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Research Paper

Virtual Laboratories: Their Impact in Students' Achievement in Science

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Abstract

The use of virtual laboratories is the outcome of the sudden shift in face-to-face to online education as it ensures that students have an opportunity to acquire practical experience independently. This research involved analyzing the effect of virtual laboratories on the grade 10 students regarding their level of performance using a quasi-experimental research design method. The level of performance was in terms of a pretest and posttest that was conducted during the first quarter. The outcomes indicated that the pretest score and posttest score of the respondents were significantly different (p = 0.001). After the addition of the virtual laboratories, the performance of the students changed tremendously, as they have changed to satisfactory (mean score of 7.56) and very satisfactory (mean score of 9.68). The results showed that virtual labs in online courses greatly increased the performance of the students. Besides having an exciting internet game that motivates children to study, virtual laboratories will ensure that students are able to do what they would be doing in the real world at school. Online instructors can use virtual laboratories to make students more interested and knowledgeable with the subject.

Keywords: *Virtual Laboratories, Student Achievement, Quasi-Experimental, Effectiveness, Science Topic*

INTRODUCTION

Due to their need to synchronize a complex set of skill, cognitive, and motivational elements, numerous scientific classes are difficult to instruct (Anderman, and Sinatra, 2009). Hence it is better to apply constructivist approaches or student-centered teaching practices to help students comprehend the concepts. Virtual laboratories are one of the ways of helping students study science, and their experiments, especially when the real-life sessions are disrupted by some unavoidable circumstances such as the COVID-19 pandemic or the unavailability of the equipment at school. As suggested by Oser (2013), virtual laboratories help students to develop their interest in scientific inquiry as it enables them to engage in activities that could not be achieved in science classrooms. Moreover, they will enable students to watch or repeat the activities at slow speed several times, and this will help them master the concepts and skills (Tuysuz, 2010).

It is essential to reach educational technology goals since technology advances, and the educational system evolves rapidly. The realization of this will lead to resources with regards to information and communication technology, or ICT. Due to this, virtual laboratories have become an element of educational technology, particularly when face-to-face learning is limited due to the epidemic. Science professors can give students virtual laboratory projects as a way of learning, in particular principles connected with laboratory work. It was discovered that the performance of

students when teaching in virtual laboratories was greatly improved (Dalgarno et al., 2009; Tatli and Ayas, 2013; Yu et al., 2005). In a digital learning environment, students are able to self-examine and closely monitor the process. Discussion sites assist both teachers and students to become more attentive and interested in the topic under discussion (Dobson, 2009).

As Russell (1999) remarks, several researchers also mention that empirical data concerning the effectiveness of science laboratories in general, and virtual simulations integration, in particular, is lacking (Harms, 2000; Hofstein and Lunetta, 2004; Javidi and Sheybani, 2006). Moreover, Ma and Nickerson (2006) showed that no information on the effectiveness of these technologies in teaching students design skills is available versus practical laboratories. One of the ways of instruction in the new normal that schools are already adopting now that they are switching their school mode of education to online education is the use of virtual laboratories.

One of the ways of teaching in the new normal is the use of virtual laboratories, which schools are already adopting during their online learning process. Thus, it is important to conduct experimental studies to further determine the effectiveness of laboratory simulations in education. Based on what has been mentioned, there does not seem to be much research done on virtual labs regarding its educational perspective. So, the concept in this research was conceived. This research was conducted to determine the performance of the students in science classes when they were using virtual labs. This analysis dealt with the questions that were accompanying it.

LITERATURE REVIEW

Virtual Laboratories

Software programs that allow students to engage in simulated experiments are known as virtual laboratories. Also known as virtual laboratories, these programs create a virtual classroom and learning environment that allows students to use their imagination and interact as if they were in a real classroom. Virtual laboratories are a good option in situations when schools do not have the ability to create laboratories and provide equipment and materials, particularly in the situation of virtual learning (Aljuhani et al., 2018). According to a study by Keller & Keller (2005), a virtual laboratory can be described as a laboratory simulation, allowing students to connect their learning to real world situations and experiments. Also, virtual laboratories are viewed as software that allows users to create and conduct the same experiment repeatedly in order to understand the impact of different variables (Toth, 2016). In many cases, virtual laboratories can be a safer and less expensive alternative to traditional laboratories (Brinson, 2015). Virtual laboratories are an effective way to teach students scientific concepts, especially when in-person teaching is not allowed due to restrictions.

In today's world, students may not get the chance to have in-person interactions with their teachers, but they can still benefit from engaging in virtual labs. They can also avoid spending money on materials and other educational resources. Their effectiveness relies on the achievement and learning of the students (Fraser, 2001).

The learning atmosphere may be enhanced in both manual and virtual labs. Despite this, there are areas in which each may be more appropriate than the other, depending on the learning environment of the students. For example, in manual laboratories, students concentrate on using and manipulating physical tools and equipment, while in the virtual laboratories, they focus on the relations of the factors and the interplay of the variables to derive the results (Toth, 2016; Widodo et al., 2017).

Actual Laboratory vs. Virtual Laboratory

Recent changes in the educational sector, particularly with the role of technology, necessitated consideration of how to structure teaching of subjects that require laboratory

components. With remote teaching or online teaching being a definitive option at both the high school and especially all university levels, the teaching and learning of lessons necessitated the development of new methods. These situations then led to considering some computer simulations as a variable for laboratory education (Bretz & Bruck, 2013). Therefore, means et al. (2010) supports the view that teaching laboratory work through computer simulations to generate and analyze data is a done deal. Nevertheless, the American Chemical Society and the College Board stated that hands-on laboratory activities are superior to online virtual research laboratories (American Chemical Society, 2011).

Active lab exercises (also called hands-on laboratories) are said to serve many functions for students. These functions include helping students master subject matter, assisting students in developing scientific reasoning, helping students gain an appreciation of the complexity of empirical work, assisting students in acquiring other practical skills, and helping students develop an interest in the discipline of science. Most of these are also the objectives of science education in general (Hofstein & Lunetta, 1982). While many of these objectives have come from previous studies on lab encounters and understudy learning, the National Research Council acknowledged the new purpose of 'understanding the complexity and obscurity of exploratory work' as demonstrating good work of lab experiences. In addition, students' direct encounters with the complexity and messness of the actual natural phenomena are fairly greater than what is presented in science lectures, learning materials, and the written science interactions and formulas (Millar, 2004). Also, science students on the virtual laboratory's platforms say lab-based courses are very important for education of logic, but those in favour of distant research laboratories say well defined arrangements are very important (National Research Council, 2005).

Furthermore, Potkonjak et al., (2016) mentioned that virtual labs are applications that give elective advanced learning apparatuses to inquiry-based science education. In addition, Lee & Wong (2014), emphasized that these applications can be utilized with cell phones and personal computers straightforwardly on the web or disconnected based on the model. The virtual lab is examined as an elective way to address the limits of real labs. It also helps students improve their understanding, abilities, and learning autonomy in science learning.

In contrast, learning by doing experimental learning allows learners to inquiry complex scientific problems by testing hypotheses, manipulating variables, etc., (Grobmann & Wilde, 2019). Unlike computer-based simulations of virtual labs, real labs offer opportunities for tactile experience of synthetic and natural objects, reagents, and materials (Hawkins & Phelps, 2013). However, about accessibility, most traditional science labs necessitate physical movement of students to a lab for experimentations and interactions with peers and instructors.

Advantage and Disadvantage of Virtual Laboratories

Learning is a process that needs a conducive environment to be effective. A comfortable classroom, suitable reading materials from reliable references, other learning tools, and a healthy social relationship between learners and teachers contribute to a favorable environment. The advent of technology has brought many societal changes, including in education. Online learning is convenient for working students or students who cannot make it to school, like those living in remote areas. The adaptability of online learning attracts more students with diverse academic needs than traditional education can meet (Gilbert, 2015). The utilization and integration of virtual laboratories have become possible in online classes.

Virtual laboratories serve as an alternative to actual laboratories, which cannot be done in this time of the pandemic. Aside from that, they also help teachers expose students to different activities that are not possible at school due to lack of facilities and equipment (Tuysuz, 2010) and those experiments that may have time and safety issues (Chan & Fok, 2009). They are also meant to use Jerome Bruner's ideas about discovery learning even when there are limitations because students can experience it at anytime and anywhere. Through virtual laboratories, students can

construct their own knowledge and understanding about a particular lesson by exploring and discovering it on its own which as emphasized by Bruner.

The laboratory is an essential component in science learning because most topics require experiments and activities to be understood better by the students through their experience. Using laboratory simulation programs may keep students away from possible dangers inside an actual laboratory, misuse of apparatus, and may serve as an alternative tool when laboratory apparatus is unavailable (Yenitepe, 2003). It can provide a safe environment for all students, which is convenient for teachers since supervision is not needed. Although most online classes are uninteresting, it has been discovered that the use of virtual laboratories is both engaging and inspiring (Josephsen & Kristensen, 2006). Aside from that, it also develops students' ability to become IT literate and innovative. Motivating students to learn science concepts is hard for teachers. Still, virtual laboratory activities might be helpful not just in uplifting their interests but also in developing their scientific skills. In general, the advantages of virtual laboratories involve the maximization of time and space, simplification of activities, elimination of physical limitations, and promotion of a safer environment.

Despite the number of advantages or benefits that the integration of virtual laboratories can offer, there are still drawbacks to it. Chan & Fok (2015) identified engineering students perceived traditional or actual laboratories as easy to operate and understand, flexible, and more satisfying than virtual laboratories. Aside from that, it was also identified that virtual laboratories did not enhance students' physical, practical, and operating skills because the students were narrowed into observing the process and the result of an experiment. Thus, it did not hone students' full sensory experiences. This limitation did not allow students to use real instruments, equipment, and chemicals. It also did not allow direct collaboration between students and teachers, which affected the development of students' communication and knowledge transfer skills.

Students' Achievement

Student achievement refers to the amount of knowledge learned by students after a specified period. Measuring students' achievement can be done through pretest and posttest because these are identical tests given to students before and after the lesson is taught (Sanders, 2019). That is why a pretest and post test were conducted in this study about virtual laboratories.

Virtual laboratories have been found in most studies to positively impact students' academic performance in science. According to Aljuhani et al., (2018), 80 percent of students improved their understanding of the experiments they performed after using the virtual lab. Moreover, a study indicated that students who learned through a digital platform outperformed those taught using traditional methods (Bozkurt & Ilik, 2010). As a result, students' interest in learning about various science concepts increased, and at the same time, they also escalated their willingness to engage in all laboratory activities (Collette & Chiappetta, 1989). This claim also coincides with another study conducted by Yildirim (2021) as it showed that the use of virtual laboratories increased students' interest and motivation to learn science lessons which had a positive impact towards their achievement in science. This means that the integration of virtual labs in science classes contributed to a meaningful learning experience to the students. In addition, several researchers had also suggested that simulations using virtual laboratories offer numerous benefits in enhancing students' academic performance in science (Narayanan & Banerjee, 2013).

According to Hawkins & Phelps (2013), virtual labs carry similar benefits to that of traditional labs as students can obtain similar understandings. This claim is further supported by Tuysuz (2010), as students were shown to improve their learning outcomes, cognitive achievement, and attitudes towards science, in addition to several other areas, by using virtual labs. Furthermore, Irwanto & Ramadhan (2018) highlight virtual labs' ability to improve students' problem solving and critical thinking, creativity, conceptual understanding, science process skills, laboratory skills, as well as other areas, including motivation, interest, perception, and learning

outcomes.

RESEARCH METHOD

Research Design

This study is in congruence with the learning by doing theory proposed by John Dewey, an American philosopher. This theory emphasizes student participation in learning. This also challenges the conventional wisdom that learning occurs through lectures and repetitive recall. Figure 1 shows the conceptual framework of this study. It shows that students' achievement is dependent on how effective the given virtual simulation is on the topic of science. Based on the experimental group's pretest and posttest results, the students' achievement was examined through their mean gain score (see Figure 1).

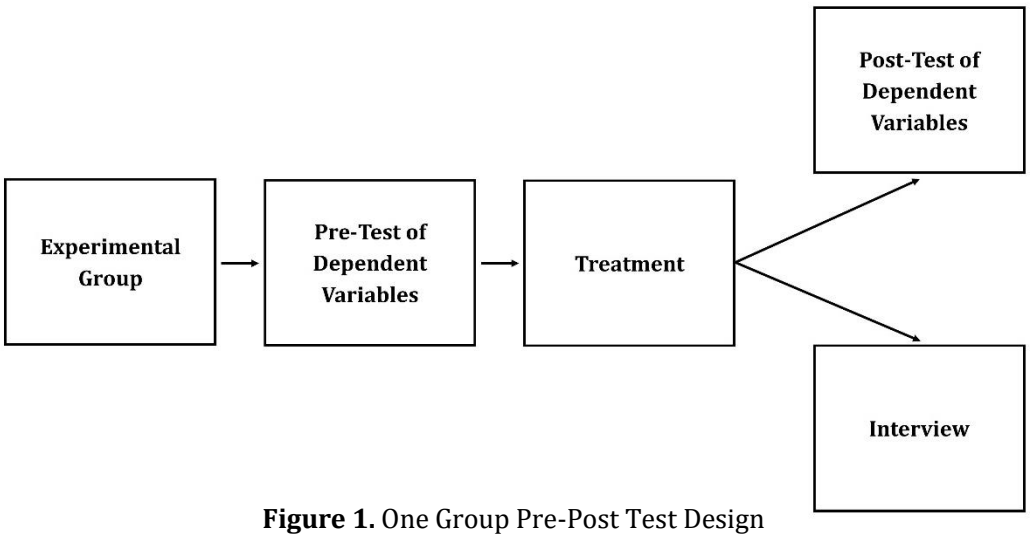

Figure 1. One Group Pre-Post Test Design

The study examined the effectiveness of virtual laboratories in students' achievement in science. In particular, this examination responded to the accompanying inquiries:

RQ1: Is there a statistically significant difference in the level of performance of the Grade 10 science students in the science pre-test and post-test?

H_0**1:** There is no statistically significant difference in the pre-test and post-test on the level of performance of the Grade 10 science students in the science pre-test and post-test.

$\mu_1 = \mu_2$

H_a**1:** There is a statistically significant difference in the pre-test and post-test on the level of performance of the Grade 10 science students in the science pre-test and post-test.

$\mu_1 > \mu_2$

RQ2: Is there a statistically significant difference between the pre-test and post-test performance of the students?

H_0**2:** There is no statistically significant difference between the pre-test and post-test performance of the students.

$\mu_1 = \mu_2$

H_a**2**: There is a statistically significant difference between the pre-test and post-test performance of the students.

$\mu_1 > \mu_2$

This research used a quasi-experimental approach to measure the impact of virtual labs as an addition to online classes. The author reports the impact of the intervention by measuring the cause and effect of the action. The impact of the measure was assessed by analyzing the difference

in results obtained in the pre and post tests. This type of design considers only one group of subjects (Thomas, 2021).

Sample and Sampling Technique

This research considered Grade 10 students in the 2021-2022 academic year of the institution as the target respondents. A total of fifty (50) respondents participated in the study, of which twenty-five (25) students belonged to each section. These students were selected because they participated in the pre-test and post-test in science which was conducted by their science teacher and the researchers.

Instrument for Data Collection

Data was gathered by means of a structured survey questionnaire. The instruments were constructed from a 15-item test which evaluated all the subjects that were delivered in the virtual laboratories. The dependability rate for the items was 0.72. The test questionnaires for the pre-test and post-test assessment were constructed from the module of virtual laboratories which set its operational limits. A table of specifications was employed to guarantee alignment and validity of the assessment result.

Procedure for Data Collection

Data collection was carried out through survey questionnaire. The respondents were contracted through their school and they were invited to answer the survey questionnaire. The data collection conducted in this study was guided by several steps. The firs step was to conduct pre-test to the respondents. The pre-test containing 15-items about the topic that was handled with a virtual lab and online simulations. Online simulations were conducted after the pre-test of the respondents through their canvas course card. The instructions and the usage of the virtual laboratories were first demonstrated by the teacher during teacher-directed online activities, which is good for 40-minutes. A post-test was administered after the virtual laboratory integration. Since the total number of test items is 15, the expected students' scores tanged from 0 to 15 as the perfect score. To substantiate the quantitative data, the researchers interviewed ten students randomly. The interview focused on the students' perceptions about their experiences and difficulties while using the virtual laboratory. This interview evaluated how students view the virtual laboratory used in the study.

Data Analysis

SPSS was used to analyze the quantitative data through frequency and descriptive statistics. Frequency and distribution were used to determine respondents' performance levels on the pre-test and post-test. A paired t-test was used to analyze the means of the pre and post-test scores.

FINDINGS AND DISCUSSION

1. Performance Level of the Students in the Pre-Test and Post-Test

Table 1. Students' Level of Performance in the Science Pre-test and Post-test

*Class Scores	Pre-test		Post-test	
	Frequency	Percent (%)	Frequency	Percent (%)
12-15	7	14	20	20
8-11	19	38	15	30
4-7	19	38	13	26

0-3	5	10	2	4

**Interpretation: 12-5 – outstanding; 8-11 – very satisfactory; 4-7 – satisfactory; 0-3 – needs improvement*

The students' performance level increased from pre-test to post-test results, as shown in Table 1 above. 10% of the respondents received a score of 0–3, 38% received a score of 4–7, another 38% had a score of 8–11, and the remaining 7% received a score of 12–15. The data shows that 5 students out of 50 needed to show their improvement from the pre-test assessment. The 7 students who showed outstanding results were joined by 19 students who achieved satisfactorily results and another 19 students who performed at a very satisfactorily. The students' overall performance level was satisfactory, as evidenced by the pre-test mean score of 7.56.

The post-test results showed that 4% of participants scored between 0-3 while 26% scored between 4-7 and 30% scored between 9-11 and 40% scored between 12-5. The data showed that 2 students needed improvement while 13 students achieved satisfactory results and 15 students earned very satisfactory results, and 20 students attained outstanding scores. The students' performance level reached highly satisfactory status because their post-test mean score increased to 9.68.

The study's findings are consistent with the study by Ozdener & Erdogan (2001) and Joseph et al., (1999), which demonstrated that the use of virtual laboratories was crucial in teaching science concepts because students' performance improved after being exposed to multiple virtual laboratories. The research demonstrated that students achieve better learning outcomes when educational institutions use virtual laboratories and simulations and movies and animations as instructional tools (Ramadhan & Irwanto, 2017).

Table 2. Statistical Analysis between the Pre-Test and Post-Test Scores of the Students

Pre-Test Mean Score	Post-Test Mean Score	*p-value	Interpretation
7.56	9.68	0.00	Significant

*α = 0.05 level of significance

The t-test results in Table 2 show the means of scores in the pre-test and post-test with the integration of virtual laboratories. The null hypothesis is rejected due to results showing that the p-value is lower than the 0.05 level of significance. This shows that there is a significant difference in the mean scores of the students for the pre-test and post-test. Furthermore, there is a 2.12 difference in scores for the pre-test and post-test, and therefore this is an explanation for the post-test being higher than the pre-test. Consequently, there is an enhancement on the students' scores after the incorporation of virtual laboratories. This agrees with Aljuhani et al., (2018) who, after using the virtual lab, stated that 80% of the students had an improved understanding of the experiments they performed. Also, this study agrees with Brinson (2015) who compared the learning outcomes in the traditional lab and the non-traditional lab (virtual lab) and stated that students who used non-traditional labs had better learning outcomes than those who used traditional labs. In addition, Faour & Ayoubi (2018) stated that learners who utilized virtual labs had much better results than learners who were taught with interactive demonstrations with actual lab equipment. These results further indicated that virtual labs are beneficial for enhancing students' achievement.

2. Students Perception Towards the Use of Virtual Laboratories

The respondents were requested to complete an interview questionnaire by the researchers following the post-test. To find out how students felt about using virtual laboratories, the researcher used an online roulette spin to select ten responses at random.

Table 3. Students' Perception to Virtual Laboratories

Positive Perception	Negative Perception
1. It is interactive and informative.	1. Virtual laboratory is very hard.
2. It is useful.	2. It is difficult to use when the internet connection is unstable.
3. It is resourceful.	3. It is very challenging.
4. It is interesting.	4. It is bad for students' health especially their eyes.
5. It is helpful as an alternative tool to hands-on laboratory when face-faced classes are not yet permitted.	
6. It made students' learning fun and meaningful.	

The table shows that 90% of students who were surveyed about their experience with virtual laboratories reported positive results. The students' opinions support the results of Josephsen & Kristensen (2006) which found that virtual laboratories used during class discussions created both engagement and motivation for students. Their typical responses were "interactive and informative," "useful," "resourceful," and "interesting." The respondent explained that the interactive nature of the program helps students learn the subject matter effectively. As a result, students' willingness to participate in all laboratory activities rose along with their enthusiasm in learning about diverse science subjects (Collette & Chiappetta, 1989).

However, there are challenges when utilizing virtual laboratories. One respondent said that using virtual laboratories is "very hard." When asked about these challenges, the unreliable internet connection was cited. According to reports, 31% of Filipino households with children studying online have slow internet connections, which is one of the issues preventing students from learning efficiently online (Gerio et al., 2021). Another respondent stated that "it is very challenging," therefore using the virtual laboratory can be made easier with improved application instructions. According to Potkonjak et al., (2016), virtual labs are programs that provide inquiry-based science teaching with elective advanced learning tools. As a result, educators need to help students manage and utilize the virtual lab.

The interviewees selected the real laboratory when they had to choose between an authentic laboratory and a digital laboratory. Students preferred physical laboratories even if they thought virtual laboratories were helpful in online programs. The real laboratories provide science students with work environments that give them convenience and understanding and complete their scientific tasks (Chan & Fok, 2015). Moreover, the American Chemical Society in 2011 said that virtual laboratories could become an effective complement to actual laboratories, but they

cannot replace them. On the other hand, when asked if they are willing to use the virtual laboratories again, six students answered "yes," because they found it interesting, fun, and helpful. One student, however, said he wouldn't utilize it again since he didn't fully comprehend the subjects covered in virtual laboratories compared to real laboratories. The most common suggestions for improving virtual laboratory integration require educational institutions to provide teachers with additional time for laboratory work and to develop comprehensive usage guidelines and to assess their internet access needs.

The researchers observed students who used virtual laboratories during the first quarter and found that these students experienced both enjoyment and educational advantages from the virtual labs. The students experienced educational problems because they lacked proper internet access which made them prefer actual laboratory experiences instead of virtual ones.

CONCLUSION

The study focused on several main research questions, including 1) how students' first quarter pre and post-test performance levels compare, 2) whether there is a statistically significant difference between students' pre-test and post-test performance levels, and 3) what students' attitudes and perceptions are regarding the usage of virtual laboratories. The students received a pre-test average score of 7.56, which is satisfactory. When compared to the average of 9.68, students' post-test average score indicates remarkable performance. The performance level of Grade 10 students in the first quarter improved following the application of virtual laboratories. The paired t-test indicates that the mean score difference is statistically significant since the p value is < 0.001. The increased test score difference demonstrates that virtual labs positively impacted the students' understanding of science. Resoundingly, students appreciated the use of virtual laboratories.

Evidence suggests that students' science skills are enhanced by integrating virtual laboratories into their studies. The interactive online experience students gain from virtual labs helps simulate a real science lab and a complete classroom experience. The system functions as an effective replacement for both real-world laboratory activities and traditional laboratory work because it maintains all educational requirements while face-to-face teaching remains unavailable. Hence, formulate strategic plans to implement a cyclical or alternative use of virtual laboratory and actual laboratory to ensure that students can learn better is highly recommended.

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