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Inquiry-Based Microscale experimentation approach and chemistry students' performance in electrolysis

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Abstract
The Inquiry-Based Microscale Experimentation Approach was used in this study. To investigate the effect of this approach on students' performance two research questions and two hypotheses were formulated to guide the study. A pre-test, post-test non-randomized quasi-experimental design was used. The population for the study was one thousand seven hundred and fifty-six (1,756) senior secondary II Chemistry students (2017/2018) academic session. Purposive sampling technique was used to draw a sample size of one hundred and twelve (112) students. Two research instruments namely Redox Reaction Concept Performance Test (RRCPT) and Electrolysis Concept Performance Test (ECPT) were developed for data collection. The RRCPT consisted of twenty (20) multiple choice objective test items while ECPT comprised of forty (40) items. The reliability coefficient of 0.75 and 0.82 was obtained using Kuder Richardson 20 (K_{20}) for the Redox Reaction Concept Performance Test (RRCPT) and Electrolysis Concept Performance Test (ECPT) respectively. Data collected were analyzed using mean, standard deviation and Analysis of Covariance (ANCOVA). The findings of the study established that inquiry-based microscale experimentation approach has a significant and positive effect on students' performance. This indicates that students exposed to Redox reactions as a pre-requisite for better understanding of electrolysis concept performed better than the group without Redox reaction pre-treatment. The findings also revealed that there is no significant difference in the performance of male and female students taught the concept of electrolysis using the inquiry-based microscale experimentation approach. Thus, gender is not a major factor in students' performance. The study, therefore, recommended that Chemistry teachers should incorporate this approach into the teaching-learning process of electrolysis in order to create a unique, interesting and motivating learning environment.

Keywords: inquiry-based, microscale experimentation, performance, electrolysis, chemistry

Introduction

Science and technology is the pathway to human development. It is a viable tool for industrialization through scientific investigations and discoveries. This is probably why the National Policy on Education of Nigeria was developed to ensure students are equipped with scientific knowledge for functional and meaningful living. This implies that relevant learning activities geared towards the participation of students and the mastery of scientific skills are to be devised and effectively utilized by science teachers. Science, particularly Chemistry is aimed at developing scientific reasoning, critical and creative thinking ability in students. Chemistry deals with the properties and compositions of matter and the energy changes as well as the transformations that matter undergo as they interact and react with other substances (matter) in the environment. It is an experimental science which is hinged on the harmonization that occurs between theory and practice, (Muhammad 2014) [21]. Therefore, the use of activity-oriented instructional approach is considered important in the teaching and learning of Chemistry. This provides students' better understanding of the basic concepts in Chemistry as well as establishes a connection between the theory learned and the practical activities conducted by students. When students are actively involved in the learning process, learning difficulties encountered are reduced and their performances are enhanced.

Therefore, the use of the traditional instructional method by Chemistry teachers is de-emphasized and instructional approaches that ensure students' active involvement and better performance are developed and utilized. This entails the use of innovative approaches that convey relevant knowledge appropriately and increase students' ability to master and retain what was taught. The activity-oriented instructional approach encourages a deep understanding of the basic chemical concepts and their applications. Omwihiren and Lawal (2016) [24] posited that the use of practical activities in teaching and learning of Chemistry would likely enhance the comprehension of Chemistry concepts. This results in meaningful learning whereby students are able to connect their prior knowledge to the concept that is been taught. As such, there is mental readjustment that enhances better conceptual understanding, meaningful learning and enhanced students' performance.

There has been low performance among Chemistry students in senior secondary school external examinations in Nigeria Gongden, {2016} [18]. Studies by Mosadom (2014) also affirmed this as revealed in the November/December General Certificate of Education of Chemistry students: 5.32% in 2011, 30.17% in 2012 and 66.41 in 2013. According to Gambari, Obielodan and Kawu, (2017) [17], less than 50% of students passed Chemistry at credit level and above. The Chemistry candidates' performance was associated with lack or inadequate preparation for the examination, lack of relevant textbooks and non-familiarization with the examination syllabus which was attributed to the wrong approach to teaching Chemistry that does not sustain students' interest (www.researchclue.com.ie). However, since 2015, there appears to be increased students' success rate with performance rate at 38.68% in 2015, 52.97% in 2016 and 59.22% in 2017. According to Olu Adenipekun, the Head of National Office (HNO) of the West African Examination Council, one of the factors that led to the significant improvement in the candidate's performance is that the quality of teachers preparing the students have improved. Therefore, the key to improved students' performance is effective teaching that sustains students' interest and relates new concepts to students' foundational facts and experiences. This motivates students to learn, arouses their interest as they do what scientist do known as scientific inquiry.

Inquiry-based instructional approach makes learning fun as it provides students with the opportunity to ask the "why" and "how" questions and in-turn explore. It simply allows students to do science by formulating good questions, plan and design as well as perform relevant experiments. Students develop critical thinking about scientific outcomes, draw educated conclusions as to "why" and "how" of certain occurrence and communicate appropriately their findings to others. Inquiry-based learning entails diagnosing problems, planning investigations, searching for information, constructing models, discussion with peers, and drawing conclusions. This instructional approach engages students' interest and challenges them to make connections between their world and the content taught. Students simply learn to gather information on their own, investigate, analyze data, evaluate their findings and create new knowledge following the same processes used by scientists. The aim of inquiry-based learning is to develop a learning process that allows students to utilize the problem-solving skills to carry out investigation and make a generalization. Inquiry-based teaching and learning according to the National Research Council (NRC 2002) in Nworgu and Otum (2013) [22] can occur in three major levels or types namely: student-centred, teacher- directed and less teacher directed. Generally, inquiry based-learning can be classified or grouped into the structured inquiry, open inquiry and guided inquiry. This study is based on guided inquiry and its effects on Chemistry students' performance. Guided inquiry is a set of activities characterized by a problem-solving approach where students are most of the time provided with problem situations and lots of relevant and suitable materials for them to explore their environment and solve problems (Nworgu and Otum 2013) [22]. Inquiry-based approach creates an environment that provides students with opportunities to construct their own meaning and develop a deep and better understanding of concepts like electrolysis through practical demonstrations (experimentation) of what was taught.

Experimentation or practical demonstrations have remained consistent in science teaching over the years. However, most of the advanced and modern technologies are expensive. Thus, one of the ways to overcome this challenge is through the effective implementation of microscale Chemistry. Microscale Chemistry is a laboratory-based, environmentally safe, and pollution prevention teaching approach where miniature glass wares are used and the number of chemicals significantly reduced (Abdullah, Mohamed, and Ismail, 2007) [2]. It is an approach utilized in carrying out Chemistry practical activities which help teachers overcome the rising cost of laboratory equipment as well as the increasing concerns about environmental pollution. Microscale Chemistry also referred to as Small-Scale Chemistry involves a reduction or use of small quantities of chemicals used in an experiment, with a shift from the usage of glassware to disposable plastic materials. Therefore, Microscale experimentation approach is carried out without compromising the quality and standard of chemical applications. As such, using microscale approach helps to address or tackle some of the challenges' teachers encounter when planning practical activities where there are lack of adequate laboratory space, dearth or lack of chemicals and equipment, absence of laboratory assistance, inadequate time and lack of confidence on the part of the teacher (Tesfamariam, Lykkness & Kvittingen, 2014) [28]. The use of microscale experimentation approach in teaching Chemistry provides the teacher and students conducive atmosphere for key demonstrations and hands-on activities. Thus, students are able to visualize the phenomenon, identify what happened and the cause of the reaction. This is because, with the microscale experimentation approach, concrete observation is guaranteed and can be used to teach Chemical concepts such as electrolysis.

Electrolysis is the chemical decomposition of a compound brought about by a direct current passing through either a solution of the compound or the molten compound (Ababio, 2014) [1]. It is using an external source of energy to drive a non-spontaneous chemical reaction. Electrolysis is simply the use of electricity or electric current to stimulate and cause a non-spontaneous chemical reaction to take place. In electrolysis, electric current is passed through the electrolyte so as to stimulate the flow of ions required to run a non-spontaneous chemical reaction. Therefore, the word electrolysis literally means to dissolve or break something apart using electricity. It can be used to separate substances into their original elements or components. This was applied in the electrolysis of Sodium tetraoxosulphate (VI) salt (Na_2SO_4) in purple cabbage extract as an acid-base indicator to produce hydrogen gas.

Therefore, the distinctive and central role of the Chemistry teacher is to device teaching strategies that present students the opportunity to manipulate and utilize natural, improvised and already made resources which they are familiar with. This creates variety and enhances the understanding of some aspects of chemical concepts perceived as difficult such as electrolysis. The use of microscale experimentation approach in teaching electrolysis is a low-cost experimentation alternative. It is cheaper and the equipment and materials are accessible and replaceable. The key aspect of the principle of microscale Chemistry is its simplicity of manipulation by students. Students' active involvement in the instructional process provides a detailed explanation, enhances understanding of the scientific contents and enable them to solve problems using scientific procedures. Therefore, effective Chemistry instruction entails theoretical explanations supported by laboratory applications. Hence, students are able to make connections between scientific theories and practical activities and are able to transfer/translate scientific theories and processes into meaningful living.

Statement of the Problem

Scientific truths can only be established through experimentations. This process entails providing students with hands-on experiences and practical activities in other to gain a better understanding of the basic conceptual ideas. However, this is not applicable in most Nigerian schools hence students have an inappropriate understanding of scientific concepts such as electrolysis (De Jong & Treagust, 2002) [10]. In the same vein, the research finding by Sia, Treagust, and Chandrasegaran (2012) [10] showed that students possessed content knowledge about several processes of electrolysis but are unable to provide suitable explanations for the changes that had occurred, with less than 45% of students showing scientifically acceptable understanding about the concept of electrolysis. This is in line with several studies that showed that students find it difficult to master the concept of electrolysis because ''they cannot observe or imagine what happens in the microscopic level in an electrochemical reaction'' (Yochum & Luoma, 1995) [30] in Sia, Treagust, and Chandrasegaran (2012) [10]. Therefore, this study sought to determine the effectiveness of inquiry-based microscale experimentation approach in the teaching and learning of the electrolysis of Sodium Tetraoxosulphate (VI), (Na_2SO_4).

Purpose of the Study

The purpose of this study is to investigate the effects of inquiry-based microscale experimentation approach on Chemistry students' performance. It specifically sought to investigate the effectiveness of using a plastic syringe Hoffmann apparatus in teaching the electrolysis of Sodium Tetraoxosulphate (VI) salt solution using purple cabbage extract as an acid-base indicator.

Research Questions

The following research questions guided the study

1. What effects do the inquiry-based microscale experimentation approach and lecture method have on students' performance when taught the concept of electrolysis?
2. What is the difference in the performance of male and female students who were taught the concept of electrolysis using the inquiry-based experimentation approach?

Hypotheses

The following null hypotheses tested at 0.05 level of significance were formulated.

1. There is no significant difference in the performance of Chemistry students taught the concept of electrolysis with the inquiry-based microscale experimentation approach and those taught with lecture method.
2. There is no significant difference in the performance of male and female students who were taught the concept of electrolysis using inquiry-based microscale experimentation approach (experimental group only).

Research Methodology

Research Design

The design used for the study was a quasi-experimental non-randomized pre-test, post-test control group design. This was hinged on the fact that an intact class was used. It involved three groups; two experimental groups and one control group. A pre-test (X_1) was administered to the three groups to ascertain their baseline knowledge on electrolysis. The two experimental groups were then exposed to inquiry-based experimentation approach while the control group was taught with lecture method. However, experimental group one (EG_1) was taught the concept of redox reaction first as a pre-requisite for the understanding of the concept of electrolysis while experimental group two (EG_2) were only taught the concept of electrolysis. The two experimental groups carried out the experiment on electrolysis while the control group was taught the concept of electrolysis using the lecture method. The instructional intervention or treatment (T_1T_2) was for a period of five weeks and this was followed by the post-test (X_2) which was administered to the three groups to determine the effects of the instructional approaches used. The illustration of the design is shown below:

Design for the Study

Table 1

Group	Pre-test	Treatment	Post-test
Experimental **1** (IMEM)	X_1	T_1	X_2
Experimental **2** (IMEM)	X_3	T_2	X_4
- - - - - - - - - - - - - - - - -	- - - - - -	- - - - - - - - -	- - - - - - -
Control (Lecture Method)	X_5	T_3	X_6

Where:

X_1 = Pre-Test (ECPPT) for Experimental Group 1
T_1 = Treatment for Experimental Group 1, using the Inquiry-Based Microscale Experimentation
X_2 = Post-Test (ECPPOT) for Experimental Group 1
X_3 = Pre-Test (ECPPT) for Experimental Group 2
T_2 = Treatment for Experimental Group 2, using the Inquiry-Based Microscale Experimentation
X_4 = Post-Test (ECPPOT) for Experimental Group 2
X_5 = Pre-Test (ECPPT) for Control Group
T_3 = Teaching with Lecture Method
X_6 = Post-Test (ECPPOT) for Control Group
- **=** Dashed Lines shows that Intact Classes were used.

Population of the Study

The population of the study comprised of Senior Secondary (II) Chemistry students in Port Harcourt Local Government Area of Rivers State. A total population of one thousand, seven hundred and fifty-six (1,756) Chemistry students in the fifteen government approved senior secondary schools in Port Harcourt Local Government Area of Rivers State was used.

Sample and Sampling Technique

The sampling technique used for the study was purposive sampling technique. Three schools out of the 15 government approved senior secondary schools within the Port Harcourt Local Government Area of Rivers State were selected. The sample of the study was one hundred and twelve (112) Senior Secondary (II) Chemistry students made up of sixty-seven (67) males and forty-five (45) female. The process of selection of schools took into consideration specific characteristics and attributes the researcher intended to measure. This include: the schools must be made up of a mixed population of male and female students with an experienced Chemistry teacher that has taught Chemistry for at least five years.

Research Instrument

Two research instruments were used for the study; Redox Reaction Concept Performance Test (RRCPT) which has the pre-test (RRCPPT) and Post-Test (RRCPPOT). This consisted of twenty (20) multiple choice objective test items which were selected from past SSCE and UTME questions on Oxidation-Reduction (Redox) reaction. This was administered only on experimental group 1 (EG1). The second instrument was the Electrolysis Concept Performance Test (ECPT) which also has pre-test and post-test. This consists of two sections; Section 'A' which elicited the background information of students while section 'B' comprised of forty (40) multiple choice objective test items which were selected from past SSCE and UTME questions on electrolysis. The pre-test (RRCPPT) and a post-test (RRCPPOT) for redox reaction are the same but the items in the RRCPPT (pre-test) were reshuffled before administering it as post-test (RRCPPOT). Similarly, the pre-test (ECPPT) and the post-test (ECPPOT) are the same but the items in the ECPPT (pre-test) were reshuffled before administering as post-test (ECPPOT).

Validation and Reliability of the Instrument of the Instrument

The instrument was given to experts in Chemistry education for content analysis to ensure it measures what it is expected to measure. The internal consistency of the test items was measured and a reliability coefficient was determined using Kuder Richardson 20 (K_{20}). The reliability coefficient of 0.75 and 0.82 was established for the Redox Reaction Concept Performance Test and Electrolysis Concept Performance Test (ECPT) respectively.

Experimental procedure

- **Step 1:** Preparation of the Acid-Base P^H Indicator Solution from Purple Cabbage (Brassica Oleracae)
- **Step II:** Construction and Use of a Microscale Plastic Syringe Hoffman's Apparatus for the Electrolysis of Sodium tetraoxosulphate (VI)

Materials and Apparatus Required: A plastic container to serve as beaker**,** 5ml Plastic syringe (two) as electrodes**,** Blunted hypodermic needles**,** Insulated copper wire or battery cap**,** 9v battery**,** Sodium tetraoxosulphate (VI) salt solution**,** Purple cabbage extract (indicator)**,** Solution of Sodium tetraoxosulphate (VI) salt in purple cabbage extract.

Construction of the Plastic Syringe Hoffman' Apparatus; Microscale Electrolytic Cell

1. Collect the clean disposable plastic container and place it on the laboratory table.
2. Add about10ml – 20ml of the electrolyte, Sodium tetraoxosulphate (VI), (Na_2SO_4) salt solution (without the purple cabbage extract) to the disposable plastic container.
3. Carefully pierce the syringe using the needle and make sure there is no leakage.
4. Draw some solution of sodium tetraoxosulphate (VI), (Na_2SO_4) salt in purple cabbage into the syringe. Fill the two 5ml plastic syringes with the electrolytes.
5. Place the syringe upside down into the container serving as the cell. Ensure the needle touches the solution in the syringe.
6. Connect the insulated copper wire to the hypodermic needles. This must be done with care to avoid leakage. Once there is a leakage, you must change and discard the syringe and start afresh.
7. Using the battery cap connect the wire to the correct terminals of the battery. The battery is the source of power and immediately the set-up is connected to the battery, the reaction starts. The microscale experimentation set up is shown in fig 1 below:

Fig 1: Umegboro, Kate (2018); Plastic Syringe Hofmann Apparatus

(A Microscale Experimentation set-up for the Electrolysis of Sodium Tetraoxosulphate (VI) Salt in Purple Cabbage extracts to produce hydrogen gas.

Method of Data Analysis

The data collected during the study were analysed using the statistical tools of mean, standard deviation and Analysis of Covariance (ANCOVA).

Result and Data

Research Question 1: What effects do the inquiry-based microscale experimentation approach and lecture method have on students' performance when taught the concept of electrolysis?

Table 2: Mean $\bar{x}$ and Standard Deviation of Pretest and Post-test Scores of Students; Classified by Treatment

Group	N	Pre-test		Post-test		Mean Gain	% Gain
		Mean $\bar{x}$	SD	Mean $\bar{x}$	SD		
Inquiry-based Microscale Experimentation (with Redox Reaction)	36	46.61	12.34	75.66	12.05	29.05	62.32%
Inquiry-based Microscale Experimentation (without Redox Reaction)	39	41.94	10.77	63.82	12.60	20.88	52.16%
Lecture Method	37	32.43	8.88	42.91	11.06	10.48	32.31%

Table 2 shows that the mean achievement score of the experimental group (with redox reaction as pre-treatment) in the post-test was 75.66 with standard deviation of 12.05 which is higher than the post-test mean of the experimental group (without redox reaction treatment) of 63.82 and standard deviation of 12.60. However, the control group has pre-test and post-test mean scores of 32.43 and 42.91 with standard deviation scores of 8.88 and 11.06 respectively. Furthermore, the mean achievement gain for the inquiry-based microscale experimentation groups (with and without redox reaction) are 29.05 (62.32%) and 20.88 (52.16%) respectively while the mean gain for students in the control group is 10.48 (32.31%). This indicates the superiority of the treatment groups due to their exposure to the Inquiry-Based Microscale Experimentation Approach over the control group in fostering students' performance in electrolysis.

Also, the results show that students that were taught redox reaction as pre-requisite for teaching electrolysis had the highest mean gain of 29.05 (62.32%). This shows that students that had a baseline knowledge of redox reaction as the pre-requisite for the understanding the concept of electrolysis performed better than their counterparts who taught without prior knowledge. This simply revealed that students understand and learn better when they are actively involved and there is a connection between what they already know and the new concept to be learned.

Research Question 2: What is the difference in the performance of male and female students who were taught the concept of electrolysis using the inquiry-based experimentation approach?

Table 3: Mean $\bar{x}$ and Standard Deviation of Pre-test and Post-test Scores of Students; Classified by Treatment and Gender

Group	Gender	N	Pre-test		Post-test		Mean Gain	Mean Diff.	%Gain
			Mean $\bar{x}$	SD	Mean $\bar{x}$	SD			
Inquiry-based Microscale Experimentation (with Redox reaction)	Male	20	50.62	15.17	76.25	11.57	25.63	5.24	50.63%
	Female	16	44.00	8.62	74.87	12.60	30.87		70.15%
Inquiry-based Microscale Experimentation (without redox reaction)	Male	29	43.52	11.00	65.07	13.72	21.55	1.30	49.51%
	Female	10	38.25	9.12	58.50	6.87	20.25		52.94%

Table 3 shows that the post-test mean achievement score of male and female students in experimental group 1 (with redox reaction as pre-treatment) was 76.25 and 74.87 with standard deviation of 11.57 and 12.60 respectively while for experimental group 2 (without redox reaction as pre-treatment) the post mean was 65.07 and 58.50 with a standard deviation of 13.70 and 6.87 for male and female students respectively. Furthermore, the mean gain of 50.63% and 49.51% for males and 70.15% and 52.94% for females indicates that female students gained more during the experimentation process than males. However, the statistical significance of the mean difference will be established after subjection to further analysis.

Hypothesis 1

There is no significant difference in the performance of Chemistry students exposed to inquiry-based microscale experimentation approach and those taught with lecture method. The result obtained using ANCOVA is shown in Table 4.

Table 4.1: Analysis of Covariance (ANCOVA) of the post-test scores; classified by treatment using pre-test as covariates

Source of Variation	Type III um of Squares	df	Mean Squares	F	Sig.
Corrected Model	25327.095[a]	3	8442.365	89.944	.001
Intercept	8387.063	1	8387.063	89.355	.001
Pretest	5401.346	1	5401.346	57.545	.001
Method	7808.272	2	3904.136	41.594	.001
Error	10137.155	108	93.863		
Total	443720.000	112			
Corrected Total	35464.250	111			

RS = 714 (Adjusted R Squared =. 706)

Table 4.1 shows that F (2,108) = 41.594, p = 001, the result of the analysis indicates that there is a significant difference between the performance of students taught the concept of electrolysis using inquiry-based microscale experimentation approach and those taught with lecture method. Based on this, the null hypothesis is rejected. Thus, the main effect of the treatment was significant and on this basis hypothesis, one was rejected. This implies that there is a significant difference in the mean scores of students exposed to inquiry microscale experimentation and students taught with lecture method. Therefore, students perform better when exposed to practical activities or experiment as shown in the post-hoc analysis in table 4.2 below:

Table 4.2: Post Hoc Analysis of Mean Gain Differences of Students Pre- and Post- Test Scores of Students' Performance in Electrolysis Concept Based on the three Instructional Approaches.

Pairwise Comparisons Dependent Variable: Posttest Performance Score						
					95% Confidence Interval for Difference	
(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
IBME (with Redox Reaction)	IBME (without Redox Reaction)	9.792*	2.275	0.01	5.282	14.301
	Lecture Method	23.458*	2.578	0.01	18.349	23.588
IBME (without Redox Reaction)	IBME (with Redox Reaction)	-9.792*	2.275	0.01	-14.301	-5.282
	Lecture Method	13.667*	2.370	0.01	8.986	18.366
Lecture Method	IBME (with Redox Reaction)	-23.458*	2.578	0.01	-28.568	-18.349
	IBME(without Redox Reaction)	-13.667*	2.370	0.01	-18.36	-8.968

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)

Table 4.2 reveals that the mean difference of IBME (with Redox Reaction) and IBME (without Redox Reaction) is 9.792 while the mean difference between IBME (with Redox Reaction) and Lecture Method is 23.458. Similarly, the mean difference between IBME (without Redox Reaction) and Lecture Method is 13.667. This indicates that the mean difference of all the groups compared is significant at 0.05 level. This observed difference in students' performance shows that students exposed to IBME (with Redox Reaction) performed better followed by students of IBME (without Redox Reaction) while observed performance was least among students taught with lecture method. Therefore, inquiry-based microscale instructional approach (particularly students exposed to the concept of redox reaction) had greater effect on improving students' performance in electrolysis concept in Chemistry.

Hypothesis 2

There is no significant difference in the performance of male and female students who were taught the concept of electrolysis using the inquiry-based microscale experimentation approach (i.e. experimental group on and two). The result obtained using ANCOVA is shown in Table 6

Table 5: Two-way Analysis of Covariance (ANCOVA) of post-test scores; classified by treatment and gender using pre-test as covariates

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	1167.116[a]	4	291.779	19.541	0.001
Intercept	1026.774	1	1026.774	68.766	0.001
Pre-test	675.112	1	675.112	45.214	0.001
Method	212.181	1	212.181	14.210	0.001
Gender	.021	1	.021	.001	.970
Method*Gender	24.309	1	24.309	1.628	.206
Error	1045.204	70	14.931		
Total	59676.000	75			
Corrected Total	2212.320	74			

R Squared =.528 (Adjusted R Squared = 501)

Table 5 shows that F (1, 70) = 1.628, p = 0.206. Since p > 0.05 then there is no significant difference between the performance of male and female students who were taught electrolysis with the inquiry-based microscale experimentation approach. In other words, the performance of male and female Chemistry students exposed to the inquiry-based microscale experimentation approach (experimental group only) significantly achieved higher academically. Based on this result the null hypothesis was accepted. This implies that both male and female students achieved significantly in the experimentation process in terms of their performance regardless of their gender.

Discussion of Findings

Effects of the Instructional Approach on Chemistry Students' Performance

From table 2, it was observed that the experimental group exposed to the inquiry-based microscale experimentation approach performed better than their counterpart in the control group that was taught with lecture method. This implies that the inquiry-based microscale experimentation approach has a significant and positive effect on students' performance when compared to students taught with a traditional lecture approach. The higher achievement of student in the experimental group can be attributed to the activity-oriented nature of the instructional approach; the use of plastic syringe Hoffman's apparatus constructed by the students during instruction.

The statistical analysis (ANCOVA) showed that there was a significant difference between the two groups as the value obtained shows that F (2,108) = 41.594, P = 001 was statistically significant at 0.05 level. Thus, the null hypothesis was rejected. The result of the findings of the study is in agreement with the findings of Celik and Cavas (2012) [6] who asserted that inquiry-based learning has a significant effect on students' academic achievement when compared with those taught with the traditional teaching method. The work of Esnaf (2013) also revealed that students taught with the experimental instructional approach performed significantly better than those taught using the traditional lecture method. Savlesbergh, Prins, Rietbergen, Fechner, Vaessen, Drayer and Baker, (2016) [26] also found a significant and large effect of innovative teaching approach on students' performance. Similarly, the findings of Evrim (2016) [14] showed a significant increase in students' academic performance when exposed to guided inquiry laboratory assignment.

Furthermore, the research findings of Abdullah, Mohamed and Ismail (2008) [2], showed there was a significant difference in the performance of students exposed to microscale experimentation approach and those taught with traditional experiment. This revealed that the mean gain score of students taught with the microscale experiment was significantly higher than those taught with the traditional experiments. Similarly, Davis, Vandevender, Crihfield, Kolanko, Shoa, Ellington, Dicks, Carva and Holland (2014) [8] in their studies affirmed that the use of microscale experimentation increases the knowledge and retention as well as improved students' critical thinking ability. The implication of the findings of this study is that the inquiry-based microscale experimentation approach is an effective instructional approach for the teaching of chemical concepts like electrolysis. This is because students understand Chemistry concepts better and are able to retain what was taught when the teacher employs instructional approaches that are problem-based and can enhance cognitive restructuring as well as enable students to connect new ideas to already existing knowledge structure (Fatokun & Fatokun, 2013) [15]. Hence, using hand-on-activities in teaching the concept of electrolysis enhances students' conceptual understanding of the concept taught. This approach makes the lesson real as students observe, manipulate and interpret the processes and the reactions taking place. Therefore, students' active involvement in the instructional process facilitates effective assimilation and internalization of the concept taught.

Influence of Gender on Chemistry Students' Performance

The result of the study as shown in Table 3 also indicated that both male and female students taught electrolysis benefited significantly with female showing a higher mean gain. Hence, two-way Analysis of Covariance (ANCOVA) was used to test the hypothesis in order to verify if the higher achievement mean gain of the female students in the post-test mean scores were statistically significant. The result of the statistical analysis showed that there was no significant difference between the performance of the male and female student as indicated in the value obtained which shows that $F (1, 70) = 1.628$, $p = 0.206$. Thus, the null hypothesis was accepted.

This is in consonance with the findings of Ensaf (2013) [11] which show that male and female students have an equal effect on their academic performance when taught with laboratory activities. It also in agreement with the findings of Dike and Umegboro (2015) [9] that revealed there was no significant difference in the performance of male and female students in Chemistry when taught the concept of saponification using local materials for experimentation. The work of Jack and Suleiman (2017) [19] which also revealed that gender has no significant effect on the academic achievement of Chemistry students is also in consonance with the findings of this study. Similarly, Etiubon and Udoh (2017) [13] affirmed that the academic performance of male and female students in Chemistry did not significantly differ from each other. The findings of Ajayi and Ogbeba (2017) [5] also agreed that there was no significant difference in the male and female students taught with hands-on-activities. The evidence of the finding is also in line with the findings of Okoye (2013) [25], Olasheinde and Olatoye (2014) [23], Udoh (2015) [29] and Enderle and Leeanne (2016) [12] whose findings showed that there was no so significant effect of gender on students' academic achievement in science. The implication of this is that when male and female students are exposed to the appropriate instructional strategies and taught in the same learning environment under similar conditions, they learn and benefit equally. This is because the main factor in knowledge acquisition is the individual intellectual ability and not gender. As such, when students are taught the concept of electrolysis both male and female benefited significantly. Hence, the use of inquiry-based microscale experimentation approach bridges the gender gap in the learning environment. However, the findings of this study are in contrast to the findings of Aniodoh and Egbo (2013) [4] which showed that gender has a significant effect on students' performance. According to their findings, female students performed better than their male counterparts when taught with inquiry role instructional model. Similarly, Etiubon (2011) [13] found out that female students performed significantly better than the male students taught electrolysis in Chemistry using the technological resource. But the studies by Gongden (2016) [18] showed that male students performed better than the female students in Chemistry. This is in line with the findings of Fatokun and Eniayju (2014) [15] which asserted that male students performed significantly better than their female counterpart.

Conclusion

Students learn best when they are actively involved in the teaching and learning process. The use of inquiry-based microscale experimentation approach provides students with the opportunity to be actively involved instead of becoming robotic learners. In other words, students are allowed to do and experience science; they are made to be responsible for the outcome of learning activities such as the planning process, experimentation, analyzing and interpretation of data and drawing of conclusions. The role of the Chemistry teachers in inquiry-based microscale experimentation approach is to guide rather than disseminate information and control the teaching-learning process. The teacher, therefore, goes beyond the traditional roles of regurgitating facts to allowing students to make decisions, perform the experiment and construct their own knowledge in order to have a better conceptual understanding. Inquiry-based microscale experimentation approach offered both male and female students were equal opportunity to be actively involved in the learning activities. Hence, they benefited significantly from instructional activities.

Recommendation

Chemistry teachers should utilize the inquiry-based microscale experimentation approach in teaching the concept of Chemistry particularly the electrolysis of Sodium Tetraoxosulphate (vi) salt (Na_2SO_4).

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