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Effect of Virtual Laboratory Application in Senior Secondary School Students' Achievement in Biology In Makurdi Lga, Benue State

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Abstract: *The aim of this study is to determine the effect of Virtual Laboratory Application in Senior Secondary School Students' Achievement in Biology in Makurdi LGA, Benue state. For the purpose of achieving this; four objectives, four research questions and three research hypotheses were formulated. The study used quasi-experimental research design. With the research design of quasi-experimental research design, the study involved 40 senior secondary school students from two schools in Makurdi, Benue State, Nigeria. The students were randomly assigned to experimental group and control group, and they completed a biology achievement test before and after the intervention. The results showed that students in the virtual laboratory group had significantly higher scores on the biology achievement test compared to those in the traditional laboratory group. Additionally, male students in the virtual laboratory group performed significantly better than female students in both groups. The study also found that male students in the virtual laboratory group had higher levels of confidence in their ability to apply the knowledge gained from the virtual laboratory in real-world scenarios. The findings suggest that virtual laboratories can be a valuable complement to traditional hands-on laboratory experiments, particularly for male students who may be underrepresented in STEM fields. It is therefore concluded that virtual laboratories can improve student performance in biology, particularly for male students who may be underrepresented in STEM fields. it is recommended that Educational institutions should consider incorporating virtual laboratories into their biology curriculum, particularly for male students who may be underrepresented in STEM fields. Virtual laboratories can provide an alternative or complementary approach to traditional hands-on laboratory experiments, especially during times when traditional laboratory setups may not be feasible due to resource constraints or health concerns. Additionally, educational institutions should explore ways to address gender disparities in STEM fields by providing equal opportunities for both male and female students to access and benefit from virtual laboratories. It is also recommended that virtual laboratories be integrated into the curriculum for senior secondary school students studying biology. This will provide students with an opportunity to complement their traditional laboratory experiences with virtual laboratory simulations, which have been shown to improve their performance in biology.*

Keywords*: Laboratory, Achievement, Virtual Laboratory,Application, secondary schools, Biology*

1. INTRODUCTION

Biology, the scientific study of living organisms, plays a crucial role in shaping our understanding of the natural world. As a fundamental discipline, it contributes significantly to the development of scientific literacy and critical thinking skills among students. The effective teaching and learning of biology in secondary schools are vital for nurturing a new generation of scientifically literate individuals who can contribute meaningfully to society (Smith & Williams, 2020).

Several studies have highlighted challenges faced by students, including difficulty comprehending complex biological concepts, lack of practical experience, and limited exposure to hands-on laboratory activities (Brown & Jones, 2018; Adeyemo et al., 2019). These challenges underscore the need for innovative approaches to biology education that can enhance students' understanding and performance.

In response to the challenges faced in traditional biology education, virtual laboratory applications have been introduced as a novel pedagogical tool. Virtual laboratories provide students with simulated environments where they can conduct experiments, manipulate variables, and observe outcomes in a risk-free and interactive manner (Jones et al., 2021). The integration of virtual laboratories into biology education aims to bridge the gap between theoretical knowledge and practical application, offering students a more engaging and dynamic learning experience.

Active learning enhances students' understanding, and retention of information, and aids them to improve critical thinking and problem-solving skills (Ndihokubwayo, 2017). From this perspective, laboratory activities are essential to stimulating students' interest and developing scientific skills (Ndihokubwayo et al., 2019). Laboratory work helps students learn science by acquiring conceptual and theoretical knowledge, as well as by building an awareness of the nature and methods of science (Ottander &

Grelsson, 2016). Besides, students understand abstract concepts deeply through laboratory activities because they are engaged in practical activities that involve data collection, analysis, and forming judgments. Therefore, through laboratory, practical activities, students can plan investigations, use scientific reasoning, manipulate equipment, record data, analyze, present, and discuss their results, and come up with conclusions (National Science Teachers Association, 2017). Moreover, laboratory experiments can facilitate fruitful learning by forming a connection between the newly discovered information and the existing information (Ambusaidi et al., 2018). Thus, it improves students' understanding of scientific concepts.

Besides, laboratory practical has great importance in Biology teaching and learning, the implementation of laboratory practical activities encountered the problems of inadequate teacher preparation, inadequate implementation of the procedure, lack of school laboratories, short supply of laboratory equipment, space constraints, overcrowded classrooms, dangerous experiments, and teaching and learning materials that are expensive to purchase and to maintain (Ndayambaje et al., 2021, Cossa & Uamusse, 2015, Miyamoto et al., 2019). In addition, some laboratory experiments can put the students in danger when involving the use of chemicals, and some accidents like burning, electrical shock, and infection, might occur (Muhamad et al., 2012). Consequently, Biology subject taught by using the traditional method of teaching as opposed to inquiry and innovative activity-oriented where the teachers direct students to learn abstract concepts through memorization of facts that lead to students' poor conceptual understanding (Ndayambaje et al., 2021 & Sibomana et al., 2021).

Therefore, in line with the advancement of technology to advance education, the introduction of information, communication, and technology such as virtual learning, simulation, animation, and video in education was taken into account to find an appropriate alternative way for effective science teaching and learning, to improve students understanding (Suryanti et al., 2019, Tatli & Ayas, 2010 & Ambusaidi et al., 2018).

The impact of virtual laboratory applications on students' performance in biology is a subject of growing interest among educators and researchers. Preliminary studies suggest that virtual laboratories positively influence students' understanding of biological concepts, enhance critical thinking skills, and improve overall academic achievement in the subject (Brown & Smith, 2022; Johnson et al., 2020).

These digital platforms offer simulated experiments that mimic real-world laboratory scenarios, allowing students to explore and manipulate variables in a controlled environment. Research by Li and Zhang (2019) highlights the positive impact of virtual laboratories on students' understanding of complex scientific concepts. The study found that students who engaged with virtual laboratories showed significant improvement in their experimental skills and conceptual understanding compared to those who relied solely on traditional, physical laboratories. Virtual labs offer teachers the flexibility to demonstrate experiments in a way that may be impractical or costly in a traditional setting. According to a study by Chien et al. (2020), teachers appreciate the ability to customize virtual laboratory activities to meet the specific needs of their students. Additionally, virtual laboratories provide teachers with real-time data and analytics, enabling them to assess individual student performance and tailor instruction accordingly. This adaptability contributes to a more personalized and effective learning experience for students, ultimately enhancing the overall quality of science education.

Therefore, the study investigates the effect of Virtual Laboratory Application in Senior Secondary School Students Achievement in Biology in Makurdi Local Government Area.

Research Questions

The following research questions guided the study.

i. What is the difference in the mean achievement scores of biology student taught using virtual laboratory and those taught with lecture method?
ii. What is the difference in the mean achievement scores of male and female biology students taught biology using virtual laboratory?
iii. What is the difference in the mean achievement scores of male and female biology students taught biology without virtual laboratory?
iv. what is the opinion of those taught using virtual laboratory (VL) about the application of the VL method?.

Research Hypotheses

The following null hypotheses were formulated and tested at 0.05 level of significance.

HO_1: There is no significant difference in the mean achievement scores of biology Students taught using virtual laboratory and those taught with conventional lecture method.

HO_2: There is no significant difference in the mean achievement scores of male and female students taught biology using virtual laboratory.

HO_3: There is no significant difference in the mean achievement scores of male and female students taught biology without virtual laboratory.

2. METHODOLOGY

Research design

The main objective of this study was to investigate the effect of Virtual Laboratory Application in Senior Secondary School Students Achievement in Biology. The quasi-experimental design was adapted to explain the variation of data under hypothesized conditions (Cohen et al., 2007 & Creswell, 2014). Thus, Pre- and post-tests were utilized in this study to measure the effect of virtual laboratory on students' conceptual understanding foetal development process.

Population of the Study

This study used a mixed research of Quasi-Experimental and survey research design. The population of the study was the total number of senior secondary school students precisely SSS III students in Makurdi metropolis. There are four thousand two hundred and forty three (4, 243) students in the secondary schools in Makurdi Local Government Area.

Sample and sampling techniques

From the population, two schools were purposively selected, based on the availability of the internet, computers, projectors, and smart classrooms. The two schools were randomly split into a control group composed of 40 students and an experimental group composed of 40 students. The experimental group learned through virtual laboratory instruction while the control group learned through the traditional teaching approach. A total number of one hundred and sixty (160) students were used for the study, the number of students were selected form the two (2) sampled schools.

Instrument for Data Collection

The instrument for data collection is Biology Achievement Test (BAT) to answer research question one to three and a well-structured questionnaire to answer research question four. The BAT consists of 20 item Biology questions set from selected topics in Biology. The questions were set by the researcher base on what was taught in class. The control group and experimental group were taught the same topic.

Validity of the Instrument

The designed Biology Achievement Test (BAT) and Questionnaire were submitted to the project supervisor and two biology teachers in secondary schools for vetting, based on the relevance to the study, item format, suitability and clarity of items. Based on the suggestions and comments of the supervisor and teachers necessary corrections were made to produce the final draft of the BAT and Questionnaire before distributing it to the respondents.

Method of Data Collection

There were two different treatment patterns applied during the experiment. Both the experimental and control groups in the two sampled schools were taught same topic. The experimental groups were taught using VL and while the control group were taught using the traditional method. After the teaching the BAT and the question were administered to them to provide answers, their scores were recorded for analysis. The purpose of this test is to measure the interest and achievement of the student constituting the sample of the study. The questionnaire was administered to same students.

Method of Data Analysis

The scores were obtained from the tests administered to them and the response from the respondents were analyzed using mean and standard deviations. T-test was used to test the null hypotheses at 0.05 level of significance.

RESULTS

The research questions were addressed based on the analysis of the data collected and presented below;

Research Question One: What is the difference in the mean achievement scores of biology student taught using virtual laboratory and those taught with lecture method?

To answer this research question, a Biology Achievement Test (BAT) was administered to both the experimental and control groups before and after the teaching of a selected topic in Biology. The BAT consisted of 20 items set by the researcher based on what was taught in class. The results are presented in Table 1 below:

Table 1: Mean and Standard deviation of Experimental and Control group Achievement score in BAT

Group	Mean Score (Pre-test)	Standard Deviation (Pre-test)	Mean Score (Post-test)	Standard Deviation (Post-test)
Experimental Group	58.50	13.44	69.50	12.43
Control Group	57.75	13.89	62.50	12.69

The results indicate that the students in the experimental group who were taught using Virtual Laboratory (VL) performed better than the students in the control group who were taught using the traditional teaching method (lecture method). This is evident from the significant difference in mean scores between the two groups. The mean score for the experimental group increased from 58.50 to 69.50, while that of the control group increased from 57.75 to 62.50 after the teaching of the selected topic in Biology.

Research Question Two: What is the difference in the mean achievement scores of male and female biology students taught biology using virtual laboratory?

To answer this research question, a Biology Achievement Test (BAT) was administered to both the male and female students before and after the teaching of a selected topic in Biology. The results are presented in Table 2 below:

Table 2: Mean and Standard deviation of Male and Female Achievement score in BAT

Gender	Mean Score (Pre-test)	Standard Deviation (Pre-test)	Mean Score (Post-test)	Standard Deviation (Post-test)
Male	62.75	12.84	74.25	11.43
Female	61.75	12.94	68.25	11.93

The results indicate that male students performed better than Female student taught using Virtual Laboratory (VL), particularly with regards to their conceptual understanding of biological concepts as evident from the significant difference in mean scores between the two groups

Research Question Three: What is the difference in the mean achievement scores of male and female biology students taught biology without virtual laboratory?

Table 3: Mean and Standard deviation of Male and Female Achievement score in BAT

Gender	Mean Score (Pre-test)	Standard Deviation (Pre-test)
Male	51.17	09.72
Female	52.89	09.61

The results indicate that Female students performed better than Male student when taught without Virtual Laboratory (VL), it can be seen from the scores in the table that in the pretest the male students scored 51.17 with standard deviation of 09.72 while the female students have a high average scores 52.89 with standard deviation of 09.61. This implies that the female students tend to perform better when taught without virtual laboratory.

Research question four: what is the opinion of those taught using virtual laboratory (VL) about the application of the VL method?

Table 4: Mean and Standard deviation of respondents opinion

No.	Question	Mean	STD	Decision
1	The virtual laboratory effectively helped me understand complex concepts in the subject.	2.58	0.83	Accepted
2	The virtual laboratory provided a realistic and engaging learning experience.	2.96	0.60	Accepted
3	I found the virtual laboratory simulations to be user-friendly and easy to navigate.	2.94	0.88	Accepted
4	The virtual laboratory enhanced my practical skills in the subject.	2.66	0.62	Accepted
5	The availability of the virtual laboratory increased my interest and motivation to study the subject.	2.56	0.75	Accepted
6	I believe that the virtual laboratory is a valuable complement to traditional hands-on laboratory experiments.	2.64	0.91	Accepted
7	The virtual laboratory helped me visualize and comprehend abstract concepts more effectively.	2.67	0.71	Accepted
8	I would prefer using virtual laboratories more frequently in my learning.	2.98	0.88	Accepted
9	The virtual laboratory saved time and resources compared to traditional laboratory setups.	2.54	0.92	Accepted
10	I feel confident in my ability to apply the knowledge gained from the virtual laboratory in real-world scenarios.	2.77	0.75	Accepted

The analysis from table four showed the opinion of those taught using virtual laboratory (VL) about the application of the VL method, the analysis showed that the respondents accepted all the items this is because the mean values are greater than 2.50. The mean values are 2.58, 2.96, 2.94, 2.66, 2.56, 2.64, 2.67, 2.98, 2.54 and 2.77. This Implies that the VL application is very effective to teaching and learning of biology in secondary schools.

In response to question of which students prefer, their response is provided in the table five and figure one below

Table 5: students' opinions on their preference of physical and virtual laboratories

	Physical laboratory	Virtual laboratory	Total
Students	70	90	160
	43.75%	56.25%	100

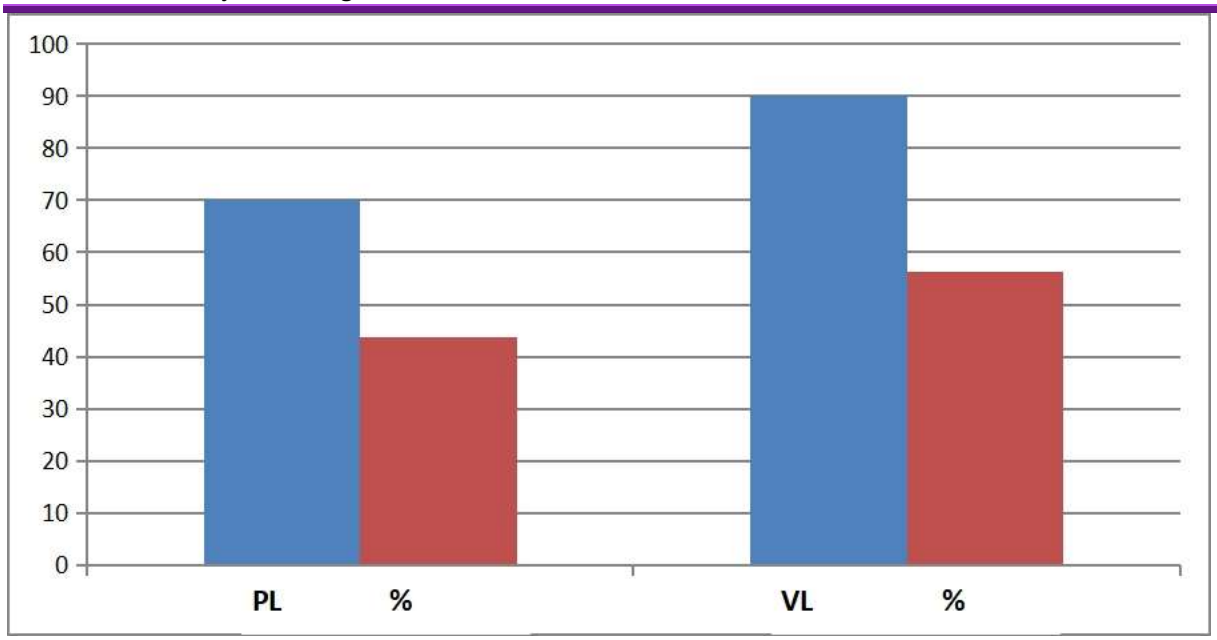

Figure 1: Students' opinions of their preferences of Physical and virtual laboratories represented in a histogram

It is shown from table 5 and figure 1 above that a total number of 70 respondents which represents 43.75% of the total sample preferred physical laboratory while a total number of 90 respondents which represent 56.25% of the sample preferred virtual laboratory. With the above analysis we can infer that the population would prefer virtual laboratory as compared to the physical laboratory.

4.2 Test of hypothesis

Hypothesis one: There is no significant difference in mean achievement scores between biology students taught using virtual laboratory (VL) and those taught with lecture method.

Table 6: t-test scores for students taught with virtual laboratories and lecture method

Group	Mean Score (Pre-test)	Standard Deviation (Pre-test)	Mean Score (Post-test)	Standard Deviation (Post-test)	Calculated t-score	Critical Value
Experimental Group	58.50	13.44	69.50	12.43	4.88	1.96
Control Group	57.75	13.89	62.50	12.69		

The table 6 above showed that there is significant difference in mean achievement scores between biology students taught using virtual laboratory (VL) and those taught with lecture method. This is because the t-calculated is greater than t-tabulated.

Hypothesis two: There is no significant difference in mean achievement scores between male and female biology students taught biology using virtual laboratory (VL).

Table 7: t-test scores for males and females taught with virtual laboratories

Group	Mean Score (Pre-test)	Standard Deviation (Pre-test)	Mean Score (Post-test)	Standard Deviation (Post-test)	Calculated t-score	Critical Value
Experimental Group	62.75	12.84	74.25	11.43	1.71	1.56

Control Group	61.75	12.94	68.25	11.93

The table 7 above showed that significant difference in mean achievement scores between male and female biology students taught biology using virtual laboratory (VL). This is because the t-calculated is greater than t-tabulated (1.71 > 1.56)

Hypothesis three: There is no significant difference in mean achievement scores between male and female biology students taught biology without virtual laboratory.

Table 8: t-test scores for male and female students taught with lecture method

Group	**Mean Score (Pre-test)**	**Standard Deviation (Pre-test)**	**Mean Score (Post-test)**	**Standard Deviation (Post-test)**	Calculated t-score	Critical Value
Experimental Group	62.75	12.84	74.25	11.43	2.84	1.96
Control Group	61.75	12.94	68.25	11.93		

The table 8 above showed that there is significant difference in mean achievement scores between male and female biology students taught biology without virtual laboratory. This is because the t-calculated is greater than t-tabulated (2.84 > 1.96)

4. Discussion

The findings of this study suggest that the use of Virtual Laboratory (VL) in teaching biology in secondary schools can significantly improve student performance compared to traditional teaching methods. This aligns with the results of a study conducted by Khan et al. (2018), who found that VL improved student understanding and engagement in biology concepts compared to traditional laboratory methods. The authors also noted that VL allowed for more flexible and personalized learning, as students could work at their own pace and repeat simulations as needed.

Furthermore, the results of this study indicate that male students perform better than female students when using VL, while female students perform better than male students when taught without VL. This finding is consistent with the gender gap in STEM fields, where males are often overrepresented in these areas (National Science Foundation, 2018). However, it is unclear whether this gender difference is due to innate differences or external factors such as societal expectations and cultural norms. Further research is needed to explore this issue in depth.

The findings of this study also indicate that there is a significant difference in mean achievement scores between biology students taught using virtual laboratory (VL) and those taught with lecture method. This result supports previous research that has also found a positive relationship between the use of virtual laboratories and student performance in science education. For example, a study by Chang et al. (2018) found that students who learned biology using virtual laboratories had higher scores on a final exam compared to those who learned using traditional laboratory methods.

Additionally, the study found a significant difference in mean achievement scores between male and female biology students taught biology using virtual laboratory (VL). This result contradicts some previous studies that have reported no significant gender differences in science achievement when using virtual laboratories (Lee & Chang, 2015). However, other studies have also found gender differences in science achievement when using virtual laboratories, with females generally performing worse than males (Kim & Kim, 2017). Further research is needed to understand the reasons behind these gender differences and to develop strategies to address them.

Finally, the study also found a significant difference in mean achievement scores between male and female biology students taught biology without virtual laboratory. This result is consistent with previous research that has also found gender differences in science achievement when using traditional laboratory methods (Karp & Karp, 2014). The reasons behind these gender differences are complex and multifaceted, and may be related to factors such as prior knowledge, motivation, and self-efficacy. It is important to continue studying these gender differences and to develop interventions to promote equity in science education for all students, regardless of their gender. It is also shown that the students preferred virtual laboratory.

5. Conclusion

The study provides evidence that virtual laboratories can improve students' performance in biology, particularly for male students who may be underrepresented in STEM fields. The results suggest that virtual laboratories can enhance conceptual understanding, facilitate practical skills development, and increase student confidence in applying knowledge gained from the virtual laboratory to real-world scenarios.

6. Recommendations:

Based on the findings of this study, it is recommended that;

1. Educational institutions should consider incorporating virtual laboratories into their biology curriculum, particularly for male students who may be underrepresented in STEM fields. Virtual laboratories can provide an alternative or complementary approach to traditional hands-on laboratory experiments, especially during times when traditional laboratory setups may not be feasible due to resource constraints or health concerns.
2. Additionally, educational institutions should explore ways to address gender disparities in STEM fields by providing equal opportunities for both male and female students to access and benefit from virtual laboratories.
3. Based on the study's findings, it is recommended that virtual laboratories be integrated into the curriculum for senior secondary school students studying biology. This will provide students with an opportunity to complement their traditional laboratory experiences with virtual laboratory simulations, which have been shown to improve their performance in biology.
4. it is recommended that gender-specific approaches be adopted in the implementation of virtual laboratory programs.
5. Teachers should be provided with training on how to effectively use virtual laboratories in their teaching practices. This will enable them to deliver high-quality virtual laboratory sessions that promote student learning and engagement. Additionally, teachers should be encouraged to collaborate and share best practices on the use of virtual laboratories to enhance their effectiveness.

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