Faculty of Natural and Applied Sciences Journal of Mathematics and Science Education
Print ISSN: 2814-0885 e-ISSN: 2814-0931
www.fnasjournals.com
Volume 4; Issue 2; October 2023; Page No. 102-109.

VIRTUAL LABORATORY AND GUIDED INQUIRY ON STUDENTS' PERFORMANCE IN REDOX REACTION IN RIVERS STATE

Ndukwe, U.E., & Obafemi, D.T.A.
[1]Department of Curriculum Studies and Educational Technology, University of Port Harcourt, Nigeria
[2]Department of Science Education, University of Port Harcourt, Rivers State, Nigeria.

Corresponding authors email: deborah.obafemi@uniport.edu.ng

Abstract
The study investigated the effect of the virtual laboratory and guided inquiry teaching strategies on students' performance in redox reactions in senior secondary schools in Obio/Akpor Local Government Area, Rivers State. The study adopted a quasi-experimental pre-test, post-test, and non-equivalent group design. Three research questions and three null hypotheses guided the study. A sample size of Eighty-five (85) SS2 students in their intact classes in three public senior secondary schools in Obio-Akpor Local Government Area were involved. A purposive sampling technique was used to select two public schools and one intact class from each school. A researcher-developed and validated instrument for data collection was the Chemistry Performance Test on Redox Reaction, with reliability coefficients of 0.88 obtained using the Kuder Richardson-21 (KR-21) formula. The mean and standard deviation were used to answer the questions, while the analysis of covariance (ANCOVA) was used to test the hypotheses at a 0.05 level of significance. The results obtained showed that guided inquiry enhanced the performance of students better than a virtual laboratory. There was a statistically significant difference between the effects of guided inquiry and virtual laboratories in favour of guided discovery. Furthermore, though the male students performed better than the female students, the difference in their performance was not significant. There is also no significant interaction between strategy and gender on students' performance. The study recommended that chemistry teachers should be encouraged to use guided inquiry and virtual laboratory teaching strategies in teaching chemistry.

Keywords: Virtual Laboratory, Guided Inquiry, Performance, Redox Reaction, Gender.

Introduction

In this era of the global world, education has assumed a prominent role. It has become a very important factor in the advancement of society. Consequently, the need for education is increasing by the day. Chemistry is a natural science that deals with the study of matter, its properties, structure, composition, changes experienced by it, and behaviour in general. In chemistry, the quality of matter, how it changes as well and why it changes are investigated. A redox reaction is a chemical reaction which involves alteration in the oxidation states of atoms. In this reaction, a shifting or transfer of electrons takes place among different chemical species, one species gains the electrons while the other loses the electrons (Olson, 2021). Redox reactions consist of two parts that always occur together. These are the reduced half and the oxidized half. Redox reactions are therefore made up of two forms of half reactions, which are Reduction-half and oxidation-half reactions (MindTouch, 2021). A redox reaction is determined by a variation in the oxidation state of two atoms. For it to occur, there must be an alteration in the oxidation number. The species that gain the electron is said to be reduced while the species that lost the electron is said to be oxidized. Redox reaction has defined all aspects of life as the form of reaction that occurs in multifarious biological processes. Laboratory activities are very crucial and essential components of the teaching and learning of scientific concepts. Afriani, et. al. (2019) noted that Laboratory activity is significant in learning science. When engaged in laboratory activities, students are enabled to acquire various scientific and problem-solving skills as well as a deeper understanding of scientific concepts. Scientific research in the form of experiments helps to demystify abstract and perceived difficult scientific concepts such as the Redox reaction as these concepts are brought into reality. Little wonder Tang et. al. (2021) submitted that in science teaching and learning, laboratory activities are indispensable.

Cite this article as:
Ndukwe, U. E., & Obafemi, D.T.A. (2023). Virtual laboratory and guided inquiry on students' performance in redox reaction in Rivers State. *FNAS Journal of Mathematics and Science Education, 4*(2), 102-109.

A teaching method is a set of deliberately and systematically arranged information that is exchanged between a teacher and the learner with a view of causing a permanent change in the behaviour of the learner (Agbarakwe & Offor, 2019). This behaviour change is known as learning. Learning is an activity where there is an interaction between the teacher, learners and the content to be taught leading to a change in the behaviour of learners towards the content being taught. This can only be realized when the learning environment and conditions are learner-centered in which the learners can use various methods, strategies and media to interact with the content being taught. Consequently, learned cane to construct knowledge under the supervision of the teacher. The teacher thus becomes the facilitator of learning.

Guided discovery is a strategy in which learners are guided by the teacher to discover knowledge through hands-on engagement in conducting experiments, manipulation and interaction with materials, specimens, etc., obtaining data, analyzing data and making conclusions. In this era of rapid technological change, Ningandih and Said (2017), viewed inquiry as a way of broadening knowledge for understanding and learning new skills. Jack (2013) submitted that a Guided inquiry strategy can enable learners to understand concepts, solve problems and develop individual responsibility. Anna et al. (2020) also reported that the guided inquiry model develops aspects of students' basic abilities and psychomotor.

Virtual laboratory is one of the emerging technological-based interventions in science education. It remedies situations in which physical reality is not obtainable such as when conducting experiments that require materials that are expensive, volatile or not available. It brings to reality scientific concepts that are abstract and difficult or teach or learn such as Redox reaction.

Oxidation-reduction reaction (also known as Redox Reaction) is a common chemical process. The mastery of the topic is fundamental to the study of Chemistry. Oxidation – Reduction reaction cuts across all topics in Chemistry and science subjects as a whole. Due to its utmost importance in our everyday life, there is a need for a proper understanding of this aspect of chemistry concept. Despite the importance of Redox Reaction in our everyday life, according to the WAEC Chief examiner's report for 2017 - 2019, Redox Reaction is one of the concepts in which students exhibited weakness. Some of the areas of weakness are a lack of knowledge of chemical concepts, inability to write simple half equations, the inability to recognize Redox reactions, the wrong use of symbols to represent ions, poor knowledge of mole concept and arithmetic errors. Students often find it difficult to distinguish between the redox process and other physical and chemical reactions in Chemistry. The non-concrete nature of this topic, which involves the gaining and the losing of electrons as a result of the increase and decrease in the oxidation state of the elements, has made it difficult for students to comprehend. The mathematical inclination in redox reactions, which is based on the knowledge of the oxidation number to identify the oxidizing and reducing agents, is a hard nut to crack, as is the balancing of redox equations. What strategy can help the students overcome this weakness? This study was therefore poised to investigate the effect of the virtual laboratory teaching strategy and guided inquiry teaching strategy on the students' performance in chemistry.

Aim and objectives of the study

The study aimed to investigate the effect of the virtual laboratory teaching strategy and guided inquiry teaching strategy on the student's performance in chemistry.

Specifically, the objectives of the study were to:

1) investigate the effect of teaching strategies (virtual laboratory and guided inquiry teaching strategies) on students' performance in redox reactions.

2) determine the difference in the performance of male and female students in redox reactions.

3) determine the joint effect of teaching strategies and gender on students' performance in Redox Reaction

Research Questions

The following research questions guided the study based on the stated objectives:

1) What is the difference in the performance of students taught Redox Reaction using VLTS and those taught using GITS?

2) What is the difference in the performance of male and female students in redox reactions?

Cite this article as:

Ndukwe, U. E., & Obafemi, D.T.A**.** (2023). Virtual laboratory and guided inquiry on students' performance in redox reaction in Rivers State. *FNAS Journal of Mathematics and Science Education, 4*(2), 102-109.

3) What is the joint effect of teaching strategies and gender on students' performance in redox reaction?

Hypotheses

The following null hypotheses were tested at a 0.05 level of significance:

Ho_1: There is no significant difference between the performance of students taught using VLTS and those taught using GITS in redox reactions.

Ho_2: There is no significant difference between male and female students concerning their performance in redox reactions.

Ho_3: There is no significant joint effect of teaching strategies and gender on students' performance in redox reactions.

Materials and Methods

The study investigated the effect of the virtual laboratory teaching strategy and guided inquiry teaching strategy on students' performance in redox reactions in senior secondary schools in Obio/Akpor Local Government Area, Rivers State. The study adopted a quasi-experimental pre-test post-test, and non-equivalent group design. Three research questions and three null hypotheses guided the study. The population for the study consists of 5,024 male and 6,896 female students, for a total population of 11,920 SS2 Science students. A sample size of Eighty-five (85) SS2 students in their intact classes in two public senior secondary schools in Obio/Akpor Local Government Area were involved. A purposive sampling technique was used to select three public schools and one intact class from each school. The following criteria were adopted in selecting the three schools:

a. They have qualified chemistry teachers.
b. They are mixed schools.
c. They have a qualified number of chemistry students.
d. A well-equipped computer laboratory and an artificial supply of electricity.
e. A sizeable classroom and a conducive learning environment.
f. Access to instructional materials for the teaching and learning of chemistry.

The research instrument used for data collection was a researcher-developed and validated instrument named Chemistry Performance Test on Redox Reaction (CPTRR), with reliability coefficients of 0.88 obtained using the Kuder Richardson-21 (KR-21) formula. The CPTRR was used to test the performance of students in Redox Reaction, it is a 30 multiple-item choice objective test question drawn from the topic redox reaction. Each test item in the instrument had four response options namely A, B, C, and D with only one option as the key while others were distracters. The items on CPTRR were from the content that was taught on redox reaction. The instrument was introduced with an instruction and the students ticked the correct answer. Each correct item was scored one mark and the incorrect answer will attract a zero score. The CPTRR had a total score of 30 marks.

The intact class in the first school was assigned the experimental group while the intact class in the second school was assigned the control group. The instrument CPTRR was administered in both groups as a pre-test to access the students' knowledge of redox reactions before being taught. Thereafter, the experimental group was taught the redox reaction using Virtual Lab Teaching Strategy (VLTS), while the control group was taught the redox reaction using the Guided Inquiry Teaching Strategy (GITS). The instrument CPTRR was then administered as a post-test to assess the student's performance after being taught. The mean and standard deviation were used to answer the questions, while the analysis of covariance (ANCOVA) was used to test the hypotheses at a 0.05 level of significance. Fisher's least significant difference test was used to carry out the post hoc analysis.

Cite this article as:
Ndukwe, U. E., & Obafemi, D.T.A**.** (2023). Virtual laboratory and guided inquiry on students' performance in redox reaction in Rivers State. *FNAS Journal of Mathematics and Science Education, 4*(2), 102-109.

Results

Research Question 1: What is the difference in the performance of students taught redox reactions using VLTS and those taught using GITS?

Table 1: Mean and standard deviation of students' performance classified by Strategies

Strategy		Pretest Mean	Posttest Mean	Mean Gain
Virtual Lab Teaching Strategy	Mean	6.7609	10.8696	4.109
	N	46	46	46
	Std. Deviation	3.394	4.097	3.957
Guided Inquiry Teaching	Mean	7.795	14.077	6.282
Strategy	N	39	39	39
	Std. Deviation	2.648	4.042	4.501

Table 1 shows a mean performance gain of 4.109 for students taught Redox Reaction using VLTS and a mean performance gain of 6.282 for students taught Redox Reaction with GITS. This indicates that students taught Redox Reaction using GITS had a higher mean performance gain. In other words, GITS enhanced students' performance more than VLTS.

Research Question 2: What is the difference in the performance of male and female students in Redox Reaction?

Table 2: Mean and standard deviation of male and female students' performance

Gender		Pretest Mean	Posttest Mean	Mean Gain
Male	Mean	7.364	12.849	5.485
	N	33	33	33
	Std. Deviation	3.595	4.169	4.055
Female	Mean	7.154	12.019	4.519
	N	52	52	52
	Std. Deviation	2.775	4.479	4.408

Table 2 shows that the mean performance gain of male students taught Redox Reaction is 5.485 while the mean performance gain of female students taught Redox Reaction is 4.519. This indicates that the male students taught Redox Reaction had a higher performance mean. In other words, the male students gained more than the female students.

Research Question 3: What is the joint effect of teaching strategies and gender on students' performance in Redox Reaction?

Table 3: Mean and standard deviation of students' performance classified by strategies and gender.

Strategy	Gender		Pretest Mean	Posttest Mean	Mean Gain
Virtual Lab Teaching	Male	Mean	7.250	11.813	4.563
Strategy		N	16	16	16
		Std. Deviation	4.583	4.461	4.457
	Female	Mean	6.500	10.367	3.867
		N	30	30	30
		Std. Deviation	2.609	3.873	3.721
Guided Inquiry Teaching	Male	Mean	7.470	13.824	6.353
Strategy		N	17	17	17
		Std. Deviation	2.478	3.746	3.552
	Female	Mean	8.046	14.273	5.409
		N	22	22	22
		Std. Deviation	2.803	4.334	5.161

Cite this article as:
Ndukwe, U. E., & Obafemi, D.T.A**.** (2023). Virtual laboratory and guided inquiry on students' performance in redox reaction in Rivers State. *FNAS Journal of Mathematics and Science Education, 4*(2), 102-109.

Table 3 revealed that the male students taught Redox Reaction using GITS gained the most, having a mean gain of 6.353, followed by their female counterparts with a mean gain of 5.409 while female students taught using VITL gained the least with a mean gain of 3.867.

Hypothesis 1: There is no significant difference between the performance of students taught using VLTS and those taught using GITS in Redox Reaction.

Table 4: Summary of Analysis of Covariance of students' performance classified by strategy using pretest as a covariate.

Tests of Between-Subjects Effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	520.817[a]	2	260.409	19.914	0.000
Intercept	795.708	1	795.708	60.849	0.000
Pretest	303.698	1	303.698	23.224	0.000
Strategy	134.885	1	134.885	10.315	0.002
Error	1072.289	82	13.077		
Total	14539.000	85			
Corrected Total	1593.106	84			

a. R Squared = 0.327 (Adjusted R Squared = 0.311)

Table 4 shows $F_{(1, 82)} = 10.315$, $p = 0.002$ ($p < 0.05$) for strategy. The null hypothesis is therefore rejected. This implies that there is a significant difference between the performance of students taught Redox Reaction using VLTS and those taught using GITS.

Table 5: Post Hoc Analysis

Pairwise Comparisons

Dependent Variable: Posttest

(I) Strategy	(J) Strategy	Mean Difference (I-J)	Std. Error	Sig[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Virtual Lab Teaching Strategy	Guided Inquiry Teaching Strategy	-2.564*	0.798	0.002	-4.152	-0.976
Guided Inquiry Teaching Strategy	Virtual Lab Teaching Strategy	2.564*	0.798	0.002	0.976	4.152

Based on estimated marginal means

*. The mean difference is significant at the 0.05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The Post Hoc analysis in Table 5 shows that a mean difference of 2.564 between GITS and VLTS. This indicates that GITS brought in a significant difference between the teaching strategies in their effects on students' performance.

Hypothesis 2: There is no significant difference between male and female students concerning their performance in Redox Reaction.

Table 6: Summary of Analysis of covariance of students' performance classified by gender using pretest as a covariate.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	395.394[a]	2	197.697	13.535	0.000
Intercept	712.416	1	712.416	48.775	0.000
Pretest	381.511	1	381.511	26.120	0.000
Gender	9.461	1	9.461	0.648	0.423
Error	1197.712	82	14.606		
Total	14539.000	85			
Corrected Total	1593.106	84			

a. R Squared = 0.248 (Adjusted R Squared = 0.230)

Table 6 shows $F_{(1,82)} = 0.648$, $p = 0.423$ ($p > 0.05$) for gender. The null hypothesis is therefore retained. This indicates that there is no significant difference between the performance of male and female students in Redox Reaction.

Hypothesis 3: There is no significant joint effect of teaching strategies and gender on students' performance in Redox Reaction.

Table 7: Summary of 2x2 Analysis of covariance of students' performance classified by teaching strategy and gender using pretest as a covariate.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	530.990[a]	4	132.747	9.999	0.000
Intercept	803.717	1	803.717	60.537	0.000
Pretest	290.122	1	290.122	21.852	0.000
Strategy	114.616	1	114.616	8.633	0.004
Gender	3.953	1	3.953	0.298	0.587
Strategy * Gender	5.815	1	5.815	0.438	0.510
Error	1062.116	80	13.276		
Total	14539.000	85			
Corrected Total	1593.106	84			

a. R Squared = 0.333 (Adjusted R Squared = 0.300)

Table 7 shows $F_{(1,80)} = 0.438$, $p = 0.510$ ($p > 0.05$) for the interaction of gender and teaching strategy on performance. The null hypothesis is thereby retained, indicating that there is no significant joint effect of teaching strategies and gender on students' performance in Redox Reaction.

Discussion

In the findings of this study, the guided inquiry teaching strategy was more effective in enhancing the performance of students, followed by the virtual laboratory teaching strategy. The two teaching strategies enhanced the performance of students but guided inquiry had a higher effect on their performance. This implies that exposing students to the two teaching strategies employed in this can improve the performance of students, but the extent of the improvement differs concerning teaching strategies. The study also revealed that there was a significant difference in the student's performance in Redox Reaction with respect to strategies. The post hoc analysis further pointed out that the guided inquiry teaching strategy had a higher effect on the teaching strategies employed in this study. This could be attributed to the fact that guided inquiry enabled collaboration and teamwork which enables the students to digest information among themselves. Guided inquiry also enables

Cite this article as:
Ndukwe, U. E., & Obafemi, D.T.A**.** (2023). Virtual laboratory and guided inquiry on students' performance in redox reaction in Rivers State. *FNAS Journal of Mathematics and Science Education, 4*(2), 102-109.

feedback when the students are guided to the right source of information. The findings of this study are in line with the findings of Anna et al. (2020) which revealed that the guided inquiry model develops aspects of students' basic abilities and psychomotor.

The study further revealed that the male students had a better performance than their female counterparts in Redox Reaction. However, the difference between the performance of male and female students was not statistically significant. This could be because the male students were able to hold a grip on the subject matter more than their female counterparts. Male students tend towards science more than the female, this could lead to their better performance than their female counterparts. The findings of this study are in agreement with the findings of Abbey-Kalio (2019) as well as Adigun et. al. (2015) who both reported that male students performed better than female students.

The findings of this study also reveal that the male students taught Redox Reaction with GITS gained the most, followed by their female counterparts while the female students taught using VITL gained the least. The interaction of strategy and gender was however not significant in students' performance in redox reaction. This finding is in agreement with the finding of Obafemi and Rowland (2022) who discovered no significant joint effect of strategy and gender on students' performance.

Conclusion

This study has revealed the effectiveness of guided inquiry in enhancing the performance of students in Redox Reaction. This is evident in the higher mean gain obtained by the students taught Redox reaction using guided inquiry than the students taught using the virtual laboratory teaching strategy. Guided Inquiry Learning Strategy needs to be utilized in the teaching and learning of scientific concepts. This will make the students benefit greatly as it allows for reflection of ideas in order the build knowledge, comprehension and interpretation of concepts in Chemistry and science at large.

Recommendations

Based on the findings of the study, the following recommendations were made:

1) Chemistry teachers should adopt the Guided Inquiry Learning Strategy in teaching abstract concepts such as Redox reaction.
2) Training and retraining of science teachers by government agencies in the use of guided inquiry teaching strategy and virtual laboratory software by experts in virtual simulation and animation.
3) Policymakers, school administrators and curriculum planners should consider guided inquiry teaching strategy and virtual laboratory teaching strategy in the planning, designing and reviewing senior secondary school chemistry curriculum, especially in the sub-topics like Redox reaction which is economical and saves students from endangering themselves with hazardous chemicals.

References

Abbey-Kalio, I. (2019). The effect of guided-inquiry approach on senior secondary school students' academic achievement in practical chemistry. *Direct Research Journal of Social Science and Educational Studies, 6*(9), 138-142.

Adigun, J., Onihunwa, J., Irunokhai, E., Sada, Y. & Adesina, O. (2015). Effect of gender on students' academic performance in computer studies in secondary schools. *Journal of Education and Practice, (*6)33, 1-7. www.iiste.org

Afriani, T., Agustin, R. R. & Eliyawati, E. (2019). The effect of guided inquiry laboratory activity with video embedded on students' understanding and motivation in learning light and optics. *Journal of Science Learning, 2*(3), 79-84. https://doi: 10.17509/jsl.v2i3.15144

Agbarakwe, H. A., & Offor, E. C. (2019). Survey of teaching methods used in senior secondary schools for the teaching and learning of computer science. *Port Harcourt Journal of Educational Studies (PHAJOES), 4*(1), 115-125.

Anna, J., Albinus, S. & Retno, D. S. (2020). The effect of guided inquiry model on improving students' learning outcomes and science process skills in qualitative analytical chemistry practicum. *Universal Journal of Educational Research, 8*(11), 5457 - 5462. https://doi:10.13189/ujer.2020.081149.

Jack, G. U. (2013). The influence of identified student and school variables on students' process skills acquisition. *Journal of Education and Practice, 4*, 16-22.

MindTouch, P. B. (2021). Oxidation-Reduction Reactions. https://chem.libretexts.org/Bookshelves/Analytical_Chemistry/Supplemental_Modules_(Analytical_Chemistry)/Electrochemistry/Redox_Chemistry/Oxidation-Reduction_Reactions

Ningsih, P., & Said, I. (2017) Application of guided inquiry learning model with mind map toward students' learning outcomes in chemistry material: reaction rate. *Advances in Social Science, Education and Humanities Research*, *174*, 1-5. https://doi:10.2991/ice-17.2018.126

Obafemi, D. T. A., & Rowland, M. I. (2022). Interaction of instructional strategy in ethnoscience setting and gender on students' performance in Basic science in Abua/Odual Local Government Area, Rivers State, Nigeria. *Niger Delta Journal of Education*, *14*(1), 270-279.

Olson, M. V. (2021). Oxidation-reduction reaction. *https://www.britannica.com/science/oxidation-reduction-reaction/General-theory*

Tang, W., Lin, Y., & Ou, K. (2021). A virtual experiment for learning the principle of daniell cell based on augmented reality. *Special Issue X Reality Technologies, Systems and Applications*, *11*, 762. https://doi.org/ 10.3390/app11020762