Effect of Virtual Laboratory Practical on Students' Attitude towards Chemistry

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Abstract

The study explored the effect of virtual laboratory practical on students' attitude towards chemistry. Three research questions and null hypotheses guided the study. A quasi-experimental research design was adopted for the study. The population comprised 5361 secondary school two (SS 2) students in Jalingo Education Zone. Multistage sampling was used to select 106 students from two intact classes: one of which was assigned to experimental group while the other was the control group. Students Attitude towards Chemistry Scale (SACS) was used for data collection. The SACS was validated by three experts, and the reliability was established to be 0.89 through Cronbach alpha. Mean and standard deviation were used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the null hypotheses at 0.05 level of significance. No significant difference was found in the attitude ratings of students who did practical through virtual and physical laboratory means ($p>0.05$). No significant difference was found in the attitude of male and female students in the virtual laboratory group and there was no significant interaction effect of the practical methods and gender on students' attitude towards chemistry ($p>0.05$). It was concluded that in the absence of or shortage of reagents in physical laboratory, virtual laboratory could complement it. It was recommended among others that virtual laboratory experience be provided in other to scale up students' attitude towards chemistry.

Keywords: Virtual laboratory, Physical laboratory, Attitude, Gender, Chemistry

Introduction

The economic and technological transformations that accompany scientific practices have made nations adopt varying means of popularising science. In Nigeria, science education is the primary means with which scientific literacy is enhanced. Measures have been put in place to this effect across all the three levels of education in Nigeria (primary, secondary and tertiary levels). In addition, Ndagoki (2019) posited that a 60-40 ratio of admission into science and liberal arts disciplines respectively in the university is one of the policies that guide the admission process into tertiary institutions in Nigeria. Vinella (2020) affirmed that this policy is connected with the government’s belief that the world is scientifically and technologically driven and as such, the country needs more scientists in all sectors of the economy. Science at the secondary school level was of concern in this study and particularly, chemistry.

Chemistry is an aspect of science that deals with the study of compositions and properties of matter (Olugbuyi et al., 2023), and is one of the subjects that promote scientific literacy. Sufficient knowledge of chemistry at the secondary school level will help the students understand their environment and chemical processes accompanying natural phenomena and prepare the students for further studies. While students could enjoy learning chemistry, some students' often consider chemistry to be relatively abstract and complex and this consideration has made some students to dislike the subject. The importance of chemistry has made students’ attitude towards it crucial to explore.

Students’ attitude towards chemistry is an important learning outcome that has been constantly emphasized in both research works and classroom activities. Attitude is defined as feelings that can be unfavourable or favourable, positive or negative, and are typically directed towards some specific object (Stiggins as cited in Eggon et al., 2022). Saputra et al. as cited in Mihret et al. (2022) stated that the common tendencies of attitude are the acceptance of an object which represents a positive attitude and the rejection of an object designating a negative attitude towards the object. While conceptualizing students’ attitude, particularly towards chemistry, Kahveci, as cited in Arniezca and Ikhsan (2021), considered students’ attitude towards chemistry to be students’ tendency to respond to chemistry based on the result of their experiences during learning. Attitude of students towards chemistry is not static; it is dynamic and a number of factors could be responsible for the changes. Consequently, they could misconstrue the subject and consider it not learnable; perhaps, way too abstract for their understanding. Alternatively, when their expectations are met through concretized, meaningful, experiential and hands-on chemistry learning, their attitude towards chemistry becomes greatly impacted.

The conventional physical laboratory practical activities which exposes students to hands-on activities in the four walls of a special and secluded building is widely considered to be effective and efficient with respect to students' learning outcomes. This is because a laboratory of this kind enables students to manipulate real tools (Husnaini & Sufen, 2019). Manipulations of tools as well as other forms of scientific activities are inseparable with effective chemistry learning. Olugbuyi et al. (2023) posited that chemistry is a laboratory science and cannot be effectively taught and learned without robust laboratory practical activities. Abdurrahman et al. as cited in Supriyatman et al. (2024) further confirmed that these practical activities have been responsible for the enhancement of students' understanding of science, stimulating analytical and critical thinking, and generating interest in science.

The indispensable role of physical laboratory in concretizing learning and consequently enhancing students' learning outcomes cannot be overemphasized. However, the current reality is that these benefits have not been acquired by secondary school students due to challenges that accompany laboratory practical activities. The inadequate number of physical laboratories, time limitation, shortage of equipment and chemicals were found to be barriers to practical activities (Ndihokubwayo, 2017). These challenges by the teachers, have made them adopt a fire brigade instruction approach to practical activities in chemistry (Omilani et al., 2016). Additionally, some experiments are harmful and could pose health threats to the teacher, students and the environment as well. This calls for the need to explore an alternative which may not necessarily be an outright replacement of physical labs but complement it. Such complementary alternative should be able to solve the problem of recurrent reagents, mobility, provide safer means of conducting practical with harmful substances, and have empirical evidence of its effectiveness on students' learning outcomes. Different alternative approaches to laboratory activities have emerged with the prospects of surmounting these challenges of physical laboratories and providing students with requisite practical experiences. These include alternative to practical, use of pre-recorded practical activities videos and virtual labs; which virtual labs was considered.

Virtual laboratory is a tool that students can use to run their own experiments using mouse to control physical actions such as pushing objects, turning objects, lifting objects, changing tools or materials, heating materials, measuring material and mixing two materials (Ratamun & Osman, 2018). It provides computer-based activities in which students use a computer interface to conduct experimental tasks or other activities (Oser & Fraser as cited in Byukusenge et al., 2023). The use of virtual laboratories is generally accompanied by a number of positives. Asiksoy (2023) outlined that virtual laboratories allow risky experiments to be performed, it has no time no space restrictions, allowing students and instructors to utilize the laboratory environment whenever and wherever they want. Virtual laboratories also allow the visualization of abstract objects that cannot be displayed in real laboratories (Winkelmann as cited in Asiksoy, 2023). This means it could be helpful for carrying out practical activities related to substances at their micro-molecular levels. Apparently, the foregoing alludes that virtual laboratory could solve the problems of physical laboratories and impact students' attitude towards chemistry; especially in Taraba where Adamu and Achufusi-Aka (2020) found that the extent of integration of practical work in the teaching of chemistry by secondary schools teachers is low.

A number of prior studies have been conducted in different locations, different subject areas and utilising different virtual laboratory packages to determine the effect of virtual laboratory. These studies have yielded varying results based on attitude. Waziri and Usman (2023) and Achimugu et al. (2023) observed significance difference, while studies by Agboola and Haruna (2017), and Erdoğan and Bozkurt (2022) showed no significant difference between practical in virtual and physical laboratories. These variations in findings call for more empirical studies to help ascertain the effectiveness of virtual laboratory on students' attitude. In addition, these prior empirical studies were neither conducted in the same subject area, location nor utilised the same Praxilabs package which was used in the current study where these gaps existed. Another factor that could influence students' attitude and has formed part of many research studies in science education is gender (Jack & Shidawa, 2025; Okorie & Ezeh, 2016) which have varying inclusive results. Previous studies (Achimugu et al. 2023; Ajayi & Ogbeba, 2017; Akhibe & Ogufere, 2019; Falode et al., 2020; Hagos, & Andargie, 2022; Manju, 2020; Oyeniran & Oteyola, 2023) on students' attitude based on gender/interactive effects upon treatment with virtual laboratory have resulted into different findings, which showed inconclusive gender gaps.

The purpose of the current study is to investigate the effect of virtual laboratory practical on students' attitude towards chemistry. Specifically, the study determined:

i. The attitude towards chemistry of students exposed to practical through virtual laboratory and physical laboratory.
ii. The attitude towards chemistry of male and female students exposed to virtual laboratory.

iii. The interaction effect of practical methods and gender on students' attitude towards chemistry.

Research Questions/ Hypotheses

The study was guided by the questions, and hypotheses tested at 0.05 significant level as follows:

i. What is the mean attitude towards chemistry rating of students exposed to practical through virtual laboratory and physical laboratory?

ii. What is the mean attitude towards chemistry rating of male and female students exposed to virtual laboratory?

iii. What is the interaction effect of practical methods and gender on students' attitude towards chemistry?

H_{01}: There is no significant difference in the mean attitude towards chemistry rating of students exposed to practical through virtual laboratory and physical laboratory.

H_{02}: There is no significant difference in the mean attitude towards chemistry rating of male and female students exposed to virtual laboratory.

H_{03}: There is no significant difference in the interaction effect of practical methods and gender on students' attitude towards chemistry.

Methodology

The study adopted a quasi-experimental design of pre-test, post-test, non-equivalent group. Intact classes were used in the study. The study was conducted in the first term of the 2024/2025 academic session and the students did practical on acid-base titration. Praxilabs package was used for virtual laboratory experience.

The population comprised all the 5361 secondary school 2 (SS 2) students taking chemistry in all the 44 co-educational public secondary schools in Jalingo Education Zone of Taraba State. The sample size of 106 was obtained through multistage sampling. First purposive sampling was used to select a number of schools from the zone with criteria being the availability and functionality of chemistry laboratory and the possession of functional computers with which students will perform practical activities. Simple random sampling was further used to select two schools and subsequently two intact classes from each of these schools. The two intact classes were randomly assigned to experimental and control groups.

A 25-item Students Attitude towards Chemistry Scale (SACS) was used for data collection. The SACS had 4-point rating scale of Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD). The scales SA, A, D, and SD translated into 4, 3, 2, and 1 respectively for positive items on the instrument but were rated 1, 2, 3 and 4 respectively for negative items on the instrument. The SACS was face and content validated by experts in Science Education and Measurement and Evaluation from Faculty of Education, Taraba State University. A reliability index of 0.89 was obtained for SACS using Cronbach Alpha.

Students in experimental and control groups were both given the instrument as pre-test before the commencement of treatment by the trained Research Assistants who were the chemistry teachers of the sampled schools. Thereafter, students in experimental group were exposed to virtual laboratory practical using Praxilabs package while students in control group were exposed to the physical laboratory practical. Treatment lasted for four weeks and SACS was given to the students to collect post-test data. Mean and standard deviation were used to answer research questions raised while Analysis of Covariance (ANCOVA) was used to test all the hypotheses formulated at 0.05 level of significance.

Results

The results are presented in tables below starting with the research questions and then null hypotheses.

Research Question 1: What is the mean attitude towards chemistry rating of students exposed to practical through virtual laboratory and physical laboratory?

Table 1: Mean and standard deviation of students' mean attitude ratings by practical methods

Practical Methods		**PreSACS**	**PostSACS**	**Mean gain**
Virtual Laboratory	Mean	71.48	81.39	9.91
	N	54	54	
	Std. Deviation	9.36	7.67	
Physical Laboratory	Mean	74.50	81.02	6.52
	N	52	52	
	Std. Deviation	9.70	7.14	

Table 1 shows that at pre-test, students in the virtual laboratory group had a mean attitude rating of 71.48 with standard deviation of 9.36 and at post-test, this means attitude rating rose to 81.39 with standard deviation of 7.67. The students in this group showed a mean gain of 9.91. Students in the physical laboratory group had a mean rating of 74.50 and standard deviation of 9.70 at pre-test but this figure increased to 81.02 and standard deviation of 7.14 at post-test. This change indicates a mean gain of 6.52.

Research Question Two: What is the mean attitude towards chemistry rating of male and female students exposed to virtual laboratory?

Table 2: Mean and standard deviation of the interest rating of students in the virtual laboratory group by gender

Gender		PreSACS	PostSACS	Mean gain
	Mean	72.40	81.84	9.44
Male	N	25	25	
	Std. Deviation	10.11	7.40	
	Mean	70.69	81.00	10.31
Female	N	29	29	
	Std. Deviation	8.78	8.00	

Table 2 depicts that at pre-test, male students exposed to virtual laboratory practical activities had a mean attitude rating of 72.40, standard deviation of 10.11 and at post-test, the mean attitude rating increased to 81.84, standard deviation of 7.40. This indicates mean gain of 9.44. Similarly, at pre-test, female students exposed to virtual laboratory practical activities had a mean attitude rating of 70.69, standard deviation of 8.78 and at post-test, the mean attitude rating increased to 81.00, standard deviation of 8.00. This indicates mean gain of 10.31.

Research Question Three

What is the interaction effect of practical methods and gender on students' attitude towards chemistry?

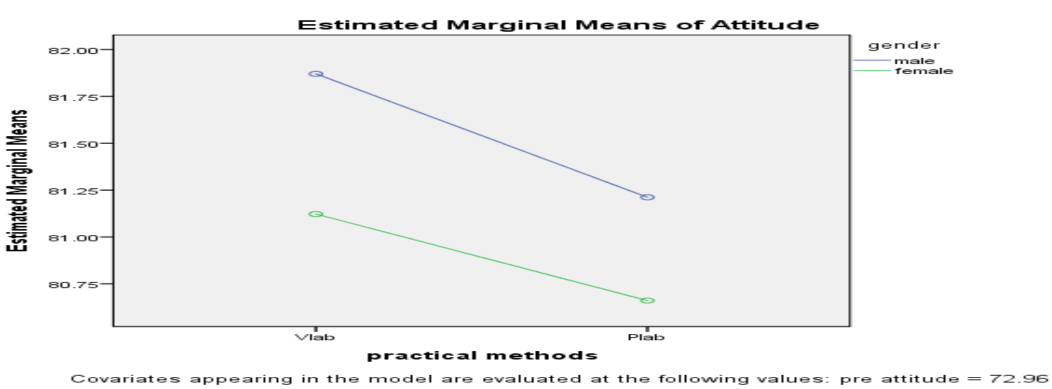

Figure 1: Plot of interaction effect of practical methods and gender on students' attitude to chemistry

Figure 1 shows that in the experimental group (virtual laboratory group), male students had a higher mean attitude rating than their female counterparts. Similarly in the control group (physical laboratory group), the male students also showed a higher mean attitude rating than their female counterparts. From the plots of practical methods and gender on the figure above, the two lines are not parallel. This indicates that there is an interaction effect of methods of practical activities and gender on students' attitude.

Null Hypothesis One: There is no significant difference in the mean attitude towards chemistry rating of students exposed to practical through virtual laboratory and physical laboratory.

Table 3: ANCOVA result of attitude ratings of students in the virtual laboratory and physical laboratory groups
Dependent Variable: Attitude

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	28.875a	2	14.438	.261	.770
Intercept	10453.242	1	10453.242	189.272	.000
PreSACS	25.255	1	25.255	.457	.500
Pract. Method	**7.140**	**1**	**7.140**	**.129**	**.720**
Error	5688.559	103	55.229		
Total	704752.000	106			
Corrected Total	5717.434	105			

Table 3 shows that F (1,103) = 0.129; p = 0.720 > 0.05. This means result of test of significance is higher than the benchmark 0.05; consequently, the null hypothesis is accepted. This implies that there is no significant difference in the attitude rating of students taught chemistry using virtual laboratory and those taught using physical laboratory.

Null Hypothesis Two: There is no significant difference in the mean attitude towards chemistry rating of male and female students exposed to virtual laboratory.

Table 4: ANCOVA result of attitude ratings students in the virtual laboratory group by gender
Dependent variable: PostSACS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	45.491a	2	22.745	.378	.687
Intercept	6817.124	1	6817.124	113.273	.000
PreSACS	36.017	1	36.017	.598	.443

Gender	**13.079**	**1**	**13.079**	**.217**	**.643**
Error	3069.343	51	60.183		
Total	360819.000	54			
Corrected Total	3114.833	53			

Table 4 shows that F (1, 51) = 0.217; p = 0.643 > 0.05. This means result of test of significance is higher than the benchmark 0.05; consequently, the null hypothesis is accepted. This implies that there is no significant difference in the mean attitude rating of male and female students taught chemistry using virtual laboratory.

Null Hypothesis Three: There is no significant difference in the interaction effect of practical methods and gender on students' attitude towards chemistry.

Table 5: ANCOVA result of interaction effect of gender and practical methods on students' attitude

Dependent Variable: Attitude

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Corrected Model	40.287a	4	10.072	.179	.949
Intercept	9977.055	1	9977.055	177.498	.000
PreSACS	26.252	1	26.252	.467	.496
Groups	8.077	1	8.077	.144	.705
Gender	11.042	1	11.042	.196	.659
Pract. method * gender	**.247**	**1**	**.247**	**.004**	**.947**
Error	5677.147	101	56.209		
Total	704752.000	106			
Corrected Total	5717.434	105			

Table 5 shows that interaction of practical methods and gender, F (1,101) = 0.004; p = 0.947 > 0.05. This means result of test of significance is higher than the benchmark 0.05; consequently, the null hypothesis is accepted. This implies that there is no significant interaction effect of methods of practical activities and gender on students' attitude to chemistry.

Discussion

The findings of the study revealed that there is no significant difference in the attitude of students exposed to virtual laboratory practical activities and their counterparts exposed to physical laboratory practical activities. This means that practical activities in chemistry using virtual laboratory can be as effective as the physical laboratory in terms of improving students' attitude to chemistry. Performing chemistry practical activities in a virtual laboratory is a relatively novel practice; especially, in the study area. This novel practice, especially one that involves use of computers, in the classroom could improve students' attitude. The students must have found it exciting; seeing that learning chemistry can be combined with computers to concretize learning experience. This is consistent with Erdoğan and Bozkurt (2022) who found that no significant difference exists between the attitude gain of students upon exposure to virtual laboratory or physical laboratory. It also supports the findings of Agboola and Haruna (2017) who found that the difference in attitude of students who did practical activities virtually and those who did practical in the physical laboratory is not statistically significant. This finding, however, disagrees with Achimugu et al. (2023) who observed that a significant difference exists with respect to students' attitude between virtual laboratory and physical laboratory group in favour of students who did practical in physical laboratory. It is also not consistent with Waziri and Usman (2023) who found that a virtual laboratory practical activities significantly impacts students' attitude in comparison with physical laboratory.

In the virtual laboratory group, it was found that no significant difference exists between male and female students' attitude to chemistry upon treatment. Again, being a relatively novel way for the students to carry out practical activities, they realized that chemistry learning can be concretised and can blend with 21st century digital gadgets. Both male and female students in the virtual laboratory group found it exciting and relatable. This could explain why there was no gender difference among the students' attitude to chemistry. This is consistent with the findings of Falode et al. (2020) who revealed that when exposed to virtual laboratory, no significant difference exists in the attitude of male and female students. It also agreed with Falode and Ogufere (2019) who found that computer simulation, which is likened to virtual laboratory, influences the attitude to chemistry of both male and female students without any significant difference. It further aligns with the findings of Manju (2020) who found that there is no significant difference in the attitude of students who learned through interactive simulation strategy based on gender. It disagrees, however, with Achimugu et al. (2023) who found that students' attitude to chemistry upon receiving treatment with virtual laboratory significantly differ based on gender in favour of male students.

More findings showed there was no significant interaction effect of methods of practical activities and gender on students' attitude to chemistry. This means that the methods of practical activities do not depend on gender before impacting students' attitude. This could be attributed to male and female students' zeal and enthusiasm that accompany them learning without abstraction such as laboratory utilisation. Concrete learning brings about meaningful learning for both male and female students and it enables them to see the relevance and importance of what they learn. This observation is consistent with Akhibe and Ogufere (2019) who found no significant interaction effects of methods and gender on students attitude with one of the methods being computer simulation. The finding is also consistent with Oyeniran and Oteyola (2023) who found that the interaction effect of methods of practical activities and gender on students' attitude is not significant.

Conclusion

The study found that virtual laboratory practical improves students' attitude towards chemistry as much as physical laboratory would since there was no significant difference observed in students' attitude post-treatment. This effectiveness shown by virtual laboratory implies that in the absence of physical laboratory, virtual laboratory could be used as a potent alternative. Similarly, virtual laboratory shows no significant gender difference (since both male and female students had nearly the same improvement of attitude towards chemistry); it also does not interact with students' gender to determine students' attitude towards chemistry.

Recommendations

The following recommendations were proffered:

1. Chemistry teachers in Taraba State should utilize virtual laboratory in the absence of physical laboratory in order to improve students' attitude of students towards chemistry.
2. Virtual laboratories could be used when there is need to eliminate gender dichotomy in chemistry classroom since it does not favour one gender over the other.
3. School administrators and chemistry teachers in Taraba State should work together to provide virtual laboratory experiences for students.

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