p- ISSN: 2708-2113 e-ISSN: 2708-3608 L-ISSN: 2708-2113 URL: http://dx.doi.org/10.31703/gesr.2021(VI-II).24

Vol. VI, No. II (Spring 2021) Pages: 243– 250 DOI: 10.31703/gesr.2021(VI-II).24

Citation: Kanwal, W., Nadeem, H. A., & Awan, S. M. (2021). Effectiveness of Virtual Laboratory Experiments for Academic Excellence of Chemistry Students at Secondary Level. *Global Educational Studies Review, VI*(II), 243-250. https://doi.org/10.31703/gesr.2021(VI-II).24

Effectiveness of Virtual Laboratory Experiments for Academic Excellence of Chemistry Students at Secondary Level

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Abstract: *This study aimed to find the effectiveness of virtual lab experiments. Quasi-Experimental was the design for this study. This study was conducted in Islamabad. Chemistry students of secondary level were selected from the Islamabad model school for boys for experimentation. Control and experimental groups were served the pretest. The experimental group was taught through virtual labs. This treatment was given for 6-weeks. To measure the achievement score of both groups, a posttest comprising of the content taught during the intervention posttest was administered. The posttest included items of the first three levels of Bloom's taxonomy related to the experiments of chemistry included in the intervention. The t-statistics were used for each control and experimental group separately. The VL had an extensive impact on academic achievement in terms of knowledge, comprehension, and application-level of the students.*

Key Words: Virtual Lab (VL), Academic Achievement, Comprehension, Cognitive

Introduction

Based upon three technological know-how topics, i.e., Physics, Biology, and Chemistry, the sphere of technological know-how schooling has been taken into consideration as a pivotal vicinity with inside the area of popular schooling in view that lengthy times. Chemistry incorporates masses of summary principles and the vicinity wherein college students can recognize those principles are simplest the laboratories (Ayas, et al., 2005; Tatli & Ayas, 2013). The laboratory paintings are a vital detail for know-how the summary principles of Chemistry. Due to the character of Chemistry concern and diverse precautions related to its coaching and experimentation of significant nature, e.g., protection concerns, time-ingesting experiments, attempt to get précised effects in practical's, it's been taken into consideration as a tough concern via way of means of the technological know-how t instructors and college students (Hofstein& lunette,2004; Durmus & Bayraktar, 2010). If we integrate programmed commands in pc language, upload required procedures, amalgamate facts evaluation system and facts presentation codecs in pc simulations, digital laboratories may be set up (Flowers, Moore& Flowers, 2011). technological know-how college students get enjoy of the experiments despite the fact that the ones are in digital forms. However, they record like the ones are carried out in herbal surroundings enables college students via way of means of enriching their experiences, carrying out and repeating experiments and enhancing their experimental abilities which include manipulation of substances and equipment, facts collection, finishing touch of experiments in interactive manner and instruction of experimental reports(Habraken, 2004). Researchers found out that the fulfillment degree of the scholars accelerated considerably who had been taught with the assistance of digital labs. In

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assessment with conventional chemistry labs, college students look at chemistry experiments in info and in a whole layout in digital labs. Moreover, there's no worry of protection risks, incomplete experiments, wastage of bodily and chemical resources, possibilities of repetitions are to be had and no want of lab assistants, lab attendant and presence of chemistry trainer all lengthy an afternoon at some stage in experimentation. In addition to that, digital laboratories sell interest and beautify motivation in the direction of the concern chemistry via way of means of imparting a dialogue platform amongst college students and instructors (Hounshell & Hill, 1989). Researches argue that appearing experiments inside digital surroundings is greater powerful than appearing experiments in actual laboratories (Farrokhnia & Esmailpour, 2010). Treatment of digital laboratories as pre-lab found out that real overall performance of the scholars in sensible paintings advanced in comparison to college students who do now no longer get pre-lab remedy of digital labs. The above-mentioned conditions encouraged the researchers to look at the impact of VL on educational fulfillment in Chemistry at secondary degree.

Statement of the Problem

Science experiments, especially in the subject of chemistry, utilize very experience materials. In Pakistan, due to the dearth of sources and resource deficient lab provisions, chemistry practicals are unusually done by the subject teachers by using the demonstration method because they cannot be performed individually by the students. Due to the increasing trend towards admission in science subjects at the secondary level, huge enrollment is tackled by group work during science lab activities. Even if there are facilities of chemistry labs and equipment, allowing students to perform chemistry practicals separately and individually has always been a great concern and risk for science teachers. Lab work can be virtually done by getting the latest apps and ICT tools. The researchers were motivated to do research to solve the above-stated problem of chemistry lab work with the help of doing it virtually.

The objective of the research

The main objective of this study was to measure the effect of the virtual lab (VL) on the academic excellence of students studying chemistry subjects at the secondary level.

Research Hypotheses

For this study following hypotheses are formulated:

H_{01}: In the control group, virtual laboratories (VL) had no significant impact on students' academic success at the secondary level.

HA1: In the control group, virtual laboratories (VL) result in an extensive impact on the academic success of secondary Chemistry students.

H02: In the experimental group, virtual laboratories (VL) do not result in a substantial increase in the academic success of secondary school Chemistry students.

HA2: Virtual laboratories (VL) in the experimental group result in a considerable increase in the academic success of secondary Chemistry students.

H03: On the posttest, the accomplishment of Chemistry students in the control and experimental groups is not significantly different.

HA3: The achievement of Chemistry differs significantly.

Significance of the Study

The major finding of this study is supportive in nature to student-centered education. Parents, as well as science students, might have guidance from this research, and they will be able to perform better in terms of examination scores along with learning risky experiments through virtual labs in which scorching acids and chemicals are consumed because there will be no security risk for any burn, etc. However, the major finding of this study is supportive in nature to student-centered education. The science teachers might have guidance from this research, and they will be able to perform better in terms of producing better examination results along with teaching risky experiments through virtual labs in which scorching acids and chemicals are consumed because there will be no security risk for any burn, etc. The fear of using dangerous chemicals will be no more excuse, and an overall

culture of professionalism will be observed by the science teachers in the field of chemistry. Their students will be performing better, and the teachers will have name and fame. The results of this study might help contribute to the change in chemistry teachers' attitude towards practical/laboratory work at the high school level in Pakistan.

Literature Review

Students of science subjects learn through experiments and primary expertise in doing things. Thanks to biological process advancements in physical and growths, the scholars used to experience the same feelings if they saw the processes moving into just about the world. A typical experience of children looking at cartoons may be quoted here because of the children begin weeping whenever their favorite cartoon hits. The same is the case with science practicals. The aim of science subjects isn't the memorization of information, however to familiarise the students with the processes while the items are done (Tatli, 2009). per principle & Heh (2007), science education focuses on educating young growing students. Teaching is shifting from ancient ways during this technological era, should verify the explanations of past issues to the requirements of the trendy data society (Farrokhnia & Esmailpour, 2010) Per Pyatt & Sims (2012), virtual experiments could be a combination of pc software for teaching and learning purpose that alter science students to create scientific inquiries through virtual experimentation in VLs. According to Stefanovic, Tadic, Nestic & Djordjevic (2013), a virtual experiment may be delineated as a visible learning surrounding wherever the science students use virtual equipment and material through the utilization of a mouse and keyboard on the pc. Computers are established because of the inquiry and tutorial support in science teaching during this dynamic paradigm from ancient to the digital era. (Koretsky, Amatore, Barnes & Kimura, 2008). In Pakistan government has been incessantly increasing its network of science and computer labs in secondary and elementary schools. The provision of ICT equipment, facilities, IT assistants, IT academics, extremely qualified teachers have created an area for doing things virtually, quickly, and in an exceedingly scientific manner (Yang & Heh, 2007). Virtual Science laboratory involves technology-mediated instruction with aiming to facilitate learning, involving scientific techniques or experimental procedures. Kolil, Muthupalani & Achuthan (2020) found that VL experiments added in understanding regarding the invention of lepton and teaching the Thomson Atom Model. It has been found that the focus of PC-assisted learning may be to enhance the standard of teaching and innovative learning in science subjects. Many virtual laboratories have themselves interactive and are available in on the market throughout the globe.

Researchers were given reimbursement for the use of those labs for educational purposes.

In addition, a virtual lab established at one of New Jersey's universities comprises a collection of things such as centrifuges, microscopes, complete organisms, or individual cells, each having pre-programmed behaviours to ensure that students interact with the objects effectively.

Students were allowed to experiment in the virtual environment (Kapici, Akcay& American state Jong,2019). Because today's kids are more clever and adept, using traditional teaching methods might be difficult (Habraken, 2004). As a result, science students require skilled education that requires active student engagement. It encourages pupils to take an active role in their learning (Faour & Ayoubi, 2018).

Virtual research laboratories are being investigated as a possible replacement for or supplement to in-person labs. (Aljuhani et al., 2018; principle & Heh, 2007). Students enjoyed working, were extremely impelled, and gained heaps of experience as per their results.

Based upon three natural science subjects, i.e., Physics, Biology, and Chemistry, the field of science education has been considered as a pivotal place in the field of general education for long time. Chemistry contains lots of abstract concepts, and the place where students can understand these concepts are only the laboratories (Ayas, et al., 2005; Tatli & Ayas,2013). The laboratory work is an essential element for understanding the abstract concepts of Chemistry. Due to the nature of Chemistry subject and various precautions associated with its teaching and experimentation of serious nature, e.g., safety concerns, time-consuming experiments, effort to get précised results in practicals, it has been considered as a

difficult subject by the science t teachers and students (Hofstein & lunette,2004; Durmus & Bayraktar, 2010).

If we combine programmed instructions in computer language, add required procedures, amalgamate data analysis procedure and data presentation formats in computer simulations, virtual laboratories can be set up (Flowers, Moore& Flowers, 2011). science students get the experience of the experiments although those are in virtual forms, they report like those are done in a natural environment helps students by enriching their experiences, conducting and repeating experiments and improving their experimental skills such as manipulation of materials and equipment, data collection, completion of experiments in interactive way and preparation of experimental reports (Habraken, 2004).

Research revealed that the achievement level of the students increased significantly who were taught with the help of virtual labs. In contrast with traditional chemistry labs, students observe chemistry experiments in detail and a complete format in virtual labs. Moreover, there is no fear of safety risks, incomplete experiments, wastage of physical and chemical resources, chances of repetitions being available, and no need for lab assistants, lab attendants, and the presence of chemistry teachers all long a day during experimentation. In addition to that, virtual laboratories promote attention and enhance motivation towards the subject of chemistry by providing a discussion platform among students and teachers (Hounshell & Hill, 1989). Research reveals that performing experiments along with virtual laboratories is more effective than performing experiments in real laboratories without virtual treatments (Farrokhnia & Esmailpour, 2010). Treatment of virtual laboratories as pre-lab revealed that actual performance of the students in practical work improved as compared to students who do not get pre-lab treatment of virtual labs. The above-cited situations motivated the researchers to see the effect of VL on academic achievement in Chemistry at the secondary level.

Methodology

The research design for this study was a Quasi-Experimental design. Under this umbrella pretest-posttest, Non-equivalent control group Design was employed. The study was conducted in Islamabad. Islamabad Model School for boys Jaba Taili were selected for the experiment. Eighty (80) students were divided into two intact groups comprising an equal number of students. There were 40 students in each group, i.e., control and experimental. These two intact groups were taken through a convenient sampling technique. Chemistry students of secondary level were selected from the Islamabad model school for boys for experimentation. Control and experimental groups were served the pretest. The experimental group was taught through virtual labs. This treatment was given for 6-weeks. To measure the achievement score of both groups, a posttest comprising of the content taught during the intervention posttest was administered. The data collection tool was an academic achievement test to measure various levels of students aligned with the first three basic levels (viz Knowledge, Comprehension, and Application) of the cognitive domain of Blooms' taxonomy.

Data Analysis and Results

The data were analyzed using a t-test for measuring the effects of usage of VL and comparing two groups of the experiment.

Table 1. Comparison of Control Group Participants on pretest and posttest (N=40)

Group	Mean	SD	Mean	SD	Gain	df	t-value	Sig (2-tailed)
Control	18.7	3.20	22.9	4.60	4.20	39	9.344	0.000

p<0.05

It is evident from table No.1 that in the control group, the average score in the pretest was 18.7, and in the posttest, it was 22.9. The gain in the scores from pretest to posttest had been 4.20 as analyzed by SPSS. The t-value calculated was as displayed in table 9.344 significant at (p<0.05) 0.000 significance level.

Table 2. Comparison of Experimental Group Participants on Pretest and Posttest (N=40)

Group	Mean	SD	Mean	SD	Gain Score	df	t-value	Sig (2-tailed)
Experimental	17.5	3.13	24.8	5.25	7.3	39	11.181	0.000

p<0.05

It is evident from table No. 2 that in the experimental group, the average score in the pretest was 17.5 and in the posttest was 24.8. If we see the table, the gain score can be calculated as (24.8-17.5 = 7.3). This gain reveals an improvement in scores from pretest to posttest of Chemistry students in the experimental group. The calculated t-value was 11.181, found significant at p<0.05 level.

Table 3. Comparison of Control group students and Experimental Group students on posttest (N=80)

Group	Mean	SD	df	t-value	Sig (2-tailed)
Control	22.9	2.85	39	11.257	0.000
Experimental	24.8	2.17	39		

p<0.05

It is evident from table No. 3 in the control group average score in the posttest was 22.9. In the experimental group, the average score in the posttest was 24.8. The t-value calculated was as displayed in table 11.257 significant at (p<0.05) 0.000 significance level. From the gain scores comparison, it is evident that the in the experimental group performed better as compared to the control group.

Table 4. Comparison of Control group Participants and Experimental group Participants on three levels of Cognitive Domain.

Levels of knowledge Domain	Means score of Students in Control Group	Mean scores of Students in Experimental Group
Knowledge	8	8
Comprehension	7.4	8.5
Application	7.5	8.3
Total	22.9	24.8

Findings

As per the analysis of the data, the findings of the study are as follows:

With reference to table 1, it is evident that the Null hypothesis is rejected because there is a gain (4.20) in the academic score of the participants of the control group in pretest and posttest. The alternate hypothesis is accepted due to this gain in scores.

With reference to table 2, it is evident that the Null hypothesis is rejected because there is a gain (7.30) in academic scores of the participants of the experimental group in pretest and posttest. The alternate hypothesis is accepted due to this gain in scores.

With reference to table 3, the evidence that means scores of experimental groups is (24.8) and control group participants is (22.9) is enough to reject the Null Hypothesis. Hence null hypothesis is rejected.

In the same way alternative hypothesis "There is a significant difference in the achievement of Chemistry students control group and experimental group on posttest" is accepted.

- It has been found from the results that there is no increase in the knowledge level of the participants in the experimental group as compared to the control group participants.
- It has been found from the results that there is a statistically significant improvement in the comprehension level

of the participants in the experimental group as compared to the participants of the control group.

- It has been found from the results that there is a statistically considerable improvement in the comprehension level of the experimental group participants in comparison with the control group participants.

Conclusions

Conclusions made from the data analysis were as in the following:

The VL has no significant effect on academic achievement in terms of *knowledge* increase among high school chemistry students in comparison with the traditional teaching methodology used in the subject of Chemistry. The VL has a significant effect on academic achievement in terms of *comprehension* increase among high school chemistry students in comparison with the traditional teaching methodology used in the subject of Chemistry. The VL has a significant effect on academic achievement in terms of *application of the concepts* increase among high school chemistry students in comparison with the traditional teaching methodology used in the subject of Chemistry.

Recommendations

Based on the observations made during the study, the following recommendations are suggested:

1. Virtual Labs may be used by the science teachers in their science teaching at the secondary school level.
2. For a major improvement in comprehension and application level of students at secondary school, VL is recommended instead of the traditional methods in the teaching of theoretical concepts of Chemistry.
3. For a noteworthy improvement in knowledge, comprehension and application skills of the students at secondary school, VL is recommended rather than the traditional methods in teaching of theoretical concepts of all the science subjects at other levels that is from early grade science comprehension to the varsity level.

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