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EFFECT OF VIRTUAL LABORATORY INSTRUCTIONAL STRATEGY ON ACADEMIC ACHIEVEMENT AND RETENTION OF CHEMISTRY CONCEPT AMONG SENIOR SECONDARY SCHOOL STUDENTS' IN CALABAR SOUTH LOCAL GOVERNMENT AREA, CROSS RIVER STATE NIGERIA

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ABSTRACT

The study examined the effect of virtual laboratory instructional strategy on academic achievement and retention among senior secondary school students in Calabar South, Nigeria. the study adopted quasi-experimental research design with a sample of 200 senior secondary II students selected using multi-staged sampling technique. Three research question and hypotheses guided the study. The instrument used for data collection was a chemistry achievement test (CAT) with a reliability index of 0.89 established with Kuder-Richardson R-20 the data collected was analysed using descriptive and ANCOVA statistics. The result indicated that there was a significant difference in the academic achievement scores of students in the concepts taught using Virtual laboratory and Conventional strategy in favour of those in the experimental group with The post-test - pre-test mean gain score differences of 34.70 and 26.60 respectively,. There was no statistically significant difference between the academic achievement of male and female students in the concepts taught given the instructional strategies used. There was a significant difference in the retention of students in the concepts taught given both strategies. The mean score shows the significance was in favour of students in virtual laboratory group. This is attributed to the strategy being student centred which engages students in activities that excite their cognitive abilities and promote deep learning, making students active participant in the construction of knowledge. It was recommended that chemistry teachers adopt the use of virtual laboratory to enhance chemistry teaching and learning.

KEYWORDS: Virtual laboratory, Academic achievement, Retention, Gender

INTRODUCTION

Science is a field of human endeavor which Seeks to describe accurately the events and circumstances that exists within man natural environment. Science and technology seems to be the factory that produces technologists, craftsmen and skilled artisans who are required to change the economy of any nation. Scientific and technological skills acquisitions are useful tools in coping with the present day challenges. Nelson (2017) opined that, one way of helping students to acquire a balanced view of chemistry is by presenting some "applied" chemistry to them before any "pure" chemistry. This can be done by describing how materials like brick, lime, glass, steel, and soap are made without going into "pure" chemical details. The resulting descriptive chemistry can then be used as a basis for developing chemical theory. Chemistry contributes to a large extent in the development and growth of a nation.

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With a better understanding of chemical principles, it has now become possible to design and synthesize new material having specific magnetic, electric and optical properties. This has lead to the production of superconducting ceramics, conducting polymers, optical fibres, etc. Chemistry has helped in establishing industries which manufacture utility goods, like acids, alkalies, dyes, polymers metals, etc. These industries contribute in a big way to the economy of a nation and generate employment. Chemistry cannot be underestimated. Famuwagun, (2019), defined Practical activities as any type of science teaching and learning activities in which students' working either individually or in small group are involved in manipulating and observing real object and materials. Practical activities help students to develop the scientific skills, enhance the learning of scientific knowledge; give insight to scientific method, stimulates students' interest; increase motivation to study science and develop scientific attitude, such as open-mindedness, objectivity among others.

Alqadri, (2018) investigated that experiment-based learning is a quite effective learning method to study chemistry. Thus chemistry laboratory is extremely needed in the learning process since it is used as a place where students learn and build their knowledge by applying theory, research and scientific development. However, chemistry experiments have some limitations in the real laboratory, such as students using hazardous and relatively expensive tools and chemicals and it takes more time to prepare and conduct experiments. One of the most suitable media to overcome some problems in the real laboratory is using virtual laboratory. The virtual-based experiment, as an advanced technology product, is quite cheap, safe, effective and efficient alternative media.

In addition, practical activities help students to understand complex, and abstracts ideas, it gives students an opportunity to participate in the process and have an appreciation for the process and method of science. Consequently, the cost of carrying out experiment and laboratory activities are laborious and much time consuming, checking students' performance in the course of laboratory activities can be tasking and rigorous especially in a large class. The observation of the researcher as a practicing chemistry teacher had reveal that, separation techniques, Acid-base reactions, titration processes, electrolysis, preparation of gases, redox titration and rate of chemical reaction are among the major practical concepts that are problematic which the students find difficult to learn and most teachers find difficult to teach. Several reports indicated poor performance of students in science, particularly Chemistry. This downward trend in the performance might be due to non-familiarity with the use of simple laboratory equipment and poor practical skills development in practical chemistry which account for 40% of the total mark allocated to SSCE Chemistry Examinations. A chemistry researcher reported that, there is no resources in conventional chemistry laboratory and where there are little at all, they are not usually in good conditions while the few ones that are in good conditions are not enough to go round the student who need them and these had reportedly hindered students' academic achievement and retention in Chemistry.

Musengimana et al., (2021), posed that, hands-on laboratory sessions and experiments have traditionally been the preferred methods of teaching chemistry, as they stimulate creativity, problem-solving skills, and foster observational learning. However, such methods are often hindered by logistical challenges, such as the high cost of equipment, lack of resources, and time constraints for preparation. This challenge was further accentuated during the COVID-19 pandemic when access to physical laboratories became severely limited.

Babincakova and Bernard (2020), also investigated that, the COVID-19 lockout situation affected people all over the world. Despite all of the disadvantages, this situation offered new experiences and perspectives and pushed education advances forward as never before. Something that seemed to be unreal became a worldwide reality within a few days. Instructors of all subjects' at all educational levels moved to a virtual environment instantly. Higher education institutions, universities, and colleges seemed to be fairly prepared for this situation. Unfortunately, primary and secondary schools, especially in eastern and central Europe, never considered distance education as a valuable alternative before, so they did not have software, hardware, and staff prepared for such a situation. Moreover, students' expectations and dilemmas concerning e-learning were not investigated earlier in the context of obligatory subject education. Moving to the virtual environment was particularly challenging for teachers, who wanted to transfer real class experiences into online lessons since chemistry is based on problems, observations, evidence, and experiments. Often, teachers claimed that they could be more efficient if they had knowledge, skills, and proper equipment to run classes online.

The Integration of technology in education has witnessed a transformative shift, and one notable facet of this evolution is the incorporation of virtual laboratories into the instructional landscape.

Cetin-Dindar et al., (2018) posed that, the advent of technology has profoundly impacted the field of chemistry education. Furthermore, Ali & Ullah, (2020), opined that, from enhancing experimental accuracy to facilitating comprehensive understanding of complex concepts, technology's integration into education has been pivotal. However, the optimal utilization of technology in education demands a defined set of professional standards to ensure efficacy and facilitate proper understanding among students.

Zhu & Liu, (2020) positioned that, the integration of technology into education has been underscored as an essential strategy by organizations such as UNESCO, as part of its sustainable development goals (SDG). Özdemir, (2019), defined virtual experiment as computer software for learning / teaching that enable learners to make scientific inquiries with a virtual experiment setup prepared with virtual laboratory materials. Thanks to the developments in information technologies, it is possible to conduct experiments in virtual laboratories that can achieve results with realistic accuracy in a virtual environment with prepared simulation software. The simulation software used in virtual laboratories is a teaching method in which the student can change the parameters of the experiment and perform the experiments exactly. Davenport et al., (2018) opined that using virtual labs can be an effective teaching method. The effectiveness of a tool in teaching students desired learning outcomes is an important piece of knowledge for any teacher. Virtual labs have been studied as an alternative to or addition to in-person labs to determine if students will learn from the virtual lab experience.

In the context of secondary school education, where the foundation of scientific knowledge is laid, understanding the impact of virtual laboratory instructional strategies on students' academic achievement and knowledge retention in chemistry becomes paramount. Traditional laboratory experiences in secondary schools, while valuable, often face challenges such as limited resources, safety concerns, and logistical constraints. Virtual laboratories offer a compelling alternative, providing students with simulated experiments that aim to replicate the practical aspects of chemistry within a digital environment. The effectiveness of these virtual strategies in enhancing academic performance and fostering knowledge retention is an area of increasing scholarly interest. The findings of Akpan et al., (2024), Alhashem et al., (2023), Yesgat et al., (2023), Peechapol (2021), Anekwe et al., (2021), Oladejo et a.,l (2021), Lin et al.,(2021), Ross et al.,(2020), AlHassan (2019) and Algadri (2018) all indicated a statistical significant impact of the use of virtual laboratory in enhancing learning outcome, promoting students interest and motivation in science.

Retention can therefore be referred to the act or process of retaining, maintaining, or keeping something. It is the ability to store ideas or information. It is also the ability to remember and continue to use ideas or information when needed is vital to learners achieving progressive success in life. In education, student retention focuses on keeping students enrolled and engaged in their studies. Educational institutions often implement support systems, mentoring programs, and academic resources to enhance student success and reduce dropout rates. Such is a virtual laboratory. The effect of inability to retain and recall what was learnt in science lesson is evident in achievement of students and it is a concern in education. Olarewaju (as cited in Ugwu, et al., 2020) defined retention as the ability to store and recall information or knowledge acquired when demanded. It is the process and ability to store and recall experiences learnt in future. The research results of Woldermariam et al., (2023), Nwafor et al., (2023), Yesgat et al., (2023), Mcconkey (2022), Anekwe etal., (2021), Lin et al., (2021) and Latifah et al., (2019) showed a significant effectiveness of virtual laboratory in improving the retention of learned concept.

According to Srairi, (2018) they found that there is a significant relationship between student low academic achievement and dropout with the gender. Males are more prone to drop out than females. As per this study, the findings revealed that gender has a strong relationship with student dropout. Gender here is simply a distinction of sex. Gender is the most important factor to consider when evaluating a student's achievement because it has a significant impact on students' achievement because male and female learners have different learning rates and behaviors. In recent years, debates about the impact of gender on academic achievement have dominated research. In fact, the majority of female students have more positive behavior than male students Srairi, (2018),opined that in comparison to men, women are clearly capable of completing their tasks efficiently within the time allotted, this is in consonance with the research findings of Akpan et al.,(2024), Yesgat et al.,(2023), Woldermariam et al.,(2023), Oladejo et al.,(2021) who observed a no significant influence of gender on learning outcomes and the retention of learned concept, indicating that both boys and girls are at parity in terms of academic achievement and retention when males and females are given equal opportunities and exposed to gender biased free instructional strategy in science such as the one the use of virtual laboratory provided.

This study seeks to contribute to the ongoing discourse by investigating the Effect of virtual laboratory instructional strategies on the academic achievement and retention of among secondary school students in chemistry. By exploring how these strategies align with established educational objectives and impact students' grasp of fundamental chemical concepts, the research aims to provide nuanced insights that can inform pedagogical practices and curriculum development. Base on the foregoing, the researcher seeks to determine the effect of Virtual laboratory instructional strategy on academic achievement and retention among Secondary School Students in Chemistry.

Research Questions

Answers to the following questions and hypotheses were sought by the researcher:

i. What is the difference in the mean achievement scores of students taught chemistry using virtual laboratory strategy compared to those taught using conventional strategy?
ii. Is there any significant difference in the mean achievement scores of male and female students taught chemistry using virtual laboratory strategy and those taught without virtual laboratory?
iii. Is there any significant difference in the mean retention scores of students taught chemistry using virtual laboratory strategy and those taught without virtual laboratory?

Statement of the Hypothesis

i. There is no significant difference in the mean achievement scores of students taught chemistry using virtual laboratory strategy and those taught with the conventional strategy.
ii. There is no significant difference in the mean achievement scores of male and female students taught chemistry using virtual laboratory strategy and those taught without virtual laboratory.
iii. There is no significant difference in the mean retention scores of students taught chemistry using virtual laboratory strategy and those taught without virtual laboratory.

METHODOLOGY

The research design adopted for this study is the quasi-experimental research design. This design allows for comparison between groups. The sample size drawn from the population for the study consisted of two hundred (200) SSII student, Males and females inclusive selected through multi-staged sampling technique from four (4) secondary Schools in Calabar South Local Government Area.

The instrument used for data collection was Chemistry Achievement Test (CAT) of 25 multiple choice questions. The CAT was used for pre-test, post-test and retention measurement, the post-test and retention test were reshuffled versions of the CAT arranged differently in serial numbering and response option. The instrument was validated and the reliability established using Kuder Richardson reliability estimate and an index of 0.89 obtained. The students were group into control and experimental groups, students in the experimental group were taught using the virtual laboratory while the students in the control group were taught with the conventional strategy, pre-test was administered as baseline for the study before treatment was administered. The data generated from the pre-test, post-test and retention were analysed using descriptive statistics and Analysis of Covariance (ANCOVA) at 0.05 level of significance.

RESULTS

Research Question 1:

Table 1, shows the pre-test and post-test mean scores and standard deviation of scores of students taught using virtual laboratory, and conventional strategy. The post-test - pre-test mean score differences of 34.70 and 26.60 respectively, show those that taught using virtual laboratory had a better mean gain score. The post-test standard deviation scores of 3.30 and 4.61 for students in virtual laboratory and conventional groups indicate however that the scattering of raw scores about the group means was widest in conventional group but closest in the virtual laboratory group.

Table 1: **Mean (□) and standard deviation of students' pre-test and post-test scores classified by treatment groups**

Treatment Groups	N	Pre-test		Post-test		Mean Gain Score
		□	sd	□	sd	
Control	100	5.92	2.76	32.52	4.61	26.60
Experimental	100	6.89	2.26	41.59	3.30	34.70

Source: Author's Field Data, 2024

Expectedly the two groups had post-test mean scores that were higher than their pre-test mean scores. Whether the observed difference in the mean scores of the two groups was statistically significant was determined by the results for testing of hypothesis one displayed in Table 2.

Hypothesis One:

Table 2: Summary of Analysis of Covariance (ANCOVA) of the students' post-test scores classified by treatment groups with pre-test scores as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	4206.347[a]	3	1402.116	88.706	.000	S
Intercept	33480.037	1	33480.037	2118.136	.000	S
Pretest	3.691	1	3.691	.234	.629	NS
Treatment	187.413	1	187.413	11.857	.001	S
Error	3098.048	196	15.806	-	-	-
Total	281919.000	200	-	-	-	-
Corrected Total	7304.395	199	-	-	-	-

a. R Squared = .576 (Adjusted R Squared = .569); b. Computed using alpha = .05

Source: Author's Field Data, 2024

In Table 2, the calculated F-ratio for the effect of instructional strategies at (df 1, 196) is 11.85, while its corresponding calculated level of significance is .001 alpha. This level of significance is lower than .05 in which the decision is based; indicating that there was a significant difference in the academic achievement mean scores of students in the concepts taught using virtual laboratory and Conventional strategy. With this observation, null hypothesis 1 was rejected.

Research Question 2:

Table 3: Mean and standard deviation of students' pre-test and post-test scores classified by gender

Descriptive Statistics

Dependent Variable: POSTTEST

GENDER	Mean	Std. Deviation	N
MALE	36.28	5.938	90
FEMALE	37.69	6.109	110
Total	37.05	6.059	200

Source: Author's Field Data, 2024

Table 4. shows the pre-test and post-test mean scores; and standard deviation of scores of the male and female students taught using virtual laboratory and Conventional strategy. The mean scores for male and female students in both groups are 36.28 and 37.69 respectively. This observation shows the female performed slightly better than their male counterparts in this group.

Hypothesis Two:

Table 4 Summary of Analysis of Covariance (ANCOVA) of male and female students' post-test scores classified by treatment groups and gender with pre-test scores as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	295.640[a]	3	98.547	2.756	.044	S
Intercept	30958.205	1	30958.205	865.747	.000	S
Pretest	173.031	1	173.031	4.839	.029	S
Gender	2.648	1	2.648	.074	.786	Ns
Treatment * Gender	.48	1	.48	.03	.867	Ns
Error	7008.755	196	35.759	-	-	-
Total	281919.000	200	-	-	-	-
Corrected Total	7304.395	199	-	-	-	-

a. R Squared = .040 (Adjusted R Squared = .026); b. Computed using alpha = .05

Source: Author's Field Data, 2024

In Table 4, the calculated F-ratio for the main effect of gender on the student's achievement at (df 1,196) is .074, while its corresponding calculated level of significance is .786 alpha. This level of significance is greater than .05 in which the decision is based; indicating that there was no statistically significant difference between the academic achievement of male and female students in the concepts taught given the instructional strategies used. With this observation, null hypothesis 2 was upheld. The implication is that both gender's achievement were comparable.

Research Question 3

Table 5 shows the post-test and retention mean score and the standard deviation of scores of the students taught using, virtual laboratory and Conventional strategy. The retention - post-test mean scores' differences of -1.70 and 3.83, respectively, for those in virtual laboratory and Conventional groups show those taught using virtual laboratory retained the concepts better than those taught using Conventional strategy as they had a lower memory decay.

Table 5: Mean and standard deviation of students' post-test and retention scores classified by treatment groups

Treatment Groups	N	Post-test		Retention		Mean Score difference
		□	sd	□	sd	
Control	100	32.52	4.61	36.35	4.49	3.83
Experimental	100	41.59	3.30	39.89	3.19	-1.70

Source: Author's Field Data (2024)

The negative sign indicates memory decay. The retention standard deviation scores of 3.19 and 4.49 for students in virtual laboratory and Conventional groups, respectively, indicate that the scattering of raw scores about the group means, was closest in virtual laboratory group.

Hypothesis Three:

In Table 6, the calculated F-ratio for the effect of instructional strategies on the retention of the students at (df 1, 196) is 125.578, while its corresponding calculated level of significance is .000 alpha. This level of significance is less than to.05 in which the decision is based; indicating that there was a significant difference in the retention of students in the concepts taught using virtual laboratory and Conventional strategy. With this observation, null hypothesis 3 was rejected. The mean scores in Table 6 shows the significance was in favour of students in virtual laboratory group.

Table 6: Summary of Analysis of Covariance (ANCOVA) of students' retention scores classified by treatment groups with post-test scores as covariate

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision at p<.05 alpha
Corrected Model	3007.269[a]	2	1503.634	468.806	.000	S
Intercept	85.893	1	85.893	26.780	.000	S
Posttest	2380.689	1	2380.689	742.256	.000	S
Treatment	402.775	1	402.775	125.578	.000	S
Error	631.851	197	3.207	-	-	-
Total	294266.000	200	-	-	-	-
Corrected Total	3639.120	199	-	-	-	-

a. R Squared = .826 (Adjusted R Squared = .825)

b. Computed using alpha = .05

Source: Author's Field Data (2024)

DISCUSSION OF FINDINGS

The findings with regard to the effects of virtual laboratory and Conventional strategy on students' achievement in chemistry showed that there was statistically significant difference in the academic achievement of the students taught chemistry using virtual laboratory and conventional instructional strategies in favour of those in virtual laboratory group. This is attributed to the strategy being student centred which engages students in activities that excite their cognitive abilities and promote deep learning, making students active participant in the construction of knowledge while the teacher takes the role of a facilitator of instruction. This agrees with the findings of Akpan and Umanah (2024), Alhashem and Alfailakawi (2023) and Yesgat et al., (2023). peeclapol (2021), Anekwe and Oparah (2021), Oladejo et al., (2021), Lin and Wu (2021) and Ross et al., (2020), also reported the enhancing effect of virtual laboratory in their studies compared to conventional method.

On the influence of gender on students' achievements, it was observed that there was no statistically significant difference between the academic achievement of male and female students in the concepts taught given the instructional strategies used. This observation indicates that gender is not a strong determinant of students' academic achievements. The no significant influence of gender observed in this study corroborates with those of Akpan and Umanah(2024), Yesgat et al., (2023), Oladejo et al.,(2021)who also reported no significant influence of gender on the mean achievement scores of students when taught with both instructional strategies. This observation indicates that gender is not a significant determinant of students' academic outcome and that male and female have reached parity in their achievement in chemistry and science.

On the effects of the instructional strategies on students' retention the findings showed there was a significant difference in the retention of students in the concepts taught using virtual laboratory and the conventional strategy. This finding agrees with Woldermariam et al., (2023), Nwafor et al., (2023), yesgat et al., (2023), Mcconkey (2022), A comparative analysis conducted by some of the researchers above, sheds light on the viability of virtual labs as alternatives or complements to traditional physical labs. The study suggests that virtual labs, despite lacking tangible experiences, offer comparable academic achievements and retention rates. Accessibility and cost-effectiveness emerge as key advantages, indicating the potential of virtual instructional strategies in enhancing chemistry education. Collectively, these literature reviews underscore the promising role of virtual laboratory instructional strategies in positively influencing both academic achievement and retention among secondary school students in the field of chemistry.

CONCLUSION

Based on the findings of the study, it is hereby concluded that Virtual laboratory is effective in facilitating students' achievement and retention in chemistry. Also, that gender has no statistically significant influence on students' achievement in chemistry. Thus, it is conceivable to draw the conclusion that chemistry instruction that incorporates technology enhances student achievement and retention, but its effect is gender neutral.

Recommendation

Chemistry teachers are encouraged to use virtual laboratory in teaching difficult concept in chemistry especially where laboratory wares and chemicals are not available or inadequate

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