Techno LEARN: An International Journal of Educational Technology

Techno LEARN: 3 (1): 43-50. June, 2013

Developing Concepts in Physics Through Virtual Lab Experiment: An Effectiveness Study

Manisha Bajpai

Assistant Professor, Education, Bonnie Foi College Bhopal, Madhya Pradesh, India

Email: manisha.bajpaimanu@gmail.com

Paper no: 59 **Received:** 9 Feb 2013 **Revised and Accepted:** 20 May 2013

Abstract

For physics learning, labs plays very active and significant role as it is essential to develop concepts and principles because students are continuously required to identify the hidden concepts, define and explain underlying laws and theories using high level reasoning skills. It is time and again observed that traditional real time physics laboratory has some limitations and problems in developing these concepts etc. In present given scenario of ICT, virtual lab through computer simulation based method of teaching physics is emerging as one of the most powerful method of experimentation in lab. The present study was conducted to see the effectiveness of virtual lab for developing concepts in physics. The main purpose of this study was to investigate the effectiveness of Virtual Lab for students' understanding of concepts of physics. The findings of the present study clearly revealed that student learned concepts of photoelectric effect through virtual lab in a better way as compared to real lab. The study also suggested the use of virtual labs in physics teaching, especially for teaching of concepts.

Keywords: Physics concept, ICT, virtual lab

Introduction

Physics is one of the most fundamental natural sciences which involve the study of universal law and the behaviors and relationship among a wide range of physical concepts and phenomena. Experiments are the hallmark of Physics. Scientific attitude and vision can be developed by allowing young minds to perform experiments in physics lab and observe and understand the scientific phenomena to happen. Learning through experiments encourages students to bring scientific thinking to the processes of strong, innovative and logical path between concept and phenomena.

For physics learning, labs also plays very active and significant role as it is essential to develop concepts and principles because students are continuously required to identify the hidden concepts, define and explain underlying laws and theories using high level reasoning skills. Traditional laboratory has some limitation and problems in developing these concepts etc. Today's traditional labs and the experiences acquired there, because of certain limitations of their own , are not meaningful adequately for students and are not able to make a significant contribution to conceptual understanding of students (Yager , Engen and Snider ,1969). According to Hofstein (1988), students are performing experiments in the laboratory in a "cookbook" approach which focused on development of low level science skills.

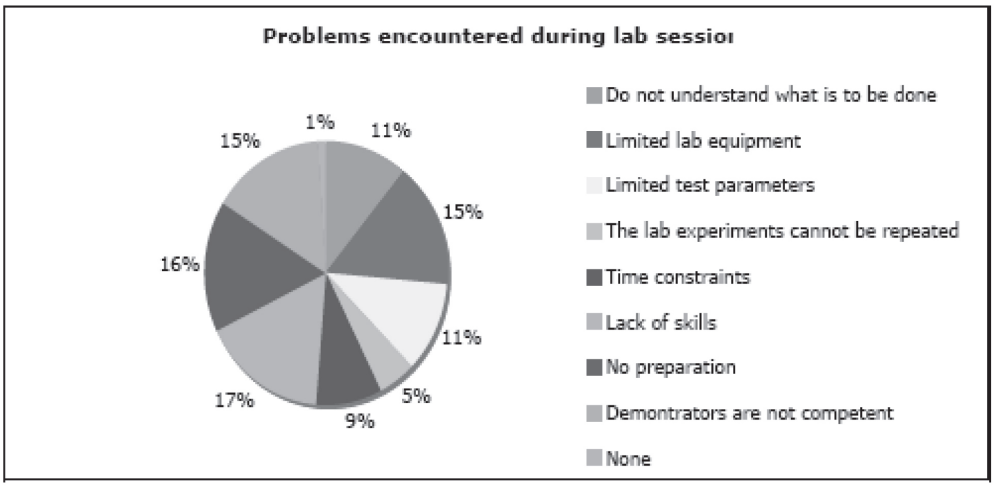

Figure 1: Results on related problems during lab sessions

Zulkifli & Hassan(2009) studied problems during physics lab session. Results on problems encountered during the physical lab session are presented (Figure-1).

17% of the students admitted on lack of skills in performing the experiments. Others agreed on lack of preparation (16%), limited lab equipment (15%) and incompetent lab demonstrators (15%). These factors may hinder them from successfully grasping the key concepts and knowledge expected from the experiments performed.

In order to overcome these problems of traditional physics lab, search of a new philosophy in which learner are actively constructing their own knowledge is needed. (Jonget 1998). In present scenario virtual lab through computer simulation based method of teaching physics is an emerging powerful method of experimentation in lab. The experiments, traditionally conducted in physical labs, can now be performed on a computer through virtual lab.

What is a Virtual Lab?

There are various ways of defining virtual lab. It can be defined as a computer program that allows student to run simulated experiments via the web or as a stand-alone application. A virtual lab could be a set of simulations put together (Examples are applets, flash base demons, animations). This allows the students to perform the experiments remotely at any time. In addition, experimental-oriented problems can be conducted without the overheads incurred for maintaining a physical lab. A virtual lab is also particularly useful when some experiments may involve hazardous chemicals and risky equipment.

Virtual Lab also, is used in the system aiming to replace physical machine with virtual machines on one host server. They eliminate the limitation of physical appearance so that students are able to complete security exercises on the local operating system utilizing the client/server architecture. The students could manipulate various parameters of the simulations and observed the result. In this approach there are certain advantage- It is very easy to learn how to use them, the leaning objectives is more clearly defined. Another approach to a virtual lab could be providing a virtual work place that obeys the laws of physics.

What Researches say about effectiveness of Virtual lab?

Research studies have indicated that visualization of phenomena through computer simulations can contribute to student's understanding of physics concepts at the molecular level by attaching mental images to these concepts (Cadmus, 1990). According to Escalada & Zollman (1997), computer simulations provide opportunities for students not only to develop their understanding and reinforcement of physics concepts, but also to develop their skills in scientific investigation and inquiry. Inquiry-based science experiences conducted in relevant, meaningful contexts have been shown to develop higher order thinking skill in students (Roth & Roychoudhury, 1993). This is further supported by Cakir and Tirez's (2006) study that found inquiry-based science teaching and learning, with the support of computer simulation and collaborative contexts help learners to develop critical thinking and inquiry skills. Lawson (1995) cites literature indicating that the Learning Cycle approach that consists of Exploration, Concept Introduction, and Concept Application phases is an inquiry-based teaching model which has proven effective at helping students construct concepts as well as develop more effective reasoning patterns.

Interactive learning environment by using simulations base virtual lab for abstract topic, where students become active in their learning, provide opportunities for students to construct and understand difficult concepts more easily (Demirci, 2003). In this, content appropriate simulations and applications based on simulations generally increase learning speed by allowing students to express their real reactions easily (Karamustafaoglu, Aydin and Ozmen, 2005). Better designed virtual labs provide students opportunities to express their cognitive style and to choose from the computer screen. Such opportunities allow students to develop their own hypothesis about the topics and develop their own problem solving methods (Windschitl ve Andre, 1998). According to Isman et al (2002), complex information given to the students is simplified by technology and provides them opportunities of learning by doing. Therefore, use of virtual laboratory overcomes some of the problems faced in traditional laboratory applications and make positive contributions in reaching the objectives of an educational system. But, Miller (1986) did not found a significant relationship between students' biology achievement and computer assisted education or traditional teaching methods.

On the other hand, physics laboratory lessons are the most favorite and preferable for students in daily life, students' benefit from the laboratory applications. Besides, students who are taught with laboratory-assisted education are more successful than students who are taught with traditional methods and also the learning with laboratory practices parallel with its theoretical knowledge in physics course increases the achievement. The laboratory applications also increase the permanence of students' knowledge. Some researches (Geban, Askar & Özkan, 1992; Svec & Anderson, 1995; Redish, Saul & Steinberg, 1997) revealed that computer simulation experiments are more effective than traditional experiments: but some researches (Miller, 1986; Choi & Gennaro, 1987; Jimoyiannis & Komis, 2000; Bayrak, Kanli & Kandil Ingeç, 2007) did not find any difference between their effectiveness.

Therefore, no conclusions can be arrived at on the basis of previous researches hence some more researches are needed. The present study was conducted with this aim in mind. The main purpose of this study is to investigate the effectiveness of Virtual Lab for students' understanding of concepts of physics.

Objectives of the Study

1. To identify and design virtual lab situations from the available resources (Java Appletsphet) with the help of which the above identified concepts and principles can be developed.
2. To Study the effectiveness of achievement of above identify concepts and principles through virtual lab compared to real lab.

Methodology of the Study

The present study employed pre- post experimental design. This experimental design enables the manipulations of the variables to be observed under the control of the researcher in order to investigate cause and effect relations. The variables under study are:

- Dependent Variable: Achievement Gains on photoelectric effect
- Independent Variable: Virtual and real laboratory Experiments on photoelectric effect
- Intervening Variable: Previous achievement in Physics

a. Identification and significance of Topic

Physics is full of concepts and principles. During studies, a student is supposed to learn number of concepts. Researchers suggested that developing conceptual understanding is only accomplished through learning that promotes conceptual change. Use of laboratory inquiry-based experimentation and virtual experimentation provided through interactive computer-based simulations could be used as conceptual change learning environments.

Photoelectric effect is one such concept crucial for understanding the particle nature of light, one of the foundations of quantum mechanics. The photoelectric effect is a significant concept which helps students builds an understanding of the photon model of light, and to probe their understanding of the concept of photon model. Experience of working with students during last so many years shows that they have serious difficulties in understanding even the most basic aspects of the photoelectric effect, such as the experimental set-up, experimental results, and implications about the nature of light. The virtual lab allows students to control inputs such as light intensity, wavelength, and voltage, and to receive immediate feedback on the results of changes to the experimental set-up. With proper guidance, students can use the virtual lab to construct a mental model of the experiment.

b. Selection of Virtual Lab Experiment

Development of Virtual Lab Experiment on the topic of Photoelectric Effect can be time consuming task. There are web sites , where developed virtual lab experiments on different topics of physics are available .One such site is PhET website .The researcher of the present study has gone through this website and found a virtual lab experiment on photo electric effect fitting in to the purpose of the study and therefore, decided to employ the same. This simulation allows students to control inputs such as light intensity, wavelength, and voltage, and it allows them to receive immediate feedback on the results of changes to the experimental set-up. With proper guidance, students can use the simulation to construct a mental model of the experiment. This simulation also allows students to interactively construct the graphs commonly found in textbooks, such as current vs. voltage, current vs. intensity, and electron energy vs. frequency. By seeing these graphs created in real time as they change the controls on the experiment, students are able to see the relationship between the graphs and the experiment more clearly than they see when viewing static images. The Photoelectric Effect simulation, shown in Fig. 1, is downloaded from the PhET website.

c. Sample of the study

Looking in to the nature of the study, Purposive sample was selected. The participants of the study were 50 undergraduate students ranging in age from 19 to 23 and taking “Physics Laboratory” class at Department of Physics of a College in Bhopal during the fourth semester of 2010-2011 academic year. The more detailed information about sampling is shown in the Table 1.

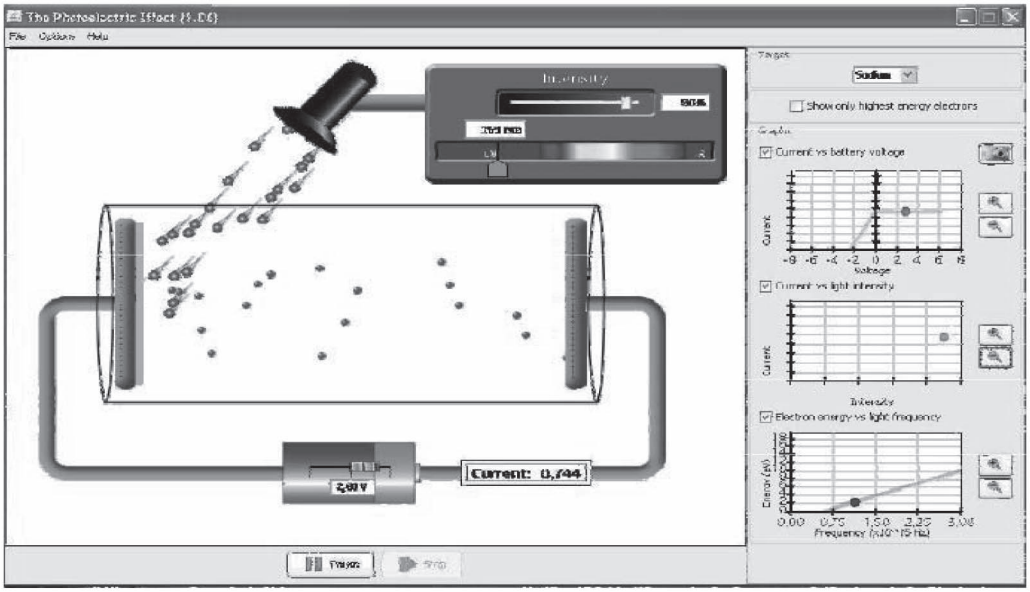

Figure 2:

Table 1

Group	Gender		Total
	Male	Female	
Ccontrol	15	10	25
Experimental	17	08	25
Total	32	18	50

d. Tools employed

The present study employed following tools:

1. Virtual Lab Experiment on the topic of Photoelectric Effect
2. Pre and post achievement test on the topic of Photoelectric Effect
3. Achievement of students in Previous semester

e. Procedure in Brief

The step by step procedure of the followed in the present study can briefly be described as below:

1. 50 undergraduate students studying in fourth semester of Graduation in science were divided in two groups based on their previous achievement marks in previous semester and their achievement was evaluated by administered Pre test through an Achievement Test". For both groups were allowed to perform the same experiment on photoelectric effect.

2. Participants in the First group, designated as control group, were allowed to conduct experiment under real lab situations. This group used real apparatus and materials about "Photoelectric effect" (for example photocell, rheostat, power supply, ammeter, and voltmeter) in a conventional physics laboratory

3. Participants in the second group, designated as experimental group were provided the facilities of virtual lab for conceptual understanding of photo electric effect. These participants used virtual apparatus and material on a computer. For the study, a virtual laboratory atmosphere was created regarding "Experiment of Photoelectric Effect". To do that, it had been benefited from the Java Simulations.

4. After completing the experiments in both the situations, students of both the groups was administered Post "Achievement Test" to evaluate the conceptual understanding of photo electric effect after the experiment and achievement gain was calculated.

5. Statistical Analysis of Data

To study the effectiveness of virtual lab, the independent samples t- test, were used for testing the data obtained in the study. The SPSS 11.00 (Statistical Package for Social Sciences) statistical program was used to evaluate all the data collected from pre-and post-tests.

Findings

Statistical results about the comparison of pre-test and post-test scores of the experimental and the control group students in the PAT are given in Table 2.

Table 2: Comparison of Achievement gain scores of students of the experimental group and control group

Group	N	X(Achievement gain)	Standard Deviation	df	t	p
Experimental	25	02	2.02	48	12.66	0.001*
Control	25	15	2.73			

Results and Discussion

In Table 2, the mean gain of the achievement in the experimental group and the control group was 15.00 and .02 respectively. Students in experimental group who learned the concept of photoelectric effect through virtual experiment gained more compared to control group, who learned the same through real experiment.

Independent t-test was employed to investigate further whether this difference in achievement gains between two groups is really significant .Independent t-test results, clearly shows that there is a significant difference between groups, scores of the achievement gain (t=12.66) is in favor of experimental group. Therefore, it can safely be concluded that student learned concepts of photoelectric effect through virtual lab in a better way compared to real lab.

The present study found that student learned concepts of photoelectric effect through virtual lab in a better way compared to real lab. The findings of the study corroborates with the findings of earlier studies such as Bennet, 1986; Güneº, 1991; Geban, Askar & Özkan, 1992; Svec & Anderson, 1995; Redish, Saul & Steinberg, 1997; Meyveci, 2005. However contradicts with that of Miller, 1986; Choi Gennaro, 1987; Jimoyiannis & Komis, 2000; Þengel et al., 2002; Bayrak, Kanlý & Kandil, Ýngeç, 2007. The contradictions in findings of

these studies with the present one may be due the nature of concept to be learned, approach of virtual lab design, control of intervening variable, different design of the study and statistical analysis etc. Therefore, some more such researches are needed to arrive at valid generalization.

Suggestions

1. According to research results, it may be suggested that using computer-simulation based virtual lab like interactive physics, Phet interactive simulation, Crocodile Physic, Edison 4.0 helped students to gain abstract concepts and so to increase students' achievements. Moreover, use of these programs is suggested by also other researchers (Þengel, Özden & Geban, 2002; Yiðit & Akdeniz, 2003; Görpeli, 2003; Bozkurt & Sarýkoç, 2008).
2. In view of time consuming and being expensive, deficiency of physics lab equipment, teachers' anxiety about the completion of the curriculum as stated in the study of Kurt (2002), these virtual lab methods as stated above should be used.
3. In physics laboratory, imaginary experiments environments should be formed by using computers to prevent harmful effects of experiments and to represent the related concept or event.
4. Teachers are the implementers of technology based curriculum. Teachers should be given training from time to time to make them aware about technological devices, effective use of these technological devices especially computers, creating volunteerism in using them , developing positive attitude towards technological devices and self-confident (Rohmer & Simonson, 1981; Okebukola, 1993; McInerney & Sinclair, 1994; Francis-Pelton & Pelton, 1996; Gökdaº, 2003).

References

Aktan, B., Bohus, C., Crowl, L., and Shor, M.H., 1996. Distance Learning Applied to Control Engineering Laboratories. <http://www.ece.orst.edu/~aktanb/distancelabs. html> (1996) date of retrieval :15.4.2011

Arduino, P., Macari, E and Wyatt, T. 1999. "Assessment of a Virtual Laboratory for Geotechnical Engineering", Proceedings ASEEAnnual Conference and Exposition, Charlotte, North Carolina, Session 1620, (On CD ROM).

B. B. 1986. The Effects of Computer Assisted Instruction on Achievement and Attitudes of Underachievers in High School Biology. *Dissertation Abstracts Int* , **47**:1270-1278

Bagci, N. and Simsek, S. 1999. The influence of different teaching methods in teaching physics subjects on student's success, *J Gazi Education Faculty*. **19** :79-88.

Bekar, S. 1996. *The influence of Lab Based Science Teaching on student's success*. Unpublished Master Thesis. Ankara. Gazi University,Institute of Science

Bennett, R. 1986. *The Effect of Computer Assisted Instruction and Reinforcement Schedules on Physics Achievement and Attitudes Toward Physics of High School Students*. Dissertation Abstracts Int, **46**:3670A.

Bhandari, A and Shor, M. H. 1998. "Access to an Instructional Control Laboratory Experiment through the World Wide Web", Proceedings of the17thAmerican Control Conference, ACC'98, Philadelphia, pp. 1319-1325.

Bryant, R. J. and Edmunt, A. M. 1987. They Like Lab-Centered Science. *Sci Teacher*, **54**:42-45.

Budhu, M. 2000. "Interactive Multimedia Web-based Courseware with Virtual Laboratories", Proceedings, Computers and advanced technology in Education, CATE, May 24 – 27, Cancun, Mexico, (On CD ROM).

Campbell. J. O., Asynchronous Laboratory Learning: Research and Field Trials On Simulated Engineering Education Laboratories - Final Report. <http://olinc.vuse.vanderbilt.edu/elseval2.html> (1997) Davies,T.G., McColl, K. nd McSporran, S., "LabSim", URL:

Choi, B. and Gennaro, E. 1987. The Effectiveness of Using Computer Simulated Experiments on Junior High Students' Understanding of The Volume Displacement Concept. *J Res Sci Teac*, **24:** 539-552.

Clark, R. 1989. Developing Technical Training, Buzzards Bay Press, Phoenix, AZ..

Coleman, A., Smith, T.R., Mayer, R.E., and Buchel, O., 2001. "Learning Spaces in Digital Libraries", Lecture Notes in Computer Science 2163. Berlin: Springer-Verlag.

Cramer, P. G. and De Meyer, G., The Philosophy of the Virtual Laboratory. <http://www.vlabs.net/philos/vlart_g.html> (1997) date of retrieval :15.4.2011

Drabenstott, K., "Analytical Review of the Library of the Future",Council of Library Resources, Washington, DC., 1994.

Edward, N. S., 1997. An Evaluation of Student Perceptions of Screen Presentations in Computer-based Laboratory Simulations. *European J Engg Edu* **22** : 143-152

http://www.civil.gla.ac.uk)(date of retrieval missing)

Karweit, M, "A Virtual Engineering/Science laboratory Course", Department of Chemical Engineering, John Hopkins University., URL:http://www.jhu.edu/virtlab/virtlab.html. date of retrieval :15.4.2011

Mannix, M., "The Virtue of Virtual Labs", Prism Online, September 2000. URL: http://www.asee.org/prism/sept00/html/toolbox.cfm**)** date of retrieval :15.4.2011

Miller, D. G. 1986. The Integration of Computer Simulation into The Community College General Biology Laboratory. *Dissertation Abstract Int*, **47**:2106-A.

Özçinar, Z. 1995. *Evaluating the laboratory activities during Science Instructions at primary schools*. Unpublished Master Thesis *Ankara* University Social Science Institute,Ankara

Redish, F. E., Jeffery S. M., and Steinberg R. N. 1997. *On the Effectiveness of Active Engagement Microcomputer based laboratories*. Department of Physics. University of Maryland College Park, MD20742 Reed,

Riche, R.D. 2000. Strategies for Assisting Students Overcome Their Misconceptions in High School Physics. *Memorial University of Newfoundland Education* 6390.

Sen. A. I. 2001 "New Approaches in Science Instruction supported with Computer" *J Gazi Education Faculty,* **21** :

Sengel, E., Özden, M. Y. and Geban, Ö. 2002. The Influence of the simulated experiments supported with computer on high school students comprehending the Replacement and Velocity concepts. *V. National Science and Mathematics Education Symposium* .Ankara: ODTÜ.

Soylu, H and Ibis, M. 1999. Science Education supported with Computer, 3rd Science Education Symposium. The Ministry of Education. ÖYGM.

Svec, M., T and Anderson, H., 1995. Effect of Microcomputer-Based Laboratory on Students Graphing Interpretation Skills and Conceptual Understanding of Motion. *Dissertation Abstracts Int*, 2338-A.

Tamir, P. 1978. "An Analysis of Laboratory Activities in Two Modern Science Curricula; Profect Physics and PSSC." Paper Presented at the National Association for Research in Science Teaching Annual Meeting in Toronto, Ontario. (date ?)

Uluçinar, S., Cansaran, A. and Karaca, A. 2004. "Evaluating the applications of Science Laboratory" *Türk Egitim Bilimleri Dergisi* ,**2** :

Yavru, Ö. 1998. The influence of the laboratory experiments on the success of the 4th and 5th graders of the primary schools about the subject of Mechanics and on internalizing these concepts. Istanbul. Unpublished Master Thesis. Marmara Universty, Institute of Educational Sciences

Yigit, N. and Akdeniz, A. R. 2000. Developing the Materials during Physics instructions supported with computer; students' working papers. I*V. National Science Symposium, Hacettepe Education Faculty.*Ankara: 711-716.