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Virtual Laboratory Experimental Method Impact on the Performance of Senior Secondary School Students in Science Subjects in Nigeria

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Abstract

This study's goal is to ascertain how the experimental approach used in the virtual lab affects senior secondary school students' performance in scientific classes. The study adopted a quasi-experimental Pretest post-test research design. The study's overall sample size was one hundred and ten (110) students, divided into sixty (60) students in the experimental groups and fifty (50) students in the control group. The researchers designed the Science Achievement Test (SAT), which was used to collect data. The statistical analysis of the acquired data was carried out using the Statistical Package for Social Sciences (SPSS) version 23. The study's findings indicated that both groups were similar before the experiment commenced and that after the experiment, the experimental group's students did better than those in the control group. Female students in the experimental group also significantly outperformed their male counterparts in the same group. Finally, the findings showed that experimental group students outperformed their counterparts in the control group in terms of their capacity to recollect scientific knowledge. Based on these results, it was suggested, among other things, that the virtual laboratory experimental teaching technique be included in the science practical instruction and learning at the secondary school level.

Keywords: Virtual Laboratory; Experimental Method; Performance; Science.

INTRODUCTION

Everyone is required to attend science classes, which cover the body of information needed to employ experiments and observation to learn about the structure and behaviour of the physical and natural world. Teaching and learning science to students in schools, college students, or the general public is referred to as scientific education. Science education encompasses pedagogical practices from the social sciences, scientific procedures (the scientific method), and other related fields. Biology, chemistry, and physics are the three main categories into which scientific education is traditionally separated. There is a growing body of scientific research in support of teaching on the Nature of Science, and this topic is finding its way into classrooms around the country. All living organisms are dissected and analyzed in biology classes, with a focus on their structure, function, inheritance, and evolutionary history. The study of life encompasses a wide range of sub-disciplines, including those of morphology, physiology, anatomy, behaviour, etymology, and distribution. Chemistry education refers to the branch of science that examines the composition, structure, and characteristics of substances as well as the changes they undergo. Understanding the relationships between matter, energy, and motion is the goal of physics education.

For a growing nation like Nigeria, science education is essential in many ways. For instance, Tunde et al. (2016) argue that self-employment is an option for physics majors. They went on to add that after an initial period of apprenticeship, most physics majors would be qualified to work as independent electronic technicians. Moreover, semiconductor is an important part of modern technology, and knowing how to use them effectively is enough to provide for oneself. In addition, Aina (2012) said that all physics majors should take semiconductor physics since it is so important for a country with a rising economy like Nigeria. He elaborated by saying that those with a background in physics education can find success in the ceramics industry and that knowledge of semiconductors is very useful. As a result, teaching physics, a vital part of scientific education, is a powerful instrument for promoting national development.

According to Aina (2013), scientific and technological progress would be impossible without access to a solid science education. If there were no teachers to provide students with the groundwork they needed, professional areas like engineering, medicine, and architecture would collapse. All of the foregoing emphasizes the importance of a strong science education to a nation's development. Even though science is crucial to a country's development, the annual enrolment and performance of secondary school students in scientific courses on WAEC and other major tests have not been promising throughout the years. The following table displays WAEC enrolment and performance data for the three scientific education disciplines from 2012-2019.

Table1.CandidatesEnrolmentandPerformanceinMay/JuneWestAfricanSeniorSchoolCertificateExaminationsinBiology,PhysicsandChemistry inNigeria2012-2019

	Biology			**Physics**			**Chemistry**		
Year	Totalsat	Creditpass	%	Totalsat	Creditpass	%	Totalsat	Creditpass	%
2012	1,646,150	587,040	35.66	624,658	429,415	68.74	627,302	270,570	43.13
2013	1,648,363	852,717	51.73	637,023	297,988	46.77	639,296	462,517	72.34
2014	365,384	766,971	56.17	635,729	386,270	60.76	636,268	397,649	62.49
2015	1,390,234	798,246	57.42	684,124	410,543	60.01	680,357	412,323	60.60
2016	1,200,367	740,345	61.68	705,125	415,655	58.95	706,873	408,122	57.74
2017	580,449	394,898	68.03	377,851	205,757	54.45	377,970	320,635	84.83
2018	1,087,063	679,299	62.48	728,354	571,687	78.49	728,551	424,231	58.22
2019	1,033,304	775,103	75.01	725,853	565,746	77.94	726,132	566,156	77.96

Source: WestAfricanExaminationsCouncil(WAEC).NationalHeadOffice,Yaba,Lagos.

If drastic action is not taken to address the dire situation immediately, Nigeria's hope of attaining the global Sustainable Development Goals by 2030 would be a fantasy, as stated above (Olojo, 2022; Mulkah & Michael, 2020). The low enrolment and performance of students over the last year have caused researchers to be quite worried. Few studies have been conducted on how students' success in practical and laboratory activities influences their overall performance on final exams, even though many academics have examined the root reasons for this terrible situation and provided solutions.

Students' total result in the WAEC science exams is based on their achievement in the three component units: objective, theoretical, and practical. Accordingly, the practical component of each of the three science disciplines is worth 35% of the overall mark, the multiple-choice portion is for 25%, and the theory section is worth 40%. This means that the sequence in which the theory, practical, and objective components are completed matters for a student's final grade. This implies that the practical exercises, which are normally performed in the laboratory, should not be taken lightly by the students.

The literature has many examples of students not doing well in this important area. For example, in 2017 and 2018, the West African Examination Council (WAEC) Chief Examiner Reports said that students didn't do well in Biology. Most of Nigeria's public high schools don't have the things they need to give their students basic science lab experiments (Adejoh & Ityokyaa, 2019). Akinleye (2011) and Gambari et al. (2013) found that many Nigerian secondary schools seldom if ever administer physical examinations to their students due to a lack of resources.

Preparing the tools and machines for doing experiments and studies in a lab requires a big amount of time and money. It can be hard to grade students' work in science labs, especially with big classes (Tuyuz, 2010). Other things that can stop the regular lab experiments from working well in teaching are not having good teachers who can use the lab method to teach science, and teachers not knowing enough about the subject.

Most research on underperforming schools has focused on factors within these four categories: classroom practices, educator qualifications, students' motivation and engagement, and the availability of appropriate laboratory resources. Thus, it is important to examine how the experimental method of the virtual laboratory influences students' achievement in scientific classes. According to Woodfield (2015), a virtual laboratory is "an online environment in which students can conduct experiments to translate theoretical knowledge into practical knowledge." Without the use of a physical laboratory, it serves as a learning setting for students to hone their laboratory techniques. There, investigations are done in what passes for a laboratory without the use of conventional laboratory apparatus or, indeed, walls and doors. This allows students to create connections between their academic learning and practical application without the need for paper and a pen.

With virtual labs, students can keep having fun or try again if they don't do well. Because these teaching methods involve everyone, it makes learning fun and easy (Ardac & Akaygun, 2014; et al., 2017) In some cases, a virtual lab might be better than a real one or a good learning environment. Students can do experiments and use equipment, collect information, and then come to a conclusion. They can use many resources to make their experiment interesting and write about what they found. Also, it gives students a place to do science experiments that are like a real laboratory.

According to studies (Dalgarno et al. 2014; Yu et al. 2012; Tatli & Ayas, 2013), the usage of virtual laboratories in the classroom significantly improves students' outcomes. Virtual settings allow students to see the process in greater detail than board and chalk activities in a traditional classroom or partially finished experiments in a real laboratory setting. Virtual classrooms also boost students' interest and engagement in their studies by offering a venue for dialogue among partners, classmates, students, and professors (Dobson, 2011).

Students can learn a lot by doing science experiments in class. Onyesolu (2019) believes that students struggle to learn the scientific method because schools do not provide the necessary tools for them to use in the lab. We need a safe and new place for students to do experiments whenever they want. One way to help is by using virtual labs. Halloun (2016) says that using fancy computer programs can help you learn in a hands-on way. It is very important to make students more interested and engaged in learning about science. Using technology to teach simple science helps students learn through hands-on activities and exploring real science experiments. Students can achieve their learning goals by using virtual labs without facing any problems. So, virtual labs are being used in schools and colleges as great tools for learning. They offer different ways for students to learn and can make them more interested and motivated to learn (Onyesolu, 2019).

LITERATURE REVIEW

Due to the many connections that must be made between unfamiliar and abstract ideas, the sciences are notoriously difficult to learn and instruct. This causes many students to resort to rote memorization rather than a genuine understanding of challenging scientific subjects (Kilic & Salam, 2014). Learning difficult subjects like biology, chemistry, and physics may be made much simpler with the help of state-of-the-art technology. Students who actively engage in the education system in Nigeria think that using multimedia technologies and wireless signals in the classroom makes learning more interesting and entertaining (PMID, 2018). It is especially important in the sciences because of the prevalence of visual representations of complicated situations in those fields (Wang, 2017).

The fast growth of technology means we need to make K-12 education better and faster. We can use the student's test scores to see how well they are learning. Good learning leads to good results in school. However, students still have many problems when trying to learn scientific things. Some scientific ideas can only be understood by seeing them directly. Students have a hard time understanding the ideas when they learn directly.

Research has looked at what makes students do well in science class. One thing that researchers have looked at is how the classroom affects students' grades in science. According to Talton and Simpson (2016), six things make up a classroom: how the class feels, what science is being taught, the way the classroom looks, the science teacher, the students, and how the students feel about science. They say that how well students do in science classes can be influenced by different things, like how the teacher feels about the subject and the overall mood in the classroom. Manoussou (2019) studied how Greek students feel about biology and how it might affect their grades in biology. She discovered a connection between the two and decided that students' attitudes toward biology are mostly influenced by the classroom environment. Simpson and Troost (2012) found that students won't remember as much science if they get in trouble a lot in science class. This is because a bad classroom makes it hard for students to learn. So, it is the teacher's job to create a positive environment that helps students learn and grow during lab work.

Teachers are thought to have a big role in how well their students do in biology and other science classes. Students often say that the teacher is the most important part of the classroom for learning. The teacher should show the students how to behave in the lab by talking to them and keeping things organized, so everyone stays interested and the lab runs smoothly (Ozkan, 2013). Many researchers, like Ozkan (2013), Chang and Moa (2012), and Schneider Marx and Soloway (2011), have praised the impact of student and teacher motivation, teaching strategies, hands-on experiments, and the atmosphere in the classroom on students' success in science. The main purpose of this research is to see how virtual science labs affect students' grades, and if gender makes a difference.

Several studies (Davenport & Ronanki, 2018; Miller, et al., 2018; Tatli & Ayas, 2013; Enneking, 2019; Pyatt & Sims, 2012) have looked at whether or not students will gain more from a virtual laboratory experience than from traditional, in-person laboratories. These studies have demonstrated that, across a wide variety of student populations, virtual laboratories are just as effective—if not more so—than traditional laboratories for teaching and learning. Miller et al. (2018) examined the posttest performance of non-science majors who took an introductory physics course and found that the group of students who performed labs in person without the use of a virtual component had higher scores overall. However, when looking at the knowledge gains before and after the lab, both groups performed similarly. Similarly, Amosa, et al. (2018) discovered that when students were taught chemistry practicallyutilizing a virtual laboratory education technique in a group setting, those students in the homogeneous ability group outperformed those taught in the heterogeneous grouping composition. They also found that when women were placed in similar groups, they did better than when students were placed in more varied ones. According to research byAbdullahi, et al. (2020) on the effect of virtual laboratory activities on students' academic achievement in physics practicals, the instructional method has a significant impact on student's performance. However, similar findings were found in research conducted by Pyatt and Sims (2012) with high school chemistry students. He found no significant difference between the virtual and in-person labs on these metrics in one study and an improvement in the virtual lab's mean assessment ratings in another. This shows that virtual labs might be a good substitute for traditional labs when it comes to conceptual learning. Other studies have also found that virtual laboratories are useful in teaching conceptual concepts; they include Tatli and Ayas (2013), Faour and Ayoubi (2018), and Tulay and Ozden (2010).

Objectives of the Study

The study is intended to:

i. Compare the mean performance scores of students who were taught science subjects utilizing an experimental virtual laboratory approach between pre-and post-test.
ii. Examine the variance between the mean performance scores of students who were taught science subjects using traditional and experimental virtual laboratory approaches.
iii. Using an experimental virtual laboratory technique, ascertain the difference between the mean performance scores of male and female science students.

Research Questions

To direct the investigation, the following research questions were posed:

1. Are there appreciable differences between the pre-and post-test mean performance scores of students taught scientific concepts using the virtual laboratory experimental method?

2. Are there any differences between the mean performance ratings of students who learned scientific concepts through traditional and virtual laboratory methods?
3. Does the mean performance score of male and female students who were taught scientific concepts utilizing the virtual laboratory experimental approach differ significantly?
4. Is there a difference between students taught scientific concepts using the virtual laboratory experimental method and those taught the same concepts using the conventional method in terms of their ability to retain information?

METHODOLOGY

A quasi-experimental research design was used in the study to examine the association between the variables. This study used a non-randomized pretest-posttest control group design as its quasi-experimental strategy. The design was chosen because it would be impossible to randomly assign the study's participants without disrupting the educational environment. The purpose of the study was to determine how the Virtual Learning Experiment (VLE) method affected the academic performance of senior secondary pupils. Two sets of students, divided into experimental and control groups, participated in the study while still in their entire classrooms. The instructional tactics used in this study are the independent factors, whereas the Science Achievement Test (SAT), created by the researcher, was used to examine the impact of the independent variables on the dependent variable—students' academic achievement.

Table 2 gives a graphical illustration of the design.

Table 2: The graphical illustration of the design

Grouping	Pre – Test	Research Condition	Posttest	Post – Posttest
Group 1 Experimental	O_1	Virtual Learning Experimental	O_2	O_5
Group 2 Control	O_3	Control	O_4	O_6

One hundred and ten (110) complete students made up the study sample, which included fifty (50) students in the control group and sixty (60) students who were taught scientific concepts utilizing a virtual laboratory experimental approach. Five schools were chosen for the study using a purposeful selection strategy. SSS2, the class chosen for the experiment, was chosen using the same method (i.e., Purposive). To reduce experimental contamination, purposeful sampling was performed (Dania, 2014).

The following criteria were used:

i. Schools with well-equipped and functional laboratories;

ii. Schools with co-educational status;

iii. Schools with at least one professionally educated teacher with at least two years of classroom experience in each of the three core disciplines of science; and

iv. Schools that have been enrolling students for the Senior Secondary School Certificate Examination (SSSCE) in the sciences.

Sixty (60) students were placed in the experimental group and fifty (50) in the control group using a random sampling procedure. There were 65 female and 45 male science students that participated in the study. The Science Achievement Test (SAT), which was designed by the researcher to gather information from the participants, served as the study's instrument. Data for the pre-test and post-test were gathered using the same instrument. The 40-item SAT was an objective test that examined a student's academic knowledge, comprehension, and application of common scientific concepts. The test yielded a total score of 100 points. These ratings were given to 40 distinct items. Each of the items received 2.5 marks.

Validity and Reliability of the Instrument

The SAT had 40 objective test questions with five choices for answers (from A to E). The validity of the instrument was determined using face and content validity techniques. This was accomplished by ensuring the test items were constructed clearly and covered the topics during the trial. The questions were adapted from previous questions from the West African Examination Council (WAEC) and National Examination Council (NECO). It was deemed that the questions were reliable because they were modified versions of standard examination questions.

The study's topics were chosen from the SSS2 curriculum. The material specifically included Osmosis and diffusion, cell division, plant, and animal cells, antigens, dental caries, calculating the gravitational acceleration using a pendulum, and calculating the spring constant using an elastic spring. A good amount of science process abilities that are anticipated of senior high school science students were needed to complete these practicals.

Instructional Package

The researcher made the stuff for teaching that was used in this study. It included science lesson plans and a virtual learning kit with experiments for the SSS2 curriculum. Experts in science education from the Bamidele Olumilua University of Education, Science, and Technology, and experienced high school science teachers found that the lesson plans for traditional teaching were good for the topics chosen. Scientists and computer experts tried out the Virtual Learning Experiment Instructional Package. They found it helpful and suitable for education, so they decided to use it.

Experimental Procedure

The researcher taught with the help of study assistants who were also the teachers in the schools they studied. The research assistants gave a test to both the control and experimental groups after they were trained on how to use the teaching techniques. The group that didn'texperiment got the same instructions as the group that experimented. Before the students were taught using any teaching method, they were given a test at the start. They wanted to find where they could enter.

Both the online lab teaching method and the usual teaching method were used for six weeks.

Right after the treatment, the researcher gave the posttest to both groups. The test to remember things was done again two weeks later using the same test (SAT). The researcher asked the schools for the test results before, after, and later to check.

METHOD OF DATA ANALYSIS

The Statistical Package for Social Sciences (SPSS) version 23 program was used to analyze the data. In terms of mean scores and standard deviation, the results from the pre-test and post-test for the experimental groups were compared. To determine whether there was a significant difference between before and after the deployment of the virtual laboratory experimental method in the science class, a paired sample t-test with a coefficient alpha level of 0.05 was utilized.

RESULTS AND DISCUSSION

Four (4) research questions were posed, and descriptive responses were given. The 0.05 level of significance was used to test the four (4) hypotheses put out for the study, and the appropriate inferential statistic was used to interpret the results. Below are the answers to the research questions and hypotheses.

Descriptive Analysis

Research Question 1: Are there appreciable differences between the pre-and post-test mean performance scores of students taught scientific concepts using the virtual laboratory experimental method?

Table 3: Responses to the difference in the mean performance scores of students taught scientific concepts using virtual laboratory experimental and conventional methods in post-test and posttest

	PRETEST			POSTTEST		
Method	**No (%)**	**Mean**	**SD**	**No (%)**	**Mean**	**SD**
Virtual Laboratory Experimental Method	60 (52.9)	10.31	3.769	60 (52.9)	22.70	3.546
Conventional Method	50 (47.1)	11.06	3.898	50 (47.1)	16.98	5.816

The pre-test mean performance scores of students who were taught scientific concepts utilizing virtual laboratories and conventional techniques were displayed in Table 3 together with their means and standard deviations. The pre-test results demonstrated that the students who were taught utilizing the virtual laboratory experimental method had a mean of 10.31 and a standard deviation of 3.769. Additionally, students taught using traditional methods had a pre-test score with a mean of 11.06 and a standard deviation of 3.898. The mean difference between the two experimental groups was clearly shown to be (0.75), which is quite small. This demonstrated the groups' homogeneity.

The table also included the average and standard deviation of the post-test mean performance scores for students who were taught scientific concepts through both traditional and experimental virtual laboratories. It was demonstrated that the post-test results of students instructed utilizing the experimental virtual laboratory approach have a mean of 22.69 and a standard deviation of 3.546. Similarly, the mean and standard deviation of the post-test results for students who were taught using the conventional technique were each 16.98. This demonstrated that there was a mean difference (5.72) between the two experimental groups. By implication, students who were taught using the virtual laboratory experimental approach performed better than those who were taught using the conventional way.

Research Question 2: Are there any differences between the mean performance ratings of students who learned scientific concepts through traditional and virtual laboratory methods?

Table 4: Responses to the difference in the mean performance score of students taught scientific concepts using Conventional and conventional method

Method	**No (%)**	**Mean**	**SD**
Virtual Laboratory Experimental Method	60 (52.9)	33.00	7.315
Conventional Method	50 (47.1)	31.28	9.618

The mean and standard deviation of the mean performance scores of students who were taught biology using traditional and experimental techniques are shown in Table 4. It was demonstrated that the average score of students taught utilizing the experimental virtual laboratory approach was 33.00, with a standard deviation of 7.315. Additionally, the standard deviation of students taught using the conventional approach is 9.618, with a mean performance score of 31.28. This suggests that students in the conventional group performed on average worse than students in the experimental group did on average. As a result, students who were taught using the virtual laboratory experimental approach performed better than those who were taught using the conventional method.

Research Question 3: Does the mean performance score of male and female students who were taught scientific concepts utilizing the virtual laboratory experimental approach differ significantly?

Table 5: Responses to the difference in the mean performance score of male and female students taught scientific concepts using the virtual laboratory experimental method

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Virtual Laboratory Experimental Method (Pre-test)	Male	45	4.81	1.424	.356
	Female	65	5.50	2.345	.627
Virtual Laboratory Experimental Method (Post-test)	Male	45	11.19	1.759	.440
	Female	65	11.50	1.787	.478

The mean performance score of male and female students who were taught scientific concepts utilizing the virtual laboratory experimental approach was displayed in Table 5. The results showed that, on average, female students scored higher on the pre-test (5.50) than male students (4.81), with a marginally smaller mean difference (0.69). Additionally, female students performed better on average (11.50) than male students did (11.19), with a mean difference of (0.31) between the two groups. This obliquely implies that the performance of male and female students who were taught via the virtual laboratory experimental method was equal, but that the performance of female students was superior.

Research Question 4: Is there a difference between students taught scientific concepts using the virtual laboratory experimental method and those taught the same concepts using the conventional method in terms of their ability to retain information?

Table 6: Responses to the retentive ability of students taught using the virtual laboratory experimental method and those taught using the conventional method

	Group	No (%)	Mean	SD
Post-test	Virtual Laboratory Experimental Method	60 (52.9)	22.67	3.559
	Conventional Method	50 (47.1)	16.80	5.519

Based on Table 6, students who were taught using the experimental virtual laboratory approach had higher mean performance scores (22.67) than those who had been taught using the conventional method (16.80), with a mean difference of 5.87. This suggests that virtual laboratory experimental method students had greater retention abilities than traditional method students.

DISCUSSION OF FINDINGS

The descriptive analysis of the study revealed that, at the pre-test stage, there was no difference between the groups of students taught utilizing virtual laboratory experimental and conventional methods of instruction. It was discovered that during the post-test phase, students who had been taught using the virtual laboratory experimental approach performed better than those who had been taught using the conventional approach. Additionally, the study found that while employing the same virtual laboratory experimental procedure as their male counterparts, female students performed better than their male counterparts. It was concluded that the experimental group of students had better retention in the sciences than the conventional group.

According to the study's inferential analysis, there is a substantial difference between the mean performance scores of science students who are taught using virtual laboratories and those who are taught using traditional techniques. Students in the virtual laboratory experimental group outperformed their counterparts in the conventional group because they received a higher mean score rating than those who received instruction utilizing the typical method. This supported Amosa, et al (2018) research, which found that a virtual laboratory experiment is a useful method to employ when aiming to increase students' mastery of a given subject, foster group project participation and learning, and advance their conceptual growth. Additionally, because students can modify their initial predictions for experiments based on immediate feedback from data manipulations, create more accurate mental models of phenomena, and even use these virtual simulations as a practice to conceptually prepare them for challenging hands-on experiments, virtual learning environments emphasize authentic scientific experiences. Also, it corroborated Pyatt & Sims' (2012) discovery that there was a definite difference in the learning experience between conventional education and the virtual laboratory experimental classroom. Students who were allocated to the virtual laboratory experimental classroom demonstrated greater accomplishment scores in those areas. Comparatively to students receiving traditional instruction, participants in the virtual laboratory experimental classroom expressed a higher positive opinion of their educational experience. Students in the virtual laboratory experimental classroom reported higher levels of intrinsic motivation, increased topic interest, and increased levels of cognitive engagement. However, they also discovered that there was an increase in the mean evaluation scores for the virtual group in a second trial lab even though there was no significant difference in these assessed outcomes between virtual laboratories and in-person labs in one experiment.

The study also showed that the mean performance scores of science students who were taught utilizing the virtual laboratory experimental approach for both genders were significantly different. Since female students' mean performance was greater than male students', it may be concluded that when exposed to a virtual laboratory experimental technique, female students did better than their male counterparts. Contrary to what Opolot-Okurut (2015) showed, males globally had higher mean scores than females for all attitudinal factors (anxiety, confidence, and motivation) males had higher mean scores than females globally on the issue of gender inequality in Science, Technology, and Biology.

CONCLUSION AND RECOMMENDATIONS

Findings shows that students who used the virtual laboratory experimental method fared noticeably better than their colleagues who used the traditional method strategy. The study concludes that there were notable differences in gender performance about the instructional approach used in the experimental group. While there was a significant difference in the capacity of students taught using the virtual laboratory experimental method and those taught using the conventional method, female students outperformed their male counterparts when exposed to the virtual laboratory experimental approach.

Since it encourages students to efficiently learn and remember scientific concepts, the virtual laboratory experimental teaching technique should be introduced into the teaching of science practicals at the secondary school level. For effective lesson delivery in secondary schools, teachers should make sure they organize their lessons with equal learning opportunities for both male and female students. To effectively transfer knowledge when teaching science classes, teachers should make adequate use of classroom resources. To increase student performance in science classes, science teachers should place more emphasis on using the virtual laboratory experimental technique. Seminars for science teachers on the use of the virtual laboratory experimental method should be organized by governments at all levels. To educate teachers and other stakeholders in the education sector about the effectiveness of the virtual laboratory experimental teaching approach to the teaching of scientific concepts, the government at various levels and other professional bodies, such as the Science Teachers Association, should establish resource centers.

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