Their work was the first attempt to statistically study the productiveness of the Virtual Lab. They designed and conducted several surveys and feedbacks on the virtual labs and hence concluded the effectiveness of these laboratories.

2. Introduction to Virtual Reality

Virtual reality technology is developing speedily. At the starting of 1990s the evolution in the field of virtual reality technology became much rougher and the word VR itself became highly popular. The term virtual reality can be heard very often in all kind of media. People misuse this term in many situations too. VR is a word used to depict a computer-generated virtual environment that may be relocated through and controlled by a user in actual time.

Virtual Reality refers to obsession, interactive, multi-sensory, three-dimensional computer-generated virtual environments and the collection of technologies demanded to construct these environments. With the help of VR technology one can navigate and see a new world of three-dimensional images in real time, with six degrees of freedom. In extract, virtual reality is duplicate of physical reality.

Apparently, you'll never go to mars, swim with fishes, run an Olympic 400 meters, or dance onstage with the Rolling Stones. But if virtual reality makes success, you might be able to perform all these activities and many others at your home. Virtual Reality is different from the reality in which we are living. It is a complete imaginary world simulating bit of our real world using high performance computers and sensory equipment, like gloves and headsets. It is not only used for gaming and entertainment purpose.

2.1 What is Virtual Reality?

Virtual Reality means to experience things that do not exist for real through computers. From that easy definition of virtual reality, the idea does not feel like especially new. For example, if you look at the wonderful Canaletto painting, you are experiencing the views and sounds of Italy as it was about 250 years ago-so that is sort of virtual reality. Similarly, if you close your eyes and starts listening to some instrumental or classical music and then starts dreaming about things, is not that an example of virtual reality-like you are experiencing a world that does not really exist? What about getting lost while reading a book or watching a movie? That is a kind of virtual reality for sure?

We need to define virtual reality clearly if we want to understand why movies, paintings, books, and pieces of music are not the same thing as virtual reality. For this purpose, I'll define virtual reality as:

A credible, interactive 3D computer-generated world that you examine or explore so that you feel you are really present there, mentally or physically.

Explaining it in another way, virtual reality is:

1. **Credible:** To keep the illusion of virtual reality alive, you really need to believe that you are in a virtual world (on another planet, or wherever). You also need to feel like you are existing in a virtual world.

2. **Interactive:** Virtual reality world moves with you as you move around. While watching 3D movies you can be taken up to the Moon or down to the seabed. But unlike virtual reality, it is not interactional in any sense.

3. **Computer-created:** It is important because only high-performance machines, with practical three-dimensional computer graphics, are quick enough to make credible, interactional, alternative worlds that convert in actual time as we roam around them.

4. **Explorable:** In order to explore virtual world, it needs to be huge and explained enough. However practical a painting is, it displays only one section, from one point of view. A big and complicated "virtual world" can be described by a book, but it can only be explored in a linear way, exactly as the writer explains it.

5. **Immersive:** Virtual reality needs to employ both our mind and our mind for both believable and interactional experience. A brief look of conflict can be given by paintings by war artists, but the sight, sound, smell, taste, and feel of war can never be fully conveyed by them.

Why listening to a classical music, watching a movie, reading a book, or looking at a painting do not meet the expectations of virtual reality can be observed from this. All of them provide a brief look of another reality, but none of them are explorable, interactive, or fully credible.

Virtual Reality is completely different. It makes us think that we are really residing inside a completely credible virtual world (on in which, you are partially or fully immersed). It is a two-way interaction: what you see responds to you, as you respond to what you see: as you turn your head all over the place, what you hear or see in virtual reality changes to match your new point of view

2.2 What equipment do we require for virtual reality?

If we close our eyes and think of VR and we possibly imagine something like the picture given below: a person wearing a wraparound headset (HMD) and datagloves, wired into a high-level workstation or supercomputer.

Fig.2.2. A geek wearing a wraparound headset and datagloves

What makes virtual reality different from ordinary computer experience is the type of the output and input. Ordinary computer uses stuff like a keyboard, mouse or speech recognition for input but virtual reality uses sensors that perceive how our body parts are moving.

The brief information about more common virtual reality input and output devices:

2.2.1 Head-mounted displays (HMDs)

Fig.2.2.1. Head-mounted displays (HMDs)

The two major dissimilarities between virtual reality and seeing at an ordinary computer screen: in virtual reality, we see a 3D image that changes evenly, in actual time, as we move our head. It is feasible by wearing a head-mounted display.

2.2.2 Immersive rooms

A substitute to using an HMD is to move inside a room onto whose walls are changing images are forecasted from outside. This technique is used by flight simulators.

2.2.3 Datagloves

When we see something amazing, our natural instinct is to touch it. The ability to deal with virtual objects is made possible by Datagloves. They are normal and ordinary gloves with sensors wired to the outside to perceive hand motions.

Fig.2.2.2. Datagloves

2.2.4 Wands

It is simpler device than a dataglove. A wand is a stick like device used to interact with a virtual world. We can use it to touch and point virtual world. It has built in position or motion sensors and mouse-like button or scroll wheels.

Fig.2.2.3. Wands

2.3 Applications of Virtual Reality

Virtual Reality has always been considered as a dream world. It is a highly practised technology used by doctors, scientists, archaeologists, dentists, engineers, architects and military for past few years. It has applications in different fields. What type of things can we do with it?

- Training of difficult and dangerous jobs is hard. Safely practising landing a jumbo jet, experiencing a parachute jump, taking a trip to space, or doing a brain surgery. All these practices come under the applications of virtual reality.
- It gets hard to examine anything on atomic or molecular level. Instead of fighting with complex equations, numbers, or two-dimensional images, you can click a complex molecule together in front of our eyes by using this technology.
- Virtual reality is used in surgical training, drug design and telemedicine.
- Earlier, architects used to make models out of papers and cards. But nowadays they started making computer models through which people can walk and explore.
- It gets much affordable to design cars, airplanes, and other complex design of vehicles on a computer screen rather than on wood, plastic or other material.
- Virtual reality has taken the gaming experience on another level. From car racing to fight simulator games, virtual reality has taken them into a new gaming world.

Fig.2.3 Non-Gaming VR Applications

2.4 Pros and cons of virtual reality

Virtual reality has also pros and cons like any other technology. It has resolved so many problems in our life but on the other it is taking us away from real world. VR is used in military, medical, engineering, archaeology in different ways. We are not using VR routinely like we use smartphones, laptops, etc.

3. Introduction to Virtual Labs

Students are more restricted to learn from physical computers located on campus. Now, with the development of new application of virtual reality, i.e. virtual labs, students are no more confined to physical computers to access applications. Virtual laboratory is like a playground for performing experiments where simulated experiments can be created and conducted. It is an interactional environment with computer-based activities. It is a place for face to face lab activities. It uses the technologies of models created by computers and digital simulations.

Virtual laboratory is a group of digital simulations holded up by video demonstrations, discussion forums, hyperlinked glossaries, and email lists.

In virtual labs, students learn about the theoretical and practical aspects of experiments without the use of papers and pen. They perform experiments without the real laboratory with its doors and walls. Computers are programmed electronically to simulate the real experiments inside the traditional labs.

Virtual labs have played an important role in the better understanding of concepts of experiments. The restricted experimental infrastructure and sources do not give satisfactory learning outcome. It becomes challenging for students to attain better understanding. Adoption of the technology of virtual labs in teaching process helped in overcoming these issues.

Nowadays, it becomes difficult to install physical laboratories due to budget, space, limited technical expertise, high setup and maintenance cost. In order to overcome these challenges, virtual labs have been developed. Students can perform practical work or experiments on real systems via web-based tools due to the virtual labs. A large group of users which are geographically separated can share virtual lab resources at the cost of single facility. Virtual lab becomes an alternative to physical or real lab due to the increasing modern trend focussing more on practical knowledge by using web tools.

There are three types of virtual labs:

1. Remote triggered labs.
2. Measurement based labs.
3. Simulation or Modeling based labs.

3.1 Architecture of Virtual Lab System

The three core components of virtual lab system architecture are named as

1. LMS (The Learning Management System)

2. TWS (The Web Server)

3. TCS (The Computation Server)

3.1.1 The Learning Management System (LMS)

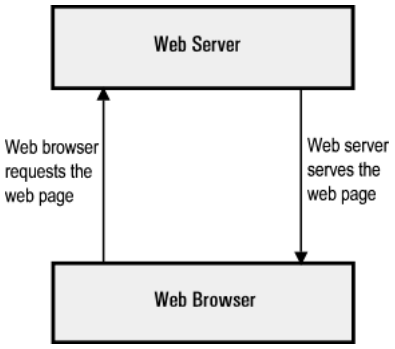
The Learning Management System is the basic module for user interaction. Various mechanisms like LDAP, Database, Open ID, etc are used by the LMS for the authentication of the user. Allocation of slots to the user to

perform an experiment is done by it. After the performance of experiment, data is sent back to the LMS, according to which grading is done. With the help of file management system, text and video documentation are uploaded. LMS also helps in achieving profile management of a user.

3.1.1. Learning Management System

3.1.2 The Web Server

A simulated environment for the student to perform experiment can be achieved by using the virtual lab web server module. Interaction between user and the system can be achieved by using a web browser like Firefox. This web browser communicates data to the web server and vice versa. Other operations like grading management, viva, communication with the computation server, pre and post experiment viva, generating reports after the examination is done, student calculation-based evaluation is performed by web servers.



3.1.2. Working of Web Server

3.1.3 The Computation Server

The computation server module by talking to computation engines like ASCEND and Scilab manages the validation of result entered by the student. The user receive result on the web interface after being sent to the web server.

3.2 Objective of Virtual Labs

The main objective of introducing the concept virtual laboratories is to remove the concept of physical labs from education. The concept of virtual lab is developed to improve the practical knowledge of a student and to provide them better and efficient learning system. The major objectives of virtual labs are as following:

- To reduce the maintenance cost of virtual laboratories.
- To encourage students to perform experiments on their own interest.
- To provide remotely accessible laboratories.
- To understand simple and complex concepts of experiments through remote access.
- To build knowledge of fundamental concepts through practical work.
- Web-based tools for learning, animated demonstrations, web resources and self-evaluation are provided.

3.3 Features of Virtual Labs

- Virtual labs arouse curiosity among students and hence enthuse them to conduct experiments.
- It develops the online interactive media.
- It is available 24/7 so that students can work on their own pace.
- Components of virtual labs look real, providing users a feel of real lab.
- Step by step guiding by wizards providing better understanding.
- It solves the problem of performing real time experiments in some limited area which require specialized equipment and skilled teachers.
- It banishes the use of harmful and toxic chemicals and dangerous equipment and hence prevent laboratory accidents.
- Students get more accurate and precise results which is not possible with real time laboratory components.
- It helps to cover the whole course curriculum within a given time period with performing practical applications.
- Synchronize the process of explaining theoretical concept and practical applications.
- Students and teachers can perform lab experiments at any time and place with the help of virtual lab system.
- The student can perform the same experiment multiple to absorb the concept deeply.
- Students can record the results, share and analyse them with others.
- Techers can analyse the progress of each student efficiently and guide them easily with the help of virtual lab system.
- It builds cooperation and interaction between teachers and students.
- Virtual lab system saves time and efforts by researchers.
- Hazardous experiments can be performed easily without harming anyone.
- Educational institutions save a lot of money.
- It helps to gain student’s attention by adding entertainment while conducting the experiment.
- Virtual lab system banishes boredom while performing experiments.
- It increases the rate of scientific researches because it saves a lot of time and efforts of researchers.

- Students who are absent can also access lab experiments at home.
- Additional infrastructure setup is not required.

3.4 Virtual Lab Project by Government

MHRD (Ministry of Human Resource Development), Government of India started the project named Virtual Labs, under the National Mission on Education through ICT (Information and Communication Technology). The main objective of project is to give remote access to Laboratories in various fields of science for students at all levels from under-graduate to research.

It also aims at developing complete and better understanding and learning management system for students where they can get benefits of many video-lectures, animated demonstrations, web-resources and self-evaluation. Expensive equipment and various resources are shared among people.

Institutions participating in this project are:

- IITD (Indian Institute of Technology Delhi)
- IITB (Indian Institute of Technology Bombay)
- IITK (Indian Institute of Technology Kanpur)
- IIT Kharagpur (Indian Institute of Technology Kharagpur)
- IITM (Indian Institute of Technology Madras)
- IITR (Indian Institute of Technology Roorkee)
- IITG (Indian Institute of Technology Guwahati)
- IIIT Hyderabad (International Institute of Information Technology Hyderabad)
- Amrita University
- Dayalbagh University
- National Institute of Technology Karnataka
- College of Engineering, Pune

The purpose of this project is to cover chemical sciences, physical sciences and various branches of engineering like CSE (Computer Science and Engineering), EE (Electrical Engineering, chemical engineering, CE (Civil Engineering), electronics and communications, IT (Information Technology) engineering and biotechnology engineering.

3.5 Comparison of Traditional Labs and Virtual Labs

Parameters	Traditional Labs	Virtual Labs
Type of educational environment	Educational environment is closed	Educational environment is open and flexible
Source of knowledge	The main sources of knowledge are the books and teachers only	Varied resources and multimedia available

Theoretical and practical knowledge	Theoretical and practical knowledge are separated	Theoretical and practical knowledge are integrated in virtual situations
Strength of students	Teaching in large groups	Teaching in small groups
Method of teaching	Teaching method is verbal	Teaching method is varied
Safety	More prone to accidents	Eliminates dangerous accidents
Result of experiment	Results are not satisfactory	Results are more accurate and precise
Engagement of students	Engagement of students is less	Engagement of students is more
Quality of experimentation	The quality of experimentation is good	The quality of experimentation is not much good
Requirement of equipment	Requirement of more equipment	Requirement of less equipment
Feasibility	Require a lot of money and time	Saves a lot of money and time
Accessibility	Their use is restricted	They can be used at any time and place
Degree of interaction	Degree of interaction is low	Degree of interaction is high
Basic knowledge of computers	Does not require any basic knowledge of computers and operating systems	Requires a basic knowledge of computers and operating systems

4. Conclusion

Virtual labs are definitely a good substitute of traditional labs. Many traditional labs have already been replaced by virtual labs and shows tremendous results in the education system. They are easily accessible and provides better understanding of concepts. Virtual labs are way much better than traditional labs. It also increases the engagement of students. It eliminates the boredom and fills student's mind with curiosity making them more enthusiastic. Their implementation in various esteemed universities and colleges has proved it as a great substitute of traditional labs.

5. References

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