Conceptual Understanding and Experimental Skills in Physics through Virtual Lab among Learners at Graduate Level

Lekshmi V[*] and Vijayakumar S[**]
N.S.S. Training College, Ottapalam and Department of Physics, N.S.S. College, Pandalam
Email: lekshmi@nssce.org[*], jevijay76@gmail.com[**]

Abstract- *Development of scientific concepts and experimental skills are essential components of learning physics and laboratory experiments plays a significant role in this. Laboratory experience helps learners to understand the concepts, laws and theories as well as to develop observation, critical thinking, and reasoning and problem-solving skill. In traditional laboratories, more time is used for familiarisation with the apparatus than for doing experiments and also there is time constraint to explore more. In addition, there is financial constraint as regards purchase of sophisticated equipment. These constraints limit the attainment of conceptual understanding and development of experimental skills of learners; and Virtual lab appears to be a solution for this. Virtual labs provide remote access to simulation-based experiments and it can be accessed anytime, anywhere by learners, which help them to learn according to their pace. Virtual labs also give opportunity for the learners to repeat the experiments by controlling the variables. Present study aims to find out whether the conceptual understanding in Physics and experimental skills among graduate level learners can be enhanced through Virtual lab intervention. For this, the investigators adopted mixed methodology. Pre-test post-test non-equivalent groups design was used for the quasi-experimentation. The sample consisted of 80 students at graduate level. Achievement test, rubrics to analyse experimental skills and focus group discussion were used to collect the data. The quantitative data is analysed through independent sample t-test. Findings of the present study revealed that the conceptual understanding in Physics and experimental skills among graduate level learners are enhanced through practicing virtual lab. Virtual labs help to arouse the curiosity among learners and help them to learn basic and advanced concepts in Physics through remote experimentation. Virtual labs provide learning flexibility, conceptual clarity, development of experimental skills and are financially viable in terms of money and time.*

Keywords**:** Experimental skills, Virtual lab, Financial constraints, learning flexibility

Introduction

Physics deals with the study of matter, energy, space and time and their interactions. Physics explains the science behind natural phenomena and Physics student needs to have excellent

observation skills, analytical skills, reasoning ability, problem solving skill, critical thinking skill, numerical skills and experimentation skills. Theory and experiments are two inevitable over linked practices of Physics learning. The theories have to be proved through experimentation and experimentation has to lead to theory construction. Experiments play a vital role in enhancing the conceptual understanding in Physics. Experimentation enhances the observation skills, skill of recording, reporting, interpretation, reasoning, analytical ability, evaluation skills, handling of apparatus and problem solving which are essential qualities of a science learner.

Need and Significance

Laboratory experiments are inevitable part of science learning, but these laboratory environment and laboratory experiments are considered as a challenge by many students; especially by the graduate level students. Even though, they know the theory well, students lack confidence in handling apparatus and doing experiments independently. Since, the laboratory experiments are very important in Physics course, we have to seek for some alternative or remedial measures to eliminate or overcome the hesitation and fear among students. Learning will be fearless and interesting if we provide it through a familiar, interesting and attractive medium. Since the students of this century are digital natives, we can make use of ICT to overcome this challenge. The simulations in virtual labs will help the learners in familiarising the apparatus and handling of apparatus (Akpan and Strayer,2010), how to do the connections or assembling of experimental set up, idea about least count and noting down the readings from different apparatus etc. and these will enhance the experimental skills of learner while doing hands on sessions in real lab. Virtual labs help learners to learn from mistakes without causing damage to costly apparatus and also themselves and to others. Moreover, virtual labs provide opportunity for multiple trials (Mwamba, George, Moong and Pondo, 2019). Virtual labs are used to produce perfection in skills (Mayer and Johnson, 2010).

Reviewing related research works, the investigators felt research gap in regard to the enhancement of conceptual understandingin Physics and experimental skills of learners at graduate level. Hence the study is entitled as “Conceptual understanding and experimental skills in Physics through virtual lab among learners at graduate level”.

Research Questions

1. Whether the virtual lab experience enhance the conceptual understanding in Physics among graduate level students
2. Whether the virtual lab experience enhance the experimental skills among graduate level students

Objectives

1. To find out the effectiveness of virtual lab in enhancing conceptual understanding in Physics among graduate level students

2. To analyse the role of virtual lab in enhancing experimental skills among graduate level students

Hypotheses

1. There will beno significant difference in the pre-test mean scores of conceptual understanding in Physics of experimental and control groups.
2. There will be significant difference in the post-test mean scores of conceptual understanding in Physics of experimental and control groups.

Theoretical construct of Hall Effect

Hall Effect is an important experiment in condensed matter physics, to characterize the materials especially semiconductors. The experiment enables the determination of the sign and density of charge carriers in a given sample.

If a current carrying conductor is placed in a perpendicular magnetic field, a voltage known as Hall voltage will develop in the conductor perpendicular to the current density and magnetic field. This phenomenon is known as Hall Effect. The current conduction is due to either the flow of electrons or holes. The magnetic Lorentz force is given by

$$F = q(vxB)$$

As a result of this force the charge carriers curve upwards and produces an electric field which can be measured using a voltmeter. In the steady state condition, the magnetic force and electric force balances each other which is given by

$$eE = evB$$

Where e is the charge of the charge carrier, E is the Hall electric field, v is the drift velocity and Bis the magnetic field. If n is the number density of the electrons in a conductor of length l, breadth b and thickness t, then

$$I = nAev$$

Using theses equations, the Hall voltage V_H can be written as

$$R_H = \frac{V_H t}{IB}$$

Where R_H is called the Hall coefficient and R_H=1/ne. Hence, we can determine both the sign and density of charge carriers in a given sample.

Methodology

For the present study the investigator adopted pre-test post-test non-equivalent group design. Random sampling was used and the experimental group consisted of 40 graduate level students and control group consisted of 40 graduate level students. Pre-test consist of objective type questions on conceptual understanding in Physics based on the topic 'HallEffect' prepared by the investigator was administered to experimental and control groups. Experimental group was treated with classroom instruction and virtual lab experience and the control group was treated with classroom instruction and demonstration of the experiment. Post- test consist of objective type questions on conceptual understanding of 'Hall Effect' was administered among experimental and control groups. The quantitative data is analysed statistically and the effectiveness of virtual lab experience is analysed qualitatively also through focus group discussion among 40 students of experimental group. Descriptive statistics and t-test were used to analyse the data quantitatively. The experimental skills were analysed through observation of real lab experimentation by students with the help of rubrics constructed by the investigator. The dimensions include involvement in performing experiments, handling apparatus, noting and tabulating the readings, accuracy of calculations and overall neatness.

Analysis and Interpretation

Here we will discuss the quantitative and qualitative analysis and interpretation of data.

Quantitative Analysis

The quantitative data collected through pre-test and post-test among experimental and control group are treated statistically.

Preliminary Analysis

Under this head, the basic descriptive statistics for the pre-test and post-test scores of conceptual understanding in Physics for experimental and control groups for the preliminary analysis is discussed.

Table 1

Descriptive Statistics for the Pre-test and Post-test scores of Conceptual Understanding in Physics for Experimental and Control Groups

Test	Group	Mean	Median	Mode	S.D.	Skewness	Kurtosis
Pre-test	Experimental	19.88	20.00	21	1.71	0.31	0.98
	Control	19.68	20.00	18	1.91	0.01	0.83
Post-test	Experimental	22.78	22.50	22	1.18	0.65	0.79
	Control	20.43	21.00	20	1.89	0.53	0.57

From Table 1, the mean, median and mode of pre-test scores of conceptual understanding in Physics are almost equal for the experimental and control groups. Analysing the descriptive statistics, it is clear that the pre-test scores and post test scores of experimental and control

groups do not vary significantly from normality and hence we can adopt parametric tests for detailed analysis.

Analysis of Group Difference

Here, the comparison of mean scores of pre-test and post-test on conceptual understanding in Physics between experimental and control groups are discussed.

Table 2

Test for significance of difference between the mean pre-test and post-test scores of conceptual understanding in Physics between experimental and control groups

Test	Group	N	Mean	S.D.	t-value	Level of Significance
Pre-test	Experimental	40	19.88	1.71	0.49	NS
	Control	40	19.68	1.91		
Post-test	Experimental	40	22.78	1.18	6.65	0.05
	Control	40	20.43	1.89		

Two-tailed t-test is administered to estimate the significance of difference between the mean pre-test scores of experimental and control groups in conceptual understanding in Physics and it is evident from Table 2, that the two groups do not differ significantly (t-value is 0.49). Hence it is clear that the two groups can be equated in terms of their conceptual understanding in Physics before the intervention. The test of significance of difference between the mean post-test scores of experimental and control groups in conceptual understanding in Physics is performed and from the Table 2, it is evident that there is a significant difference between the mean post-test scores of experimental and control groups in conceptual understanding in Physics (t-value is 6.65, which is significant at 0.05 level) and the effect size indicates that the effect of virtual lab experience on conceptual understanding in Physics is large.

Qualitative Analysis

Analysis of Experimental Skills

Experimental skills of the experimental group is analysed through systematic observation with the help of rubrics constructed by the investigators. The assessment criteria include involvement in performing experiments, handling apparatus, noting and tabulating the readings, accuracy of calculations and neatness. The assessment levels were classified as excellent, good, average and poor. It is observed that, the involvement in performing experiments, handling apparatus, noting and tabulating the readings, accuracy of calculations and neatness are improved after the experimental intervention.

Analysis of Focus Group Discussion

Focus group discussion was conducted among experimental group members to understand the effect of the experimental intervention from the experience of participants. It will improve the quality of quantitative analysis also. From the reflections of focus group discussion, it was clear

that the concept was made clear through the virtual lab experience and the fear to approach real lab scenario was reduced through virtual lab practice. The virtual lab experience improved the confidence of students and they felt the virtual lab interesting and useful.

Major Findings

- The experimental and control groups showed no significant difference in conceptual understanding in Physics before experimental intervention
- The experimental group showed significant difference from the control group in conceptual understanding in Physics after experimental intervention
- The experimental skills of experimental group improved through the experimental intervention

Limitations

The digital divide existing in our nation is the major limitation for virtual lab integration. The virtual lab intervention needs high quality internet strength and computers. Hence in remote areas it will be difficult to implement the virtual lab integration.

Conclusion

Present study reveal that the virtual lab experience enhances the conceptual understanding and experimental skills of graduate level students. Virtual laboratories make learning the concepts of Physics simpler and reduce the complexity. The virtual platforms enhance the interest of learners and the interactive nature of virtual labs sustains the interest of learners. In fact, virtual labs act as a bridge between theory and real lab experience.

Reference

Akpan, J., and Strayer, J. (2010). Which comes first: The use of computer simulation of frog dissection or conventional dissection as academic exercise ?. *The Journal of Computers and Science Teaching*, 29 (2), pp 113-138. Retrieved from https://www.learntechlib.org/primary/p/32309/

Bordeur,M., Braithwaite, N., Kolb,U., and Minocha,S. (2015). Improving undergraduate engagement with online labs: Student prioritiesand strategies for virtual and remote investigations. In T. Lars-Jochen and G. Raimund (Eds.), *Proceedings of 20th International Conference on Multimedia in Physics Teaching and Learning*, Ludwig Maximilians University, Munich, Germany, pp 71-78. Retrieved from https://epub.ub.uni-muenchen.de/29030/7/MPTL20_Proceedings.pdf

Dalgarno, B., Bishop,A.G. and Bedgood Jr, D.R. (2013). The potential of virtual laboratories for distance education science teaching: reflections from the development and evaluation of a virtual chemistry laboratory. *Uniserve Science Improving Learning Outcomes Symposium Proceedings*, Sydney. pp 90-95. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.83.8602&rep=rep1&type=pdf

Harms,U. (2000). Virtual and remote labs in Physics education. *Proceedings of Second European Conference on Physics teaching in Engineering Education*, Budapest, Romania,pp.1-6. Retrieved from https://pdfs.semanticscholar.org/62be/5ec4a9060ba2594ce792316c8f52dc3a8797.pdf

Mayer, R.E., and Johnson, C.I. (2010). Adding instructional features that promote learning in a game like environment. *Journal of Educational Computing Research*, 42(3), pp 241-265. Retrieved from https://www.learntechlib.org/p/69424/

Mwamba, R., George, J., Moonga, M., and Pondo, J., K. (2019). Impact of using physics education technology (phet) simulations in teaching electromagnetism on learner performance and attitude. Journal of Basic and Applied Research International, 25(5), pp 218-226. Retrieved from https://www.ikprress.org/index.php/JOBARI/article/view/4735

Roth,T., Andres,T., Schwingel, A., Appel,J. and Hein,U. (2015). Improving undergraduate engagement with online labs: Student prioritiesand strategies for virtual and remote investigations. In T. Lars-Jochen and G. Raimund (Eds.), *Proceedings of 20th International Conference on Multimedia in Physics Teaching and Learning*, Ludwig Maximilians University, Munich, Germany, pp 111-121. Retrieved from https://epub.ub.uni-muenchen.de/29030/7/MPTL20_Proceedings.pdf