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Virtual Laboratories as Interactive E-Learning Resources: Benefits and Limitations

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Abstract: ***Laboratories are integral part of the curriculum. With the advancement of technologies especially information and communication technology there is a pace for the designing and development of virtual labs. There are different types of online labs which are accessible through digital devices over internet. Virtual labs based upon 3D simulations are very close to the traditional or physical laboratories. Due to interactivity, such labs can give a pre-lab hand-on practice of experiments in a safe, secure and self pace environment. Purpose of the study is to investigate advantages and disadvantages of the virtual labs with the emphasis on their limitations.***

Keywords: Virtual Labs, 3D labs, Interactive Labs, e-learning, distance learning, remote labs

I. INTRODUCTION

Practical work has always been regarded as an important vehicle in delivering high-quality education and a distinctive feature of science teaching and learning[1]. A laboratory is that area where testing, research, innovations are tried, tested and validated before it reaches the market. It is the second house of scientists, where they perform experiments to develop new drugs, chemicals, study various types of living cells, DNA and lot more of research that helps to progress in Science and Technology[2].

For students labs are great places which help them enhance their learning by understanding the theoretical concepts of science which are taught in classrooms[3]. Laboratory teaching assumes that first-hand experience in observation and manipulation of the materials of science is superior to other methods of developing understanding and appreciation[4]. Laboratory training is also frequently used to develop skills necessary for more advanced study or research[5]. Well-designed laboratories not only make science experiments fun but also help students in achieving good academic results.

The use of technology in education plays an essential role in enhancing the learning process and increasing its effectiveness. It helps teachers explain and present information efficiently in an enjoyable way and helps students collaborate with their teachers, access other educational resources, and learn technical skills[6]. With the advancement of science, technology and advent of information and communication technology a new type of laboratory[7] called virtual laboratory came into existence where teachers should use digital technologies to support and enhance practical experience, but not to replace it. Cramer et. al. (1997) gave a definition of virtual laboratory as a software simulation of an experiment whose output data is indistinguishable from data from a real physics experiment[8]. A virtual laboratory is one where the student interacts with an experiment or activity which is intrinsically remote from the student or which has no immediate physical reality.

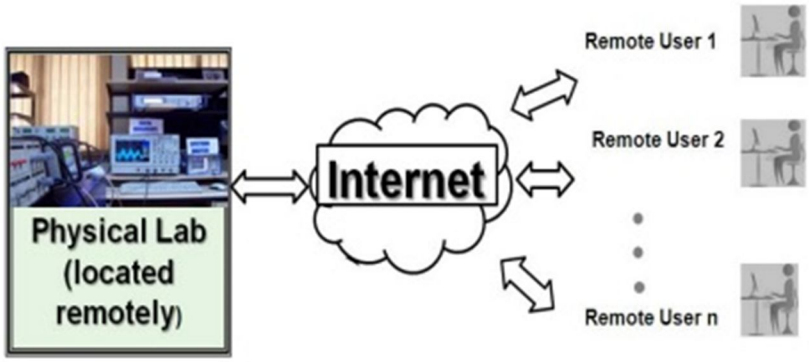

Figure 1: Concept of Virtual Lab

A. *Computer Simulations*

A computer simulation is the usage of a computer for the imitation of a real-world process or system[9]. A simulation requires a model, or a mathematical description of the real system. This is in the form of computer programs, which encompass the key characteristics or behaviors of the selected system[10]. Computer simulations are used in a wide variety of practical contexts, such as: analysis of air pollutant dispersion using atmospheric dispersion modeling, design of complex systems such as aircraft and also logistics systems.

Interactive computer simulation is a human in the loop simulation programmed inside a computer[11]. Interactive computer simulation software enables users (teachers and students) make decisions and input these decisions into the computer. The computer uses the model to calculate new values for the new inputs in the system[12].

B. *Interactive Learning Environments*

Interactive learning is any sort of academic plan that uses computer technology in order to emphasize or teach specific material. An interactive learning environment is learning that requires student participation[13]. This participation can come through class and small group discussions as well as through exploration of the interactive learning materials given in a digital classroom[14].

C. *Virtual Labs As Interactive Learning Resources*

Education has always been based on the traditional model of pursuing learning by books or locations like the library, college or any kind of field trips[15]. Other than that, people get to know through a chat process through blogs or workshops by witnessing the real-life scenario. Today's technology makes it possible to secure extraordinarily fragile structures and objects from further deterioration, given the re-establishment of verifiable information by keeping track of a current database system. As one of the most important eLearning tools, they allow the student to conduct various experiments without any constraints to place or time, in contrast to the constraints of real labs.

II. CHALLENGES WITH TRADITIONAL LAB

A. Limited or no access to physical laboratories. Students and employees don't necessarily have access to a lab at any time.

B. Risk of accidents. Experimenting with equipment and hazardous substances is particularly dangerous when learners are inexperienced.

C. Expensive lab equipment. Learners don't get to experiment with modern, advanced machines as they're often out of budget. Therefore, their learning experience is incomplete.

D. Crowded labs. Equipment and materials are limited. Not every learner will have the chance to play around and conduct experiments first-hand.

E. Low priority for learning. Few companies are able to afford equipment used specifically for training purposes. When machines and programs are used for actual work, little or no time is left for learning.

F. Lack of engagement. Common limitations of physical labs (e.g. inadequate number of machines, outdated equipment, etc.) turn learners off. If they can't practice what they're learning in theory, it's harder to understand complex concepts and stay motivated.[16]

III. TYPES OF VIRTUAL LABS

1) *Online Labs:* This is used for a laboratory accessible through the internet, which can either be a remote triggered, a virtual one (simulated) or measurement based.

2) *Simulation-based Virtual Labs:* In these types of labs, there is no real hardware or equipment at the back end. Instead, there is a simulation engine that provides output based on mathematical equations that model the real-world. This can, at-best, provide an approximate version of the 'real-world' experiment. The simulations are carried out remotely at a high-end server, and the results are communicated to the student over the Internet. Such labs are scalable and can cater to a large number of simultaneous users.

3) *Remote-triggered Labs:* Refers to a remotely accessible real lab. In these labs, the user is able to trigger a real-experiment on a real piece of equipment or hardware. The output of the experiment (being conducted remotely) is communicated back to the student over the Internet. This class of Virtual Labs gives the student the output of real-time experiments. Typically, time-slots are booked before conducting such experiments. Many such labs provide additional inputs to the students like accompanying audio and video streaming of an actual lab experiment and equipment.

4) *Measurement Based Labs:* These labs provide the corresponding measurement data for the experiment previously carried out on an actual system. These labs are closer to the 'real-world' experiment than the simulation based labs, because they deliver to the students measurement data from real equipment[17].

IV. BENEFITS OF THE VIRTUAL LABS

A virtual laboratory, though, can tackle those challenges, one by one, and virtual labs come with a bunch of benefits. Here are some of them[18]

1) *Reduce Costs:* Purchasing a high-end simulator for training seems to be expensive. But, in comparison, getting multiple devices so employees can get trained in a physical space is more costly. Besides, maintaining all this equipment will cost more than maintaining one platform.
2) *Guarantee Safety:* In a virtual laboratory, learners can try all kinds of experiments without the risk of damaging equipment or injuring themselves. They can also test different scenarios, compare, and determine which one is the most effective without having to try them out in real life.
3) *Create a True-to-life Learning Experience:* Often learners have to make guesses about how a machine operates, what the outcome of a piece of code will be, etc. They may also ignore limitations or malfunctions that could happen in a real work environment. Virtual labs help build a realistic learning environment so that learners get complete training and are more prepared.
4) *Boost Learners' Confidence:* Working with hazardous substances or handling heavy machines can be intimidating, especially for less experienced employees. Give them the chance to practice in a virtual, interactive lab environment before they're being exposed to real-life work conditions.
5) *Offer Blended Learning:* Virtual training doesn't necessarily replace traditional training; combined, they create an enhanced learning experience. In virtual laboratories, learners have the chance to apply what they learned in theory, experiment, and practice as many times as they want. Instructors can assign projects and then have follow-up sessions to discuss results.
6) *Engage Learners:* Lectures and presentations can be demotivating when it comes to hands-on jobs, like chemical experiments or construction projects. You can capture learners' attention, though, by giving them the opportunity to test those procedures in a virtual lab.
7) *Give Unlimited Time to Experiment:* Learners can repeat experiments as many times as needed and practice at their own pace. Also, they can speed up training as they don't have to wait before some equipment becomes available.
8) *Explain Complex Concepts and Procedures:* Theory can be too abstract when you can't see how it applies in real-life. But in virtual laboratories, learners can play with orbits of planets, tinker with the global economy or create a crossbreed between two species. You can use virtual t[19]raining labs to simulate any level of scale, complexity, or abstraction.
9) *Self-pace Learning:* The student is given the opportunity to control the inputs of the experiment, change the different transactions, and observe the changes in the results without the existence of a supervisor and without being exposed to any risks[20].
10) *Increase Research Speed:* The virtual labs will increase the scientific research rates because it saves time and effort and enables researchers to use their time more effectively.
11) *Collaborative Study:* The ability to record all the results electronically, which helps in analyzing them using the latest software programs and sharing the results and analysis with others.
12) *Easy Learners Monitoring and Evaluation:* Help the teacher to evaluate students electronically and easily to guide them and follow their progress in conducting experiments.
13) *Save Time And Energy:* Save time and effort for researchers by eliminating the need to move between different laboratories.

V. DISADVANTAGES AND LIMITATIONS OF THE VIRTUAL LABS

There are some major limitations and disadvantages of virtual labs, most of which are in general limitations and disadvantages of the e-learning itself.

1) *Limited Feedback:* In traditional laboratories, teachers can give students immediate face-to-face feedback. Students who are experiencing problems during the experimentation can resolve them quickly and directly by hand-on demonstration. Personalized feedback has a positive impact on students, as it makes learning processes easier, richer, and more significant, all the while raising the motivation levels of the students.

2) *Social Isolation:* The virtual labs developed so far tend to make participating students undergo contemplation, remoteness and a lack of interaction with other students. As a result, many of the students and teachers who inevitably spend much of their time online can start experiencing signs of social isolation, due to the lack of human communication in their lives. Social isolation coupled with a lack of communication often leads to several mental health issues such as heightened stress, anxiety, and negative thoughts[21].
3) *Lack of Self-Motivation:* In traditional labs, there are numerous factors which constantly push students towards their learning goals. Face-to-face communication with professors, peer-to-peer activities, and strict schedules all work in unison to keep the students from falling off track during their studies. In virtual labs, however, there are fewer external factors which push the students to perform well. In many cases, the students are left to fend for themselves during their learning activities, without anyone constantly urging them on towards their learning goals. Students performing experiments will find that they are often required to learn difficult materials in a comfortable home setting without any of the added pressure normally associated with traditional colleges. As a result, keeping up with regular deadlines during online studies can become difficult for those students who lack strong self-motivation and time management skills.
4) *Lack of Communication Skill in Students:* Due to the lack of face-to-face communication between peers, students and teachers in an online setting, the students might find that they are unable to work effectively in a team setting. Neglecting the communicational skills of the students will inevitably lead to many graduates who excel in theoretical knowledge, but who fail to pass their knowledge on to others.
5) *Technology and Infrastructure:* The success of virtual labs depends on the sound infrastructure. Networking and connectivity are two important elements in the infrastructure. The accessibility of virtual labs can be successful if and only if sound technological infrastructure exists. In this case availability of Internet plays a vital role[22].
6) *Copyright Issues:* The ownership of rights in virtual labs development is complicated and contentious. The development of virtual labs requires various tools and techniques which may be protected under the copyright laws. Some of the development platforms are proprietary in nature and limits development of virtual labs.
7) *Limited Curriculum Integration:* The concept of virtual labs is relatively new and is still under development. Without their integration to the curriculum students will not be able to pay attention towards this.

VI. CONCLUSION

As the world undergoes a radical transformation in techniques and methods of education and the use of digital devices in education, it is essential that educational institutions keep up with that transformation in order to help their students compete in the global market and fields of research. It is clear to us that the digital age will only open the way for those who can keep up with it and have technological skills that enable them to adapt to the technological applications in all aspects of life. Virtual labs are excellent digital resources that help to save costs and enhance student productivity manifolds. Moreover, they allow students to take part in course work from any location and seamlessly combine the convenience and ease of use offered by contemporary technology. While virtual labs still need some improvements to replicate the physical laboratories, it won't be wrong to say that they are very important and interactive resources for education especially e-learning and distance learning.

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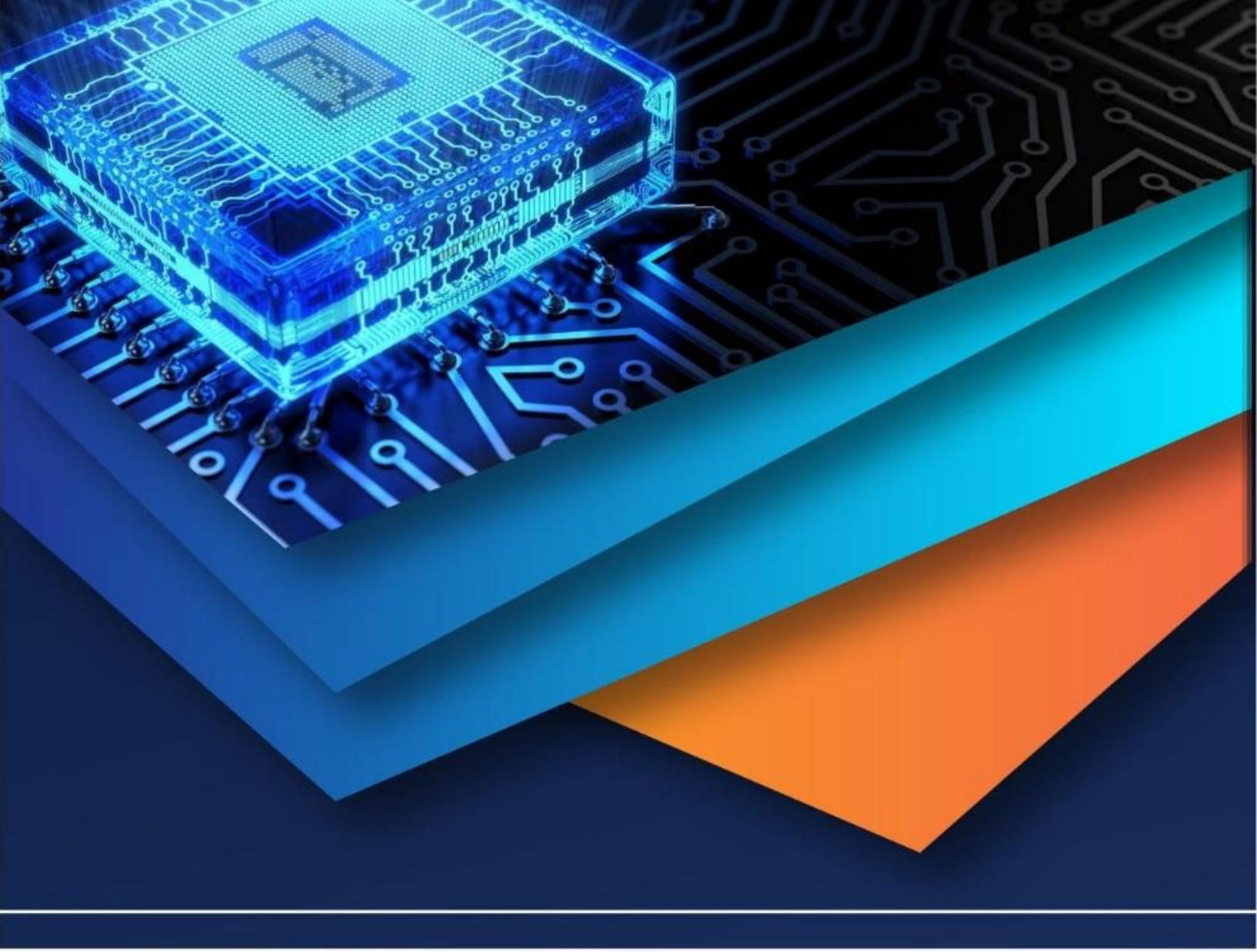

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