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Effect of Virtual Chemistry Laboratory on Senior Secondary School Chemistry Students' Academic Achievement in Enugu Education Zone of Enugu State

[1]Cynthia Onyinye, [2]Joy Johnbest Egbo & [3]Agujiobi Ujunwa P.

[1,2&3]Department of Science Education, Enugu State University of Science and Technology (ESUT), Enugu.

Email: [1]omejeonyinyechukwu@yahoo.com; [2]joybest66@gmail.com & [3]ujayagujiobi@gmail.com

ABSTRACT

This study investigated the effect of virtual chemistry laboratory on senior secondary school students' academic achievement in Enugu Education Zone of Enugu State. Two research questions guided the study and three null hypotheses were formulated and tested at .05 level of significance. The researcher adopted a quasi experimental research design for this study. This study was conducted in Enugu Education zone. The population for the study comprised all public co-education senior secondary school two (SS II) students in Enugu Education Zone, academic session. They were four thousand, four hundred and twelve (4,412) SS II chemistry students. Purposive random sampling technique was used to draw a sample size of 334 SS II students. However, the number of chemistry students in the experimental group was 203, while there were 131 chemistry students in the control group drawn from 4 schools out of twenty-three co-education secondary schools in Enugu Education zone. Chemistry Practical Achievement Test (CPAT), used as Pre-Test (PRECPAT). The instrument was developed by the researcher and validated by experts. The reliability coefficient of the instrument obtained using spearman-brown prophecy formula was 0.81. The pretest was administered to subjects in both groups to measure their knowledge in separation techniques. The control group was taught separation techniques for four weeks using only the class demonstration method while the experimental group was also taught separation techniques for four weeks with virtual laboratory demonstration method. POSTCPAT was administered to all the subjects at the end of the fourth week. Two weeks after the administration of POSTCPAT, the PPCPAT was administered to both groups. The results revealed that the students who were taught using virtual chemistry laboratory method achieved better than those who were taught using demonstration method. It was also discovered that gender has no effect on the achievement of those exposed to treatment. Based on the findings of the study, it was recommended among others that the use of virtual chemistry laboratory should be encouraged since most chemical concepts are abstract in nature.

Keywords: Virtual Chemistry Laboratory, Academic Achievement

INTRODUCTION

The role of technology in the education field in numerous developing nations, such as Nigeria, is of utmost importance. According to Falode (2014), the technological revolution has introduced fresh advancements into classroom instruction and has significantly impacted how educators strategize, create curricula, and evaluate students. As indicated by Asare, Annan, and Ngman-Wara (2022), the integration of Information and Communication Technology (ICT) within science education has witnessed substantial growth in recent times, proving highly effective in diverse contexts. Okechukwu and Ukeh (2022) posited that ICT has brought about transformative changes in the teaching and learning process across the education sector. Notably, Chemistry has played a pivotal role in the evolution of contemporary technology by applying its principles to modern innovations (Asiyai, 2016).

Chemistry, as outlined by Okafor and Uzoechi (2012), is a field within the realm of science focused on the makeup and transformations of substances. This branch of science holds significance for various disciplines like medicine, biochemistry, microbiology, pharmacy, and engineering, among others. It is a vital component of the curriculum in Nigerian secondary schools, and it's also a prerequisite for entrance into scientific fields like Medicine, Engineering, Pharmacy, and Agriculture across educational institutions (Azare, 2017). Successfully passing chemistry at a satisfactory level is a requisite for gaining admission into higher education programs in science-related fields. The study of chemistry encompasses both theoretical and practical aspects.

The practical aspect of studying chemistry is pivotal in facilitating effective and engaging science education. In the context of the Senior School Certificate Examinations (SSCE), practical chemistry is evaluated independently and holds a substantial weight in terms of scoring (Chief Examiner's Report, 2014). However, challenges arise in secondary schools when it comes to conducting practical chemistry experiments. Shortages or inadequacies of equipment, chemicals, and qualified staff often hinder the proper execution of practical sessions. Financial constraints and the high expenses associated with maintaining fully equipped chemistry laboratories, as opposed to virtual alternatives, contribute to this issue. The equipment used is often delicate, expensive, and necessitates frequent replenishment of potentially hazardous consumables (Okafor and Uzoechi, 2012).

Numerous studies have highlighted the alarming rate of failures among secondary school chemistry students during both internal and external assessments. These failures are attributed to ineffective teaching methods, as well as insufficient consumables and non-consumables during practical exercises (WAEC Chief Examiners Reports, 2019; Okafor and Uzoechi, 2012). Furthermore, Okafor's (2016) research underscores the influential role of teaching methodology in determining students' performance in chemistry practical sessions.

Methods of teaching are the methods and principles adopted by teachers to ensure students' learning outcome (Daluba, 2013). The current mode of learning in Nigerian education has been found to be mostly based on conventional chalk-and-talk approaches. According to Aladejana in Bamidele and Yoade (2017), teaching still follows the old conservative model with teachers serving as repositories of information and students as latent receivers. Nworgu and Okereke (2011) stated that conventional method subjects the learner to passive role. However, Hofstein and Kind (2012), the method of teaching that allows students to become acquainted with the facts through direct experiences is called the laboratory method.

A laboratory refers to experiences in school settings where students interact with devices and materials or secondary data sources to observe and understand nature (Hofstein and Kind, 2012). Chemistry laboratories are more expensive to implement in secondary schools because they require a lot of and more expensive reagents than other science subjects like physics and biology. The poor performance in chemistry is mainly attributed to poor performance in actual practical paper and alternative practical paper (Asiyai, 2016). Insufficient or lack of practical experiments is a major challenge for chemistry due to insufficient or lack of laboratories, apparatus, expertise or reagents in the country. Other factors identified include inadequate and poor utilization of laboratory resources, poor foundation of science, and digital illiteracy (Okafor and

Uzoechi, 2012). In schools, laboratory experiments can be carried out virtually, using computer simulations or animations (Okafor, 20017; Gambari, Olumorin and Yusuf, 2013).

A virtual laboratory is a computer-based activity where students interact with an experimental apparatus or other activity via a computer interface. Virtual laboratory is perceived by Falode (2014), Chaurura and Chuma (2015), as an interactive environment without real laboratory apparatuses meant for creating and conducting simulated experiments. Similarly, Virtual laboratory is viewed by Ratamun and Osman (2018), as a computer-assisted teaching through the integration of computer simulations with laboratory activities. Virtual laboratories according to Lkhagva, Ulambayar and Enkhtsetseg (2015), provide simulated versions of traditional laboratories referring to a learner-centered approach in which the learner is provided with objects that are virtual representations of real objects used in traditional laboratories. There are two main types of virtual laboratories; the on-line and off-line virtual laboratory. The off-line according to Martin, Ľuboš and Miroslav (2011) does not require the use of internet connection for its application; it is on disk or CDs, it can be installed on a personal computer for its application in the school and outside the school. The online virtual laboratories are publicly accessible by users from home or any other place with internet connection.

Furthermore, virtual laboratories may contribute to teaching and learning processes by giving students the opportunity to learn by doing, providing them with intriguing and enjoyable activities urging them to discover, and guaranteeing an active classroom interaction by means of discussions and debates. A well-designed virtual laboratory can provide students with meaningful virtual experiences and present important concepts, principles, and processes (Tatli and Ayas, 2013; Kapici et al., 2019, 2020; Tugtekin and Dursun, 2022) particularly for the STEM subjects. Comparing to hands-on laboratories, virtual laboratory experiences provide flexibility of self-learning with greater accessibility in safe environment by saving time and costs (Alkhaldi et al., 2016; Faulconer and Gruss, 2018; Ali and Ullah, 2020). By means of virtual laboratories, students have the opportunity of repeating any incorrect experiments as well as to deepen the intended experiences. Some researchers even argue that performing experiments within a virtual environment is more effective than performing experiments in real laboratories (McCoyKozma, Chin, Russell, and Marx in Tatli and Ayas, 2013; Browne, 2014). The urgent need for virtual chemistry laboratory was borne out of the closure of schools during the outbreak of covid-19.

However, the outbreak of covid-19 pandemic has no doubt affected every sphere of human endeavours from social, economic, educational and sporting activities around the globe. The consequences of this impact is mostly felt in education as many students were out of class for several months except those schools with high tech facilities who were able to engage their learners through an e-learning or virtual classes (Kuhfeld, Soland, Tarasawa, Johnson, Ruzek and Liu, 2020). Based on the advantages of virtual chemistry laboratory, the researcher found it necessary to determine its effect on students' achievement in chemistry in senior secondary schools in Enugu Education zone.

Academic achievement refers to an individual's degree of accomplishment in school subjects. Academic achievement, according to Ademola (2013), is an indicator of a student's progress in

completing particular activities in a subject or field of study after a learning experience. Achievement is an important academic factor that is influenced by teaching strategies. Achievement is the process of getting something done effectively and successfully using effort and skills aimed at accomplishment of academic goals. Falode (2016) defined achievement as measurable changes in students' behavior in academic as a result of exposure to a given concept. A study by Mohammed, Chado and Dalhatu (2021), showed that virtual laboratory package impacted positively on students' academic achievement in chemistry practical than the traditional methods. Kelly and Jones (2008), study showed that virtual laboratory improved students' performance in high school biology. Okafor, Okunuga and Ojo (2020), revealed that virtual laboratory improved students' achievement in secondary school chemistry. One related factor that is confronting the use of virtual chemistry laboratory is its ability to have the same impact on both male and female chemistry students. There are controversial reports on studies about gender in chemistry.

Gender issues have been linked with achievement of students in academic tasks in several studies but without any definite conclusion. Some studies revealed that male students performed better than the female in science courses. For instance, Voyer (2014), found that male students performed better than female in interactive physics, while Gambari, Folade and Adegbenro (2014), found that girls performed better than boys using science process skills method of teaching. However, Adeyemi (2008), Jescheke, Richter and Zorn (2010), investigated the use of virtual laboratory in science and mathematics and found their correlation with gender and internet awareness with males positively favoured. Base on the foregoing, the researcher determined the effect of virtual chemistry laboratory on senior secondary school students' academic achievement in Enugu Education zone of Enugu State.

Statement of the Problem

The poor achievement in Chemistry practical by students in secondary schools as observed by the researchers has been ascribed to inappropriate teaching method. The demonstration practical approach has been the most widely practiced among the chemistry teachers in Nigeria, especially in Enugu Education Zone of Enugu State. Not much effort has been made to effect a fundamental change to ensure effective learning among chemistry students. The reports of 2018, 2019 and 2020 indicated declining students' achievement in practical chemistry. The results revealed that chemistry students' achievement in chemistry practical were highly declining. The abstract nature of content delivered to students in their secondary schools affected most students.

It is observed in this study that researchers have made a lot of efforts to find out the causes of students' poor academic achievement in Chemistry, especially, in practical chemistry but much has not been done on the use of virtual chemistry laboratory particularly, in Enugu Education zone. Studies on the effect of virtual chemistry laboratory on students' achievement in chemistry are very scanty and scarce to the researchers' best knowledge. Research findings about gender influence on students' academic in chemistry have also been inconclusive. Therefore, there is need to conduct a study to determine the effect of virtual chemistry laboratory on students' academic achievement in practical chemistry in secondary schools in Enugu Education zone.

Purpose of the Study

The purpose of this study was to investigate the effect of virtual chemistry laboratory on

senior secondary school students' academic achievement in Enugu Education zone of Enugu State. Specifically, the study investigated the:

1. effect of virtual chemistry laboratory on SS II Chemistry students' academic achievement when taught separation techniques and those taught the same topic using conventional chemistry laboratory;
2. influence of gender (male and female) on Chemistry students' academic achievement when taught separation techniques using virtual chemistry laboratory.

Research Questions

The following research questions guided the study:

1. What are the mean achievement scores and standard deviations of SS II Chemistry students taught separation techniques with virtual Chemistry laboratory and those taught the same topic using demonstration method?
2. What are the mean achievement scores and standard deviations of male and female SS 11 Chemistry students taught separation techniques with virtual chemistry laboratory?

Hypotheses

The following hypotheses guided the study and they were tested at 0.05 level of significance:

Ho_1: There is no significant difference between the mean achievement scores and standard deviations of SS 11 Chemistry students taught separation techniques using virtual chemistry laboratory and those taught the same topic using demonstration method in both pre-test and post-test.

Ho_2: There is no significant difference between the mean achievement scores and standard deviations of male and female SS 11 Chemistry students taught separation techniques with virtual chemistry laboratory.

Ho_3: There is no significant interaction effect of gender and methods on students' academic achievement in separation techniques.

Research Method

The researcher adopted a quasi experimental research design for this study. Quasi experimental research design is described by Dodo in Uba (2014) as the design where the treatment variable is manipulated but the groups not equated prior to manipulation of independent variable. It is type of experimental research method used to estimate the causal impact of an intervention on target population without random assignment, using a pretest, posttest, control design. This research design sought to establish the cause-effect relationship between the independent and dependent variables. This study was conducted in Enugu Education zone. The population for the study comprised all public co-education senior secondary school two (SS II) students in Enugu Education zone. They were four thousand, four hundred and twelve (4,412) SS II chemistry student. The sample for the study comprised three hundred and thirty four (334) SS II chemistry students. Purposive sampling random technique was used to draw the sample size of 334 SS II students. However, the number of chemistry students in the experimental group was 203, while there were 131 chemistry students in the control group drawn from 4 schools out of twenty-three co-education secondary schools in Enugu Education zone. Chemistry Practical Achievement Test (CPAT), used as Pre-Test (PRECPAT), Post-Test (POSTCPAT) and Post-Post-Test (PPCPAT), developed by the researchers. The instrument was face validated by three experts; two experts from Chemistry Education and one for Measurement and Evaluation, all from Faculty of Education, Enugu State University of Science and Technology Enugu (ESUT), Agbani.

The reliability coefficient of the instrument obtained using Spearman-Brown formula was 0.81. The pretest was administered to subjects in both groups to measure their knowledge in separation techniques. The control group was taught separation techniques for four weeks using only the class demonstration method while the experimental group was also taught separation techniques for four weeks with virtual laboratory method. POSTCPAT was administered to all the subjects at the end of the fourth week. Two weeks after the administration of POSTCPAT, the PPCPAT was administered to both groups. Mean scores and standard deviation were used to analyse data and provide answers to the research questions. Mean was used because it is the most reliable measure of central tendency while standard deviation is the most reliable estimate of variability. The hypotheses formulated for the study were tested at 0.05 level of significance, using Analysis of Covariance (ANCOVA).

Data Analysis and Results Presentation

Research Question 1: What are the mean achievement scores and standard deviations of SS II Chemistry students taught separation techniques with virtual Chemistry laboratory and those taught the same topic using demonstration method?

Table 1: Mean achievement scores and standard deviations of students taught separation techniques using virtual chemistry laboratory and those taught using demonstration method

Groups	Number	Pre-test		Post-test	
		Mean ($\bar{x}$)	Standard Deviation (s)	Mean ($\bar{x}$)	Standard Deviation (s)
Experimental	203	26.24	4.88	38.37	5.91
Control	131	25.92	4.68	34.84	5.61

Data on Table 1 showed that at pre-test, the achievement mean score for experimental group was 26.24 with a corresponding standard deviation of 4.88. After post-test, it was observed that for the experimental group, mean achievement score was 38.37. For the control group, at pre-test, the achievement mean score was 25.92 with a corresponding standard deviation of 4.68. After post-test, it was observed that for the control group, mean achievement score was 34.84. However, the standard deviation scores of the students in the Post test for the experimental group was 5.91 while for the control group it was 5.61, indicating that the students individual scores were more clustered around the mean with demonstration method than with the virtual chemistry laboratory. This implies that students in the experimental group achieved higher than those in the control group considering their higher mean achievement scores at posttest.

Research Question 2: What are the mean achievement scores and standard deviations of male and female SS 11 Chemistry students taught separation techniques with virtual chemistry laboratory?

Table 2: Mean achievement scores and standard deviations of male and female students taught separation techniques using virtual chemistry laboratory

Groups	n	Pre-test		Post-test	
		$(\bar{x})$	(s)	$(\bar{x})$	(s)
Experimental (Male)	96	26.09	4.97	38.25	5.31
Experimental (Female)	107	26.45	4.77	39.55	6.02

Data on Table 2 revealed that at pre-test, the mean achievement score for male students was 26.09 with a corresponding standard deviation of 4.97. The female students mean score at pre-test was 26.45 and a standard deviation of 4.77 respectively. After post-test, it was observed that the male students' mean achievement score was 38.25 with a standard deviation of 5.31 respectively. For the female students at post-test, their mean achievement score was 39.55 with a corresponding standard deviation of 6.02 respectively. Similarly, the standard deviations for the male and female students after post-test are 5.31 and 6.02, indicating that the individual scores of the male students are more clustered around the mean than those of their female counterparts that had more extreme scores. This implied that the female students in the experimental group achieved higher than their male counterparts considering their higher mean achievement score at post-test.

Hypotheses

Ho_1: There is no significant difference between the mean achievement scores and standard deviations of SS 11 Chemistry students taught separation techniques using virtual chemistry laboratory and those taught the same topic using demonstration method in both pre-test and post-test.

Table 3: Analysis of Covariance on the mean achievement scores of Chemistry students taught separation techniques using virtual chemistry laboratory and those taught using demonstration

Tests of Between-Subjects Effects

Dependent Variable: ACHIEVEMENT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	999.798[a]	1	999.798	30.249	.000
Intercept	428659.574	1	428659.574	12969.019	.000
GROUP	999.798	1	999.798	30.249	.000
Error	10576.826	332	33.053		
Total	446421.000	334			
Corrected Total	11576.624	333			

a. R Squared = .086 (Adjusted R Squared = .084)

Table 3 showed that the calculated F-value for the effect of treatment (method) on students' achievement in Chemistry is 30.249 significant at .000 level of significance, which is less than 0.05 set for the study. The null hypothesis is therefore rejected. This means that a significant difference exists in the mean achievement scores of chemistry students taught with virtual chemistry laboratory and those taught with demonstration method.

Ho_2: There is no significant difference between the mean achievement scores and standard deviations of male and female SS 11 Chemistry students taught separation techniques with virtual chemistry laboratory.

Table 4: Analysis of Covariance on the mean achievement scores of male and female Chemistry students taught separation techniques using virtual chemistry laboratory

Tests of Between-Subjects Effects

Dependent Variable: ACHIEVEMENT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.824[a]	1	3.824	.121	.728
Intercept	249899.962	1	249899.962	7914.497	.000
GENDER	3.824	1	3.824	.121	.728
Error	5430.894	201	31.575		
Total	261655.000	203			
Corrected Total	5434.718	202			

a. R Squared = .001 (Adjusted R Squared = -.005)

Table 4 showed that the calculated F-value for the effect of treatment (method) on gender in AAT is .121 significant at .728 level of significance, which is more than 0.05 set for the study. The null hypothesis is therefore rejected. This means that a significant difference exists in the mean achievement scores of chemistry male and female students taught with virtual chemistry laboratory in favour of female students.

Ho_3: There is no significant interaction effect of gender and methods on students' academic achievement in separation techniques.

Table 5: Analysis of Covariance on the interaction effect of gender and method (virtual chemistry laboratory) on Chemistry students' achievement in separation techniques

Tests of Between-Subjects Effects					
Dependent Variable: ACHIEVEMENT					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.824[a]	1	3.824	.121	.728
Intercept	249899.962	1	249899.962	7914.497	.000
GENDER * GROUP	3.824	1	3.824	.121	.728
Error	5430.894	201	31.575		
Total	261655.000	203			
Corrected Total	5434.718	202			
a. R Squared = .001 (Adjusted R Squared = -.005)					

Table 5 showed that the calculated F-value with respect to the effect of interaction of gender and teaching method on students' mean achievement scores in the Chemistry Practical test is .121 at .728 level of significance. This is greater than the 0.05 level set for the study. Consequently the null hypothesis is not rejected, indicating that there is interaction effect of gender and instructional methods on students mean scores in the Chemistry practical achievement test.

Discussion of Findings

The findings of this study showed that there was significant effect of Virtual Chemistry Laboratory over the demonstration method on secondary school chemistry students' achievement during separation techniques experiment in which the female students did better than the males on both the treatment and control groups respectively. The findings of this study is in accordance with Brinson (2015), who posited that virtual laboratory provides students with opportunities of enriching their learning experiences; conducting experiments as if they were in real laboratories; and improving their experiment related skills such as manipulating materials and equipment, collecting data, balancing of chemical equations, completing experiment process in an interactive way (with boundless supplies), and preparing experiment reports. The finding also supports Okafor (2012) who posited that teaching with ICT tools contributes meaningful to learning outcomes among secondary school chemistry students. The study was equally found not to be in consonance with Okafor (2016) who explained that chemistry students' achievement is influenced by their perceived learning styles.

The study also revealed that there is significant difference in the achievement of male and female students taught separation techniques using virtual chemistry laboratory in favour of female students. The finding agrees with Nworgu in Giginna (2013) and Egbughara in Giginna (2013) who posited that female students perform better than their male counterparts in science. Similarly, the result of Ratamun and Osman (2018) contradicted the finding of this study, the analysis showed that the interaction effect between group and gender in Virtual Chemistry Laboratory towards chemistry is not significant.

Conclusion

This study focused on the effect of virtual chemistry laboratory on senior secondary

school students' academic achievement in Enugu Education Zone of Enugu State. Based on the findings, this study concludes that the group of chemistry students that was exposed to separation techniques using virtual chemistry laboratory had higher academic achievement than those that were exposed to demonstration method. It is important to state that the demonstration method has been well-established in many Nigerian secondary schools at all level. This method has not yielded positive results, considering the challenges teachers envisage in chemistry emanating from non-availability of basic reagents required during chemistry during practical. The study also concludes that the mean difference of the female group is higher than the male group on both the treatment and control groups respectively.

Recommendations

Based on the findings, the following recommendations were proffered:

1. The use of virtual chemistry laboratory should be encouraged by the Chemistry educators since most chemical concepts are abstract in nature.
2. Examination bodies like West Africa Examination Council (WAEC) and National Examinations Council (NECO) should introduce virtual chemistry laboratory in all their internal and external examinations.
3. Chemistry teachers should be trained professionally on how to conduct quantitative and qualitative experiments meaningfully with ease using Virtual Chemistry Laboratory.
4. Educational agencies and other stakeholders should organize workshops and seminars for Chemistry teachers on the use of virtual laboratory package to enhance better performance of secondary school students.

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