

Virtual lab: A powerful learning tool in science

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Abstract

Practical experiences are an important component of the educational process. However, the time and economical resources often required for the setting up and construction of scientific laboratories is outside the scope of many institutions. A solution to this problem could be found in the adaption of the Virtual Reality technology, which could allow the creation of Virtual Laboratories, simulate the processes and actions that could take place in real laboratories. During the last decades, the ICT has witnessed a rapid development in all fields. The resources of knowledge became various and numerous. The course of science is obviously connected with technology, both cognitively and practically. The importance of integrating ICT in science learning, to facilitate many scientific phenomena among learners and the use of educational software in various streams of science e.g. physics, chemistry biology etc., has gained importance. According to NCF-2005 teacher should act as a facilitator and not as a transformer of contents where they can think, realize, analyze and develop their own way of learning which should be something beyond the text book. Hence, virtual reality is considered to be a new model of computer-based learning, it provides the individual learner with a wider range of scientific vision. This kind of educational technology provides an advanced individualized learning which meets the educational needs and provides a high level of flexibility and freedom from constraints of time and place. One of the most important features of virtual reality is the easily and continuous materials update aiming to attain learning objectivity and interest. With the increasing popularity of virtual lab, globally and locally, the development of virtual learning environment has become an important field of science which has its own basics principles. On observing the reality of science education in India today, learner is constrained to the theoretical method in acquiring knowledge, rarely allowed to apply the knowledge practically. This is due to several reasons including, the lack of laboratory devices, the risks that may result from applying some scientific experiments, and the high cost of materials. In particular this paper describes the fundamentals of educational virtual laboratory, which aims to meet the requirements of a real laboratory and furthermore it explains advantages of virtual lab in present scenario and what can a virtual lab in reality do to improve experimental skills with virtual environments, and it also explains how simulation based teaching- learning enhances the teaching – learning process.

Key Words: Virtual reality, Simulations, Virtual Laboratories, e-learning, traditional lab, science education.

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INTRODUCTION

Teaching-learning activity is not limited to the delivery of theory content and evaluation but they also include some experiment activity in laboratory for some subjects like Biology, Chemistry, Mathematics, Physics etc.,

laboratory experiment and other form of experiment in teaching-learning are expected to assist learner to acquire the technical ability. The experiments should be an important source of teaching-learning in order to have a better understanding of both concepts and theories. The reality of learning activities shows the fact that many institutions don't have the required instruments to conduct the experiment. It is because of the high laboratory operational cost. Only a few learners have the opportunity to develop thinking ability because of the lack of lab experiments. Many learners receive an explanation from the teacher alone without performing experiments. Another cause that can inhibit the creative potential in the formal educational environment is the learning process which is mostly teacher-centered. Teacher explains the subject with a lecture then give exercises and assignments while the learners become information recipient, as a

result, the learners merely copy what the teacher says and asks, without further explanation and understanding. The learners assume that it is enough to work the study as exemplified. It causes the learner's lack of interest and lack of curiosity which does not help in the enhancement of creative thinking skills. During the last decades, the ICT has witnessed a rapid development in all fields. The resources of knowledge became various and numerous. The course of science is obviously connected with technology, both cognitively and practically, but the importance of integrating ICT in teaching-learning, facilitates studying many scientific phenomena. ICT has become an essential component of teaching-learning in a way it does not affect the teacher, student or course materials but it connects all these elements and the output of the educational process is of high quality. In particular, science education is greatly affected by ICT in terms of the nature of the laboratories, work and equipment. Many methods and tools used in the traditional lab no longer meet the needs of learner's for many reasons. There is a need to activate and utilize the latest ICT techniques to achieve effective science teaching-learning process. By using innovation facilitated by the possibilities of ICT in science education and practices, we can utilize the advantages of safe interactive learning that simulates real laboratory work. In general, many learners consider that science subjects (Biology, Chemistry, Mathematics and Physics) a daunting and tedious, resulting many learners have no interest in understanding and mastering basic concepts in science subjects. The teachers are expected to present the science subjects in a more interesting, innovative and creative manner. The learners may rid the wrong prejudice that a science subject is difficult for them. To teach science subjects in a more attractive manner, teachers must have the ability to develop learning methodology or model and utilize teaching-learning media in such way that raise learner's interest and achieve learning objectives well. Currently many schools hold learning activities both theory and practical conventionally. Distance learning as a form to support independent learning activities is not effective, due to the lack of independent experiments performed in the laboratory. Learners only fixated on learning activities in the classroom and experimental activities in laboratories. The current curriculum emphasizes that learners are required to meet some competencies as subjects minimum completion. The competency reached not only from conventional class but also from assignments, discussion, independent experiment and some activities that take place outside of school. Virtual laboratory is important in the school, so that learners may perform experimental activity such as experiment in physical laboratory. There are two important components in virtual laboratories, i.e.,

simulation and animation. Simulation aims to describe the real environment in a system. Through simulation the learners can experiment by replacing parameters value so experiment produce different behavior. The different behaviors are then displayed through animation. These experimental results may also be automatically recorded by the system and taken as report. Moreover, a ICT-enriched environment would greatly enhance learners motivation and develop positive attitude towards the course. Subsequently, the academic achievement would be enhanced. Several studies emphasized the vital role of virtual labs in developing academic achievement, providing awareness of scientific concepts, and modifying misconceptions. The main goals of this study was: (1) To design and develop a virtual lab (VL) application to help creating and managing independent and interactive experiment activity process (2) accommodate learners experiment independency, which is limited by the number of hours, the number of meeting and inadequate equipment for experiment. (3) Create an innovative learning system in order to improve the quality of learners as a reflection of learning independence. The science teachers at school level must be trained properly to perform some basic experiments in order to inculcate scientific temperament and appreciation for science teaching-learning using ICT. Use of the virtual lab for science concepts may be helpful to understand several science terms which include the following:

1. To stimulate an interest in science subjects.
2. To improve their experimental and communicational skills and to develop scientific attitude and interests.
3. To inculcate divergent thinking and cooperative attitude among the students.
4. To make science subjects more enjoyable and a sound fundamental knowledge of facts and principles.
5. To satisfy scientific curiosity.
6. To encourage independent thinking.
7. To make use of environment.
8. To give practice in critical thinking.
9. To develop problem solving techniques.
10. To make scientific principles more meaningful.
11. To increase self-confidence.

Virtual lab (VL) for science concepts and experiments can make the study of science more exciting, enjoyable and educational. This provides an opportunity to teachers and learners to get a first hand experience of the process involved in scientific concepts at school level. It represents one method of helping learners, explore their special interests in depth. The resulting findings are often for more valuable to the students who are involved, than the information presented in regular class periods.

VIRTUAL LAB (VL)

Physical distances and the lack of resources make us unable to perform experiments, especially when they involve sophisticated instruments. Also, good teachers are always a scarce resource. Web-based and video-based courses address the issue of teaching to some extent. Conducting joint experiments by two participating institutions and also sharing costly resources has always been a challenge. With the present day internet and computer technologies the above limitations can no more hamper students and researchers in enhancing their skills and knowledge. Also, in a country such as ours, costly instruments and equipment need to be shared with fellow researchers to the extent possible. Web enabled experiments can be designed for remote operation and viewing so as to enthuse the curiosity and innovation into students. This would help in learning basic and advanced concepts through remote experimentation. Today most equipment has a computer interface for control and data storage. It is possible to design good experiments around some of this equipment which would enhance the learning of a student. Internet-based experimentation further permits use of resources – knowledge, software, and data available on the web, apart from encouraging skillful experiments being simultaneously performed at points separated in space (and possibly, time). A virtual laboratory is a system that can be used to support a system that run an alternative learning environment without real laboratory. It enables the learner to link between the theoretical aspect and the practical one, without papers and pens. It is electronically programmed in computer in order to simulate the real experiments inside the real laboratories. This virtual lab may provide an opportunity to the learners for studying and learning environment that stimulates the real lab. It also provides the learners with tools, materials and lab sets on computer in order to perform experiments subjectively or within a group anywhere and anytime. These science concepts and experiments are saved on DVD, CDS or on web site. The elements of virtual lab are

1. **Electronic device (Computer/Laptop/Mobile/Tablet):** Virtual labs can be operated through electronic devices like computer laptop, mobile and tablet etc.
2. **The programs/apps of virtual lab:** These simulation programs can be design as according to operating system by programmer. Programs can be made interesting by using animations, videos and the three dimensional creatures.
3. **The lab set and equipments:** Sometime some lab sets or equipments are required to take reading by sensors of electronic gadgets which is

further processed by program to perform virtual experiment.

4. **Internet facility:** There are many educational institute which offers e-lab facility for users, so as to access such lab, internet connection is necessary. Various simulations, videos, application animations can be downloaded using internet.
5. **Co-operation programs and Management:** These programs provide link between management system of the lab and one who perform the experiment. The system analyses the kind of user and provide each user or suitable access in the different experiment.
6. **Technical staff:** To prepare simulations or programs for any experiment technical staffs (programmer or computer expert) are required.

Virtual lab is a revolutionary technologic way in the field of science laboratories through which the learner is accustomed to computer not only as a means of calculation or information storage but as a laboratory tool used for measurement and control. Moreover, it becomes a tool to study and clarify the experiments their relation to theory so the learner can understand the meaning of conducting practical experiment while doing them. The benefits of virtual lab can be summarized in the following points.

1. Virtual lab is an excellent substitute for traditional laboratory as it offers learners experience of skills close to the direct experience.
2. It contributes to overcoming the obstacles that prevent the learners from conducting actual experiments.
3. Virtual lab provides learners with an interesting interactive scientific environment.
4. It allows learners the possibility to conduct scientific experiment step-by-step with immediate feedback.
5. It enriches curricula by providing learners with experiences that would be too hazardous or prohibitively expensive in a conventional setup.
6. Virtual lab can use unique visualizations to provide insight not available in conventional labs, this is particularly the case for phenomena that are not directly observable. Virtual labs will be made more effective and realistic by providing additional inputs to the students like accompanying audio and video streaming of an actual lab experiment and equipment. For the touch and feel part, the students can possibly visit an actual laboratory for to a short duration. Although traditional labs provide learning by

doing experience to learner it has some limits and profiles as follows:

7. **High cost:** Availabilities and requirement of suitable and sophisticated equipment make the laboratory activities expensive.
8. **Time consuming:** Arrangements of experimental setup and performing experiment consume much time.
9. **Lack of personal experience and observation:** Usually in traditional laboratory, experiment is done in groups or demonstrational study. Therefore, learner cannot receive personal experience and observation. It becomes difficult to evaluate student's performance during the activity in overcrowded class.
10. **Requirement of skilled operator:** All traditional experiments operator demands skilled operator to perform experiments. Results may be altered by mistake made by operators and it may also become cause of misuse of laboratory. Unskilled operator may harm to the experimental equipment permanently or to himself.

Science and Virtual Lab: Scientific understanding attitude are enhanced by relating theory to practical aspects. These enhance development of concepts and building of scientific temper. Schools of rural and tribal belts lack laboratories and instrumentation facilities which prove to be a hindrance in teaching- learning process. Science education at elementary level does not include practical aspects in curriculum due to which students do not develop a scientific vision. Henceforth, development of practical approach towards understanding and concept building in science has become a burning issues of discussion among academicians and researchers. ICT, the most valuable tool of present day education system can be utilized to its fullest in filling up of this gap. Through ICT, virtual or real experiments can be demonstrated to students which would impart a great enhancement of their understanding and also would facilitate their learning. ICT techniques provide audio-visual cues that help in memorizing the key concepts at ease and furnishes a better ability to understand and relate to theoretical aspects of science. Students are thus free to share scientific ideas and observations among themselves which will help them to improve their academic performance. ICT based virtual lab modules aims to be used to develop quality of science education and enhance teaching- learning process. It will also enhance the quality of lecture delivery in classroom and make learning effective, interactive and enjoyable.

AIMS AND OBJECTIVES OF THE VIRTUAL LABS

1. To formulate strategies to make teachers aware to integrate the use of the virtual laboratory in the class room teaching-learning so that the student can understand the concept easily
2. To facilitate neat, easy, harmless and efficient ways of learning techniques to use ICT enabled virtual laboratories
3. To identify wider range of experiments on virtual labs so that students can relate science to the real life experiences.
4. To integrate the use of mobile technology in the classroom teaching-learning.
5. To provide remote-access to labs in various disciplines of science and engineering. These virtual labs would cater to students at the undergraduate and post graduate level as well to research scholars.
6. To enthuse students to conduct experiments by arousing their curiosity. This would help them in learning basic and advanced concepts through remote experimentation.
7. To provide a complete learning management system around the virtual labs where the students can avail the various tools for learning including additional web-resources, video-lecture, animated demonstrations and self evaluations.
8. To share costly equipment and resources, which are otherwise available to limited number of users to constraints on time and geographical distances?

Development of Virtual Lab In Science At Secondary Level:

The evolution of computer technology brought significant changes in education. Among them, the use of educational software in various streams e.g., physics, chemistry, biology etc seems to be the most important one. In addition to conventional software, the use of virtual reality techniques emerges as a new possibility. The technology advents allow today the building of a virtual laboratory in instrumental methods in teaching learning process. The advantages of such a virtual lab are:

- The safety in the operation of instruments
- Access to the instruments from each student
- Low cost
- Flexibility to use.

Hence, looking into growing need to make use of cost effective virtual lab to offer sciences at a distance a package was developed for secondary school teachers and students'. An outline of format was framed to develop the modules giving liberty to the teachers for variation as per their requirement. Each module had feature of video/simulation along with various exercises for practice like MCQ, True or False, Drop down activity etc. The package is specially developed for the students of classes

IX and X to provide them access to laboratories through virtual labs. The main objective is to provide access even offline to facilitate the availability for urban and rural area students, where there is no access to physical labs/equipments, which are not available owing to being scarce or costly and the lack of internet connectivity. The experiments can be accessed anytime and anywhere. Exercises are provided at the end of each experiment for self evaluation. This attempt also fulfills the objective of inclusive education where each child can access it as per their need and thus everyone's learning can be enriched. The following virtual lab experiments were developed for IX and X class students:

FOR IX CLASS STUDENTS

1. Verification of Archimedes principle.
2. Determination of density of a solid (which is denser than water) by using a spring balance and a measuring cylinder.
3. Verification of third law of motion using two spring balances.
4. Study of chemical change.
5. Law of conservation of mass.
6. Differentiate between compound and mixture.
7. Preparation of true solution, colloidal solution and suspension.
8. Separation of mixture of sand and ammonium chloride.
9. Study of the structure of squamous epithelial cells.
10. Determination of mass percentage of water imbibed by raisins.

FOR X CLASS STUDENTS

1. Verification of Ohms law.
2. Determination of focal length of a concave mirror.

3. Determination of refraction of light through glass slab.
4. Determination of pH of given samples by using pH paper.
5. Study of physical and chemical properties of acetic acid (ethanoic acid).
6. Study of light is essential for photosynthesis.
7. Determination that carbon dioxide is released during respiration.
8. Preparation of a temporary mounts of leaf peel to observe stomata in the leaf.

Details of a few simple experiments developed for virtual lab

TO FIND THE pH OF THE FOLLOWING SAMPLES BY USING pH PAPER.

1. Dilute hydrochloric acid.
2. Dilute NaOH solution.
3. Dilute ethanoic acid solution.
4. Lemon juice.
5. Water.
6. Dilute sodium bicarbonate solution.

THEORY/BASIC PRINCIPLE INVOLVED

pH is the measure of hydrogen ion concentration.

Hydrogen ion concentration of a solution is equal to 10 to the power minus pH. i.e.

$$[H^+] = 10^{-pH}$$

pH can also be defined as: "The negative logarithm (base 10) of the hydrogen ion concentration (in moles per litre) is called pH" $pH = -\log[H^+]$ Neutral solution has pH value 7. pH of acid solution is always less than 7, whereas that of alkaline solution is always more than 7. pH of a sample can be measured by the use of pH paper or by the use of universal indicator. Solutions of different pH gives different colours on pH paper (or with universal indicator).

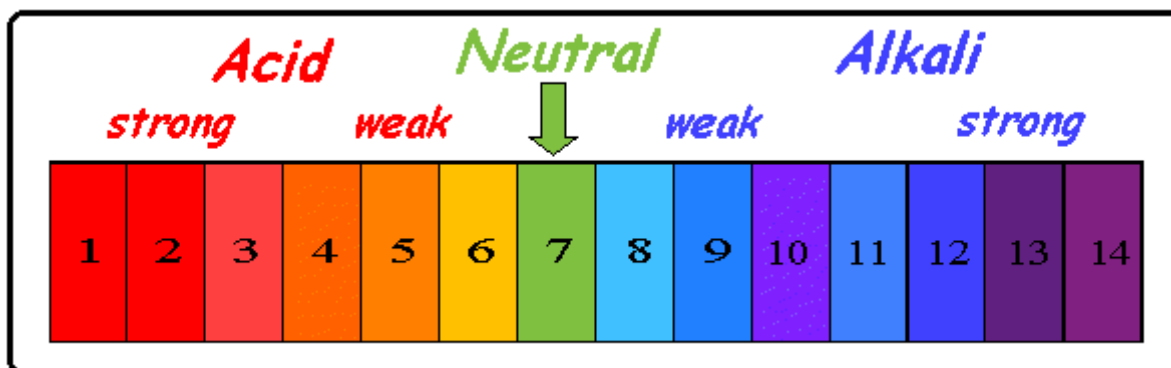


Figure 1:

PROCEDURE

1. Take the given solution in a separate clean test tubes and mark them as A, B, C, D, E and F respectively.
2. Remove a strip from the packet of the pH paper (test strip) and place it on a clean and dry glazed white tile.
3. Withdraw the solution from test tube A in a dropper and put 2 drops of pH paper.
4. Compare the colour developed on the test strip with the standard chart and record the pH.
5. Perform the similar experiment with other solutions and record your observations.

RESULT

1. The pH values of dilute hydrochloric acid dilute ethanoic acid and lemon juice are less than 7. Therefore these have acidic character.
2. The pH values of dilute solution of sodium hydroxide and dilute solution of sodium hydrogen carbonate and lemon juice are more than 7. Therefore these have basic character.
3. pH value of distilled water is 7. Therefore, it has neutral character.

Suggestion for Further Investigation

1. Find the pH of soil of your backyard or garden.
2. Find the pH of road side soil and compare it with pH of garden soil.
3. Find pH of soap solution.
4. Find the pH of lake or pond water around you.

Dropdown Activity read and complete We know how acid-base indicators can be used to distinguish between an acid and a base. We have also learnt in the previous section about dilution and decrease in concentration of H⁺ or OH⁻ ions in solutions. Can we quantitatively find the amount of these ions present in a solution? Can we judge how strong a given acid or base is? We can do this by making use of a Cloze (1);, which is a Cloze (2): of several indicators. The universal indicator shows different Cloze (3): at different concentrations of hydrogen ions in a solution. A scale for measuring hydrogen ion concentration in a solution, called Cloze (4): has been developed. The p in pH stands for Cloze (5): in German, meaning power. On the pH scale we can measure pH generally from 0 (Cloze (6):) to 14 (Cloze (7):). pH should be thought of simply as a number which indicates the acidic or basic nature of a solution. Higher the hydronium ion concentration, Cloze (8): is the pH value. The pH of a neutral solution is 7. Values less than 7 on the pH scale represent an Cloze (9): solution. As the pH value increases from 7 to 14, it represents an increase in OH⁻ ion concentration in the solution, that is, increase in

the strength of alkali. Generally paper impregnated with the universal indicator is used for measuring pH.

Bottom of Form

Multi-choice question Which one is correct statement about universal indicator?

- a. It is a mixture of HCl and NaOH
- b. It is a mixture of many indicators
- c. It is a solution of phenolphthalein in alcohol

pH values of distilled water, lemon juice and sodium bicarbonate were measured using pH papers. What is the correct decreasing order of pH values?

- (a) Water > lemon juice > sodium bicarbonate
- (b) Sodium bicarbonate > water > lemon juice
- (c) Water > sodium bicarbonate > lemon juice

To Establish The Current -Voltage Relationship And Verify Ohms Law. Apparatus Required:

The apparatus required are Voltmeter (0 - 5 V), Ammeter(0 - 500mA), resistance wire, rheostat, key, connecting wires, battery or eliminator (0 - 3 V). Ohm's law states that If all the physical conditions such as temperature, length and area of cross section remains constant the current through a conductor between two points is directly proportional to the potential difference across the two points. The ratio of voltage to current is called the resistance, and if the ratio is constant over a wide range of voltages, the material is said to be an "ohmic" material. If the material can be characterized by such a resistance, then the current can be predicted from the relationship:

$$\text{Ohm's Law} \quad I = \frac{V}{R}$$

Electric current = Voltage / Resistance

Figure 2:

CONCEPT OF RESISTANCE: Resistance is the property of a component which restricts the flow of electric current. Energy is used up as the voltage across the component drives the current through it and this energy appears as heat in the component. Resistance is measured in ohms; the symbol for ohm is an omega (Ω).

DISADVANTAGES OF RESISTANCE: Resistance can be both good and bad. If we are trying to transmit electricity from one place to another through a conductor, resistance is undesirable in the conductor. Resistance causes some of the electrical energy to turn into heat so some electrical energy is lost along the way..

ADVANTAGES OF RESISTANCE: However, it is resistance that allows us to use electricity for heat and light. The heat that is generated from electric heaters or the light that we get from light bulbs is due to resistance.

In a light bulb, the electricity flowing through the filament, or the tiny wires inside the bulb, cause them to

glow white hot. If all the oxygen were not removed from inside the bulb, the wires would burn up.

Image Gallery

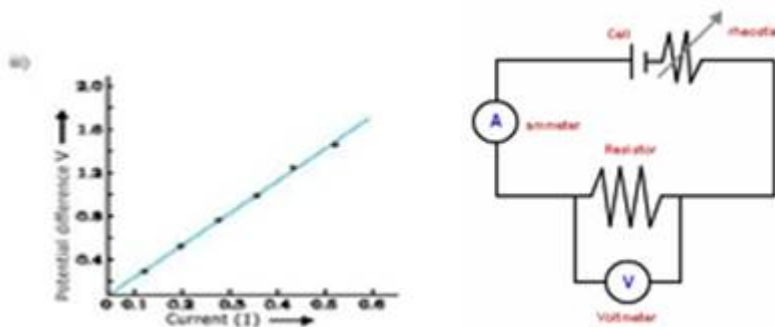


Figure 3:

Multi-choice question

Which is the correct statement of Ohm's Law?

- a. $R = IV$
- b. $V = IR$
- c. $I = R/V$
- d. $V = R/I$

When a current of 10.0 A flows through a 50.0-Ω resistor in a circuit, what is the voltage of that circuit?

- a. 5 V
- b. 60 V
- c. 0.20 V
- d. 500 V

A 9-V battery is hooked up to a 3-Ω resistor. What current is flowing through this circuit?

- a. 3 A
- b. 0.3 A
- c. 12 A
- d. 27 A

Why does Ohm's Law hold true only at a constant temperature?

- a. As temperature increases the potential difference in most batteries increases as well
- b. As temperature increases electrical resistance in most materials decreases
- c. As temperature increases electrical resistance in most materials increases as well
- d. As temperature increases the potential difference in most batteries decreases

Bottom of Form: Bottom of Form

Dropdown Activity: Read and complete Top of Form
Ohm's law states that If all the physical conditions such as Cloze (1), length and area of cross section remains Cloze (2): the current through a conductor between two points is directly proportional to the Cloze (3): across the two points. The ratio of voltage to current is called the Cloze (4), and if the ratio is constant over a wide range of voltages, the material is said to be an "ohmic" material. If

the material can be characterized by such a resistance, then the current can be predicted from the relationship. Resistance is the property of a component which restricts the flow of Cloze (5): Energy is used up as the voltage across the component drives the current through it and this energy appears as heat in the component. Resistance is measured in ohms; the symbol for ohm is an omega (Ω).

Important Features of the Package are:

- Content aligned to the NCERT/CBSE curriculum.
- Physics, Chemistry, Biology Virtual Labs for Class IX and X.
- Interactive simulations, animations and lab videos.
- The concepts and understanding of the experiment.
- The ability to perform, record and learn experiments - anywhere, anytime, and individualized practice in all areas of experimentation.

Training on Develop Science Virtual Lab For Secondary Teachers:

The main objective of the training was to make teachers aware how to use the package and help the students to develop practical skills. One of the objectives of the training was also to take feedback from the teacher participants to improvise the package as per the ground requirement. We as a team were thrilled to experience the involvement of the teacher participants to learn, ask and giving valuable feedback. The resource persons were able to transmit the learning required and help each participant teacher to clear their doubts. They had hands on experience everyday as an important feature of the program. The developed modules were distributed to each participant teacher in a DVD and many participant teachers have given their impressions about the program stating the benefit and learning aspect. The

package has information about mobile apps to learn physics by smart phone and also the software giving details about its uses etc as an add on feature. The amalgamation of ICT experts and subject experts has resulted to produce comprehensive, encyclopedic virtual lab simulations for better understanding and developing practical skills. The package is developed as a learning resource for academic purpose in free domain. To make it interactive blog is made available, the viewers can visit blog.vlabriebpl.blogspot.in for feedback and queries.

Educational Implication/Inculcation Of Virtual Labs

1. It develops the observation skill and insight of a person.
2. It proves that whole is always important than parts.
3. We had a whole situation and on its overall observation we succeeded in reaching a logical conclusion.
4. Such type of an activity develops handling of apparatus, reasoning, scientific attitude and creativity.

CONCLUSION

The use of virtual lab increases students achievement level and made positive impact on student's attitude toward science learning. Obviously, simulations based program cannot be more effective than the real lab activities. Instead, when we are forced not to perform real lab activities due to reason such as danger of lab activity, time concern, lack of laboratory or equipment or insufficient lab conditions which limit us to perform a simple lab activity, a virtual lab can be alternative. Also, before operating on real experiment setup if experiment is performed on simulated experiment than it can provide good skill of experiment to students. It is anticipated that virtual lab will be adopted as supplementary and supportive elements in future. This will provide not only an effective learning environment but will also minimize school expenditures and the time spent on such activities to a large extent.

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