American Journal of Educational Research, *2017, Vol. 5, No. 7, 717-724*
Available online at http://pubs.sciepub.com/education/5/7/4

DOI:10.12691/education-5-7-4

Effectiveness of Guided-Inquiry Laboratory Experiments on Senior Secondary Schools Students Academic Achievement in Volumetric Analysis

Jack Gladys Uzezi*, Suleiman Zainab

Department of Science Education, Taraba State University, P.M.B 1167, Jalingo, Nigeria
*Corresponding author: gjackuzezi@yahoo.com

Abstract The persistent poor performance of students in practical tests in chemistry has been blamed on poor choice of teaching methods and poor understanding of basic concepts in qualitative and quantitative analysis. The purpose of this study therefore was to investigate the effects of guided-inquiry laboratory experiments on Senior Secondary School students' academic achievement in Volumetric Analysis. The design for the study was a pre-test post-test control group quasi-experimental design. The instrument used for data collection was Volumetric Analysis Achievement Test. The statistical tools used for data analysis in the study were means, t-test and Analysis of Covariance. The findings from the study showed that guided-inquiry laboratory experiments have significant effect on students offering chemistry' academic achievement than the traditional teaching method since it motivated the students and this was positively reflected in their chemistry mean achievement scores. The findings also revealed that gender has no significant effect on academic achievement of students exposed to Chemistry through guided-inquiry laboratory experiments. This showed that males and females benefited significantly from the instructional approaches; since it was student-activity oriented which made them engaged in in-depth critical thinking and process skills. The findings of this study imply that guided-inquiry laboratory experiments had much more effect on students' academic achievement than the traditional teaching method. Chemistry teachers should therefore incorporate it into the teaching-learning process since it developed students scientific and practical skills, motivated the students and fostered the spirit of competitiveness among them; and its effectiveness is not being limited by gender.

Keywords: *guided-inquiry laboratory experiments, academic achievement, gender, volumetric analysis*

Cite This Article: Jack Gladys Uzezi, and Suleiman Zainab, "Effectiveness of Guided-Inquiry Laboratory Experiments on Senior Secondary Schools Students Academic Achievement in Volumetric Analysis." *American Journal of Educational Research*, vol. 5, no. 7 (2017): 717-724. doi: 10.12691/education-5-7-4.

1. Introduction

Practical chemistry entails a major part of chemistry education, which needed to be handled or taught properly; otherwise other related science courses will be affected negatively. Therefore secondary schools require properly equipped and functional laboratories. When the students offering chemistry are taught in abstraction or theoretically, the students will not learn properly. The chief examiners reports of WAEC [35,36,37] indicated poor performance of students in the sciences particularly chemistry. The persistence poor performance of students in chemistry has been blamed on inadequate teaching methods, inadequate laboratory equipment and lack of understanding of basic concepts in qualitative (identification of elements or ions by simple tests) and quantitative (volumetric) analysis [21,22]. As opined by Oduntuyi [25], the laboratory is an important means of instruction in Chemistry teaching and learning. The Chemistry laboratory environment provides scope for learning through discovery which is both exciting and stimulating to the students enhancing performance and sustaining the interest of the students in the subject [15,16,24].

Available evidence from West African Examination Council and some science educationist [21,29,36,37] indicates that student's poor academic achievement in chemistry. Empirical evidence from WAEC, Chief Examiner's report [35,36,37] in Nigerian educational system in the sciences and chemistry in particular; indicates that secondary school students' academic achievement is still not at its best, with a raw mean score of 36 and a standard deviation of 16.52 performance was slightly better than 2009, but was still generally poor [35]. The grades that students get at the end of a course of study continue to be on the decline. The result of this situation is that the goal of secondary school education as lighted by the national policy on education [11] has not been fully realized the performance of students in chemistry over the past decades have been very poor in both internal and external examinations, this could be attributed to many factors such as teaches qualification, teaching methods, lack of laboratory equipments etc. Consequently, there is a great need to help improve students offering chemistry' perceived learning difficulties of chemical concepts not just for them to sail through SSCE/GCE examinations, but also for them to be aware and be appreciative of the contributions they can make to the country's development in scientific researches in well developed and equipped science laboratories.

Laboratory experiment is an area of great importance in all fields of natural science, especially chemistry. Laboratory experiments has unquestionable importance in chemistry education since it helps in developing understanding related to the scientific content, problem solving skills; science processes skills and understanding the nature of science which are the key goals of chemistry education. Students are expected to realize the connection between experiments and scientific theory. Laboratory experiments which are inquiry-based learning supports students apply their knowledge; understand real world situations and supports discovery scientific facts and principles. In inquiry based learning environments, students are more active and they guiding their own learning processes [8]. Apart from knowledge of the theoretical aspects of the subject, it is very important that students offering chemistry also have a sound knowledge of practical work which permits individual observation and experience. In chemistry student-activity classrooms, laboratory work is of great importance since it provides learners' an opportunity to perform different hands-on activities. There are also science educationists who opined that laboratory work or instruction leads to effectiveness on students understanding of science concepts more than the traditional teaching methods [13,30]. This is because the traditional teaching method is inadequate for supporting the development which is aimed by laboratory since it does not help students to develop scientific processing skills and understand the nature of science. Teachers should therefore move away from traditional lecturing and demonstrations to active learning strategies such as problem based learning, cooperative learning and inquiry based learning which help students to develop their cognitive processes and help them to become lifelong learners [33].

Researchers have sorted and used a variety of interventions on innovative instructional strategies to improve students' learning in chemistry. Omiko [27] stated that "hands-on experience helped students' in developing the spirit of inquiry and also to acquire scientific skills; and appropriate attitude to handle scientifically tools and materials during laboratory work. Science laboratory work provides students with the richest experiences which they will transfer to the society and their various places of work. It helps in providing the students the opportunities to practice science as the scientist do. In order for the laboratory to be effective and efficient, students need to have an adequate knowledge of experimental work, and what purpose it serves for better understanding of scientific concepts, most especially in chemistry.

Laboratory activities have long played a distinctive and central role in the science curriculum and science educators have suggested that many benefits accrue from engaging students in science laboratory activities [16]. More specifically, they suggested that, when properly developed, designed, and structured, laboratory-centered science curricula have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science. In addition, the literature revealed a clear correlation between students' attitudes towards learning science and various modes of instruction in the science laboratory. Although the literature failed to provide a clear relationship between learning science and practical experiences in the laboratory, many research studies conducted mainly during the 1960s and 1970s reported that students enjoy laboratory work in some courses and that laboratory experiences resulted in positive and improved attitudes and interest in science [16]. However, as Hofstein and Lunetta [16] suggested, throughout the 1980s the focus of scholarly research within the science education literature moved slightly away from the affective domain towards the cognitive domain in general and towards conceptual change in particular. This is unfortunate since scientific experiences (e.g. laboratory work) that promote positive attitudes could have very beneficial effects on interest and learning. This is why Thompson and Soyibo [34] opined that laboratory work is an effective learning environment for enhancing attitudes, stimulating interests and enjoyment, and motivating students to learn science.

Most empirical studies on the effectiveness of laboratory experiments when used as an instructional strategy found significant improvement in students' achievement since they were actively engaged [4,7,8,15,16,24,25]. Ensaf [7] investigated the effect of laboratory experiment on grade ten students' achievement in Physics. The study showed that the experimental group students' achievement was higher than that of the control group students showing that there was a significant achievement difference between the experimental group that was taught with the laboratory teaching method and the control group that was taught with the traditional approach in favour of the experimental group at $P < 0.05$.

Inquiry-based laboratories support students' meaningful learning, conceptual understanding, and understanding of the nature of science [8,18,32]. Inquiry-based laboratories are more student-centered, contain limited direction of the teacher and students take more responsibility; and students can design their own experiments and instead of following a verification process, they try to reach the scientific concepts by themselves and they develop higher order cognitive skills [8]. Inquiry-based laboratories are separated into two groups namely guided inquiry and open inquiry.

Guided-inquiry laboratory method according to studies by Evrim and Irinoye et al. [8,20] showed that guided-inquiry method enhanced students' achievement. Students search for the experiment process and reach scientific information through the experiment. Inquiry-based laboratory requires students to search for knowledge, generate hypothesis, collect data, interpret evidence and make conclusions [5]. Akkus, et al [2] compared the effectiveness of inquiry-based approach with traditional teaching practices and the findings of the study revealed that inquiry based teaching approach have a positive effect on students' achievement.

Guided-inquiry laboratory method also encourages students to make scientific research and consider science as careers [14]. Gaddis and Schoffstall [12] stated that guided-inquiry experiments are generally based on a discovery, the procedure is predetermined but the outcome is not specified. Students develop understanding of science by participating in hands-on, open ended and student-centered activities in guided inquiry method [20]. In guided-inquiry laboratory method, students search for a solution from an unstructured problem and they establish the laboratory process while solving the problem. But, finding a solution to the problem and establishing experimental processes is time consuming and more difficult for students to adapt unlike the traditional teaching method which is widely used in Jalingo Metropolis. Therefore, guided-inquiry laboratory experiments would be more suited to our student understanding in volumetric analysis and achievement and would not be gender-stereotype. Since traditional teaching methods uses traditional laboratory experiments which forces students to follow a lab manual, students learn scientific information in difficultly and they cannot notice the relationship between the experiment and scientific theory

Academic achievement of students has often been associated with their gender. Gender refers to the fact of being male or female [31]. Gender can also be referred to as an analytic concept that describes sociological roles, cultural responsibilities and expectations of men and women in a given society or cultural setting [23]. Gender also describes the personality traits, attitudes, behaviours, values, relative power, influence, roles and expectation (femininity and masculinity) that society ascribes to the two sexes on a differential basis [10]. Therefore, gender is a psychological term and a cultural construct developed by society to differentiate between the roles, behaviour, mental and emotional attributes of males and females. Gender in this study is defined as biased role expectation of culture and society, ascribed based on being males or females. Gender role stereotyping continues to permeate our society and culture; and as it were, determines the extent of progress and achievement of students offering chemistry [26]. The influence of gender on learning and achievement has remained a controversial and topical issue amongst educationists and psychologists. In a study, Eze [9] asserted that gender had significant effects on students' achievement in chemistry, and showed that male students achieved higher than their female counterparts did. Owoyemi [28] asserted that student's achievement in chemistry course has 'nothing to do with whether the student is male or female'. Agbir [1] found that gender was not a significant factor in the overall mean achievement rating of students in practical skills on acid-base titration. Ifeakor [19] showed a significant gender-related difference in students' cognitive achievement in favour of male students over their female counterparts. It would appear, from the above studies that gender has an influencing factor in learning and achievement in aspects of chemistry remains important but controversial. None of the reviewed studies was on effect of inquiry laboratory experiments on student achievement and gender in volumetric analysis which is a chemistry difficult concept; that is students find difficult to understand and teachers find difficult to teach in senior secondary schools in Jalingo Metropolis; causing an underachievement in chemistry generally which is a gap in knowledge, thus creating a need for this present study.

1.1. Purpose of the Study

The purpose of this study therefore was to investigate the effectiveness of guided-inquiry laboratory experiments on Senior Secondary School students' academic achievement in Volumetric Analysis.

1.2. Research Questions

To guide this study, the following research questions were raised and answered:

i. What are the mean achievement scores of the students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method?
ii. What are the mean achievement scores of male and female students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method?

1.3. Hypotheses

To also guide the study, the following null hypotheses were also stated and tested at; 0.05 level of significance:

Ho_1: There is no significant difference between the mean achievement scores of students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method.

Ho_2: There is no significant difference in the mean achievement score of male and female students taught volumetric analysis using both guided-inquiry laboratory experiments and traditional teaching method.

Ho_3: There is no significant interaction effect of treatment and gender on students' academic achievement in volumetric analysis.

2. Materials and Methods

2.1. Research Design

The design for this study was the quasi-experimental non-randomized pre-test, post test control design. The design was hinged on the fact that intact classes were used. In this study, the topic; volumetric analysis in Chemistry was taught in the experimental group using laboratory experiments and the control group using traditional lecture method for the period of 6 weeks. Schematically, the design is represented as follows:

Table 1. Design for the study

Group	Pre-test	Treatment	Post-test
Experimental (GILEM)	T_1	X1	T_1
Control (TTM)	T_1	X2	T_1

Where: T_1 is Volumetric Analysis Achievement Test (VAAT)
X_1 is treatment package Guided-Inquiry Laboratory for Experiment Method
X_2 is treatment package Traditional Teaching Method for Control Group
GILEM: Guided-Inquiry Laboratory Experiment Method
TTM: Tradition Teaching Method

2.2. Samples and Sampling Technique

The sampling technique used for the study was a multi-stage random sampling technique. The first stage was selection of Local Government Areas (LGAs) using purposive sampling technique that have senior secondary schools offering chemistry subject from Jalingo educational Zone, Taraba state, Nigeria. The second stage was selection of two co-educational public schools from Jalingo Educational zone through purposive sampling techniques due to the fact that not all public schools in Jalingo metropolis are offering chemistry and have laboratories. The sampling did not discriminate between male and female respondents since intact classes were used and students' consent that participated for the study was obtained from the respective schools. A total of 144 Senior Secondary Two (SS2) students from four intact classes from Jalingo Metropolis, Nigeria with an average age of 17 years of 2015/2016 academic session participated in this study. One of the classes served as the experimental group that used GILEM (N75=: 42 males and 33 females) while the other was the control group that used TTM (N=69: 37 males and 32 females). Both schools had two science classes each which were randomly assigned through balloting to experimental 75 (E_1=39, E_2=36) and control groups 69 (C_1=33, C_2=36); a total sample of 144. The selected schools for the study which was done randomly using balloting were first considered for selection after due consideration of some parameters which included a well-equipped chemistry laboratory as well as trained and experienced chemistry teachers. So, schools without laboratories were isolated from the study.

2.3. Instruments

Two major instruments were used for the study. The instruments included: (i) A four weeks lesson plan or instructional guide for guided-inquiry laboratory experiments and Lesson plan or Instructional guide for traditional teaching method on Volumetric Analysis (Acid-Base titration) which is an SS II topic in chemistry syllabus; (ii) Volumetric Analysis Achievement Test (VAAT) which was divided into two sections (section A and B) consisted of 25 multiple choice test items in section A and 5 essay questions in section B which were adapted from WAEC past questions related to the 4 weeks instructional unit on volumetric analysis.

The instrument for data collection was the Volumetric Academic Achievement Test (VAAT). The VAAT was constructed from past standardized WAEC chemistry practical test. The pre-test by twenty-five multiple-choice items and 5 essay questions was developed to identify students' pre-knowledge and concepts that are basis for learning. The instrument (VAAT) was already validated by the measurement and evaluation and chemistry experts in the SSCE board. In each test item in section A, the correct answer was determined as "1" point and at this state the highest point was determined as "25" point given a minimum score of '0' or '1' while in section B, each test item was determined as '5' points and at this state the highest point was determined as "25" point given a minimum score of '0' and maximum score of "25" given a total of 50marks. The reliability of the research instrument (VAAT) was determined through test-retest method and a reliability coefficient (r) of 0.80 was obtained which indicated reliability of the instrument.

2.3.1. Pre-Treatment Procedure

This study was carried out during a course on Volumetric analysis (acid-base titration). For both groups, the study was carried out during a five class-hour week over a six week period. Teaching of the topics in the experimental groups was performed in the following sequences:

Week 1: Introduction to Acid-Base titration

- Principles of Acid-Base titration
- Steps of Acid-Base titration
- Indicators used for various titrations
- Methods to determine the end-point
- Precautions of Volumetric Analysis

Week 2: Titration of a strong acid with a strong base

Week 3: Titration of a weak acid with a strong base/ Titration of a strong acid with a weak base

Week 4: Titration calculations and Titration curves

Week 5: General Evaluation.

The researchers with the assistance of the chemistry teachers would teach each sub-topic per week following the lesson plans for each sub-topic for a period of four weeks prepared by the researcher while the 5th week would be general evaluation. The experimental group was taught using guided-inquiry laboratory experiments method while the traditional teaching method was employed in the control group. A pre-test was administered to the groups to equalize their pre-knowledge about the topics to be taught in volumetric analysis to ascertain the psychometric properties of the test items (normality test, the test for homogeneity of variance, difficulty, discrimination indices and reliability coefficient). The pre-test was given to determine the students' entry knowledge of volumetric analysis prior to treatment. After the study was completed, the test used as pre-test was again administered to both groups as a post-test in the 6th week.

2.3.2. Treatment Procedure

The guided-inquiry laboratory experiments were conducted following the steps used by Blanchard, et al [4]. The steps used for the guided-inquiry laboratory experiments conducted in this study are itemized below:

1. A semi-structured problem has been given to the students group a week before. In the content of the application, basic chemistry experiments have been given in a semi-structured problem format. Students have been given a new question every week.
2. For the solution of the mentioned problems, the students have searched for an experimental process until the next laboratory practice.
3. Groups have decided on an experimental process based on their research.
4. Student groups have explained their research and experimental process. They have discussed their process with other groups and shared their ideas. At this point, students have explained all stages of experiments, the materials they have used and why they have chosen this process and materials.
5. Materials required in the experiments have been provided by the teacher.

6. During the experiments, students have taken notes related to their observations.

7. The theoretical part of the course, students have been required to explain the information they have reached by their observations and experimental data.

8. By following to the experiment, the groups have tried to answer the questions related to the experiment and the conclusions have been discussed in the classroom.

After each experiment, evaluations were conducted to ascertain students understanding for theoretical and scientific information related to the experiments conducted or lesson taught.

The control group was taught by the traditional teaching method, discussion and teacher demonstrations were the students are spectators. In the experimental (treatment) group, the teacher gave a minimal guidance were taught: using an organized, sequenced and well-designed lesson plan in diverse meaningful stages involving questioning; exploring science materials and apparatus; experimenting through guided inquiry; writing and discussion of findings of their mental construct; and appraising students' knowledge-base and understanding.

This strategy is to make identification of the respondents with their performance in test easy. Both the experimental and control groups were taught the same learning objectives. "Volumetric Analysis" was taught supported with guided-inquiry laboratory experiment; traditional teaching method was used in the control groups. The laboratory experiments related to indicators, reactions of acids and titrations were developed.

2.4. Method of Data Analysis

The statistical tools used for data analysis in the study are means used to answer the research questions; and t-test statistic used to test hypotheses 1 and 2 and for hypothesis 3 Analysis of Covariance (ANCOVA) was ; where the covariate variable was a pre-test used to control for variations in the students' prior knowledge of the subject matter. ANCOVA was used where the post test scores were the dependent variables, treatment and gender the independent variables and pre-test scores the covariates, The Statistical Package for Social Sciences (SPSS) 17.0 was used to conduct an ANCOVA to determine if the post-test scores differ between students exposed to guided-inquiry laboratory experiment method and those exposed to the traditional teaching method.

3. Results

Answering Research Question One: What are the mean achievement scores of the students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method?

Table 2 showed that the experimental and control groups mean scores of the experimental and control groups as 18.60 and 17.90 respectively for the pre-test with a mean difference of 0.70; and mean scores 36.65 and 27.76 respectively in the posttest with a mean difference of 8.89. To verify whether the difference between the two means in the post-test of the experimental and control groups was statistically significant, an Independent t-test statistic was used to test hypothesis one and Table 3 showed the result.

Ho_1: There is no significant difference between the mean achievement scores of students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method.

Table 3 showed that, the t-value of 4.22 was obtained and the p-value observed was 0.001. The p-value of 0.001 is less than the alpha value of; 0.05 level of significance. This indicated that there is a significant difference between the experimental and control groups taught volumetric analysis in favour of the experimental group. Based on this result, the null hypothesis one is therefore rejected.

Table 2. Mean achievement scores of the students taught using guided-inquiry laboratory experiments and traditional teaching method

Group	N	Mean Pre-test	Mean Post-test
Experimental (GILEM)	75	18.60	36.65
Control (TTM)	69	17.90	27.76
Mean difference		0.70	8.89

Table 3. Summary of t-test analysis of mean achievement scores of students in guided-inquiry laboratory experiments and traditional teaching method

Group	N	Mean	SD	Df	T	Sig. (2-tailed)
Guided-inquiry laboratory experiments	75	36.65	11.23	142	4.22	.001*
Traditional teaching method	69	27.76	5.93			

Statistical significance level **α = 0.05**
Significant at* **α <0.05.

Table 4. Mean Achievement scores of male and female students using both guided-inquiry laboratory experiments and traditional teaching method

Group	N	Mean Post-test
Guided-inquiry laboratory experiments method (GILEM)		
Male	42	32.96
Female	33	32.02
Traditional teaching method (TTM)		
Male	37	31.56
Female	32	30.68

Table 5. Summary of t-test analysis mean achievement scores of male and female students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method.

Group	N	Mean	SD	Df	t	Sig. (2-tailed)
Guided-inquiry laboratory experiments						
Male	42	32.96	2.59	73	1.24	0.185
Female	33	32.02	2.27			
Traditional teaching method						
Male	37	31.56	2.60	67	1.38	0.211
Female	32	30.68	2.42			

Significant at α <0.05.

Table 6. Analysis of Covariance (ANCOVA) of interaction effect of treatment and gender on students' academic achievement in volumetric analysis

Source of Variation	Sum of squares	Df	Mean Square	F	Sig
Corrected Model	30676.48	4	30676.48	2.57	.000
Intercept	61642.71	1	20560.63	33.97	.000
Pre-treatment	2736.96	1	2736.96	33.38	.085
Method	20264.64	1	26264.22	54.30	.000*
Gender	120.62	1	120.62	55.34	.135
Method*Gender	556.40	1	556.40	32.46	.113
Error	62512.35	137	15630.34		
Total	16545.36	142	55.40		
Corrected Total	79066.72	141	279.35		

Significant at* **α <0.05 S= significant, NS=Not significant.

Answering Research Question Two: What are the mean achievement scores of male and female students taught volumetric analysis using Guided-inquiry laboratory experiments and traditional teaching method?

The overall result of mean achievement scores for the experimental group taught through the guided-inquiry laboratory experiments and control group taught by traditional teaching method is shown in Table 4. The result revealed that the male and female students had mean scores of 32.96 and 32.02 respectively for GILEM and mean score of 31.56 and 30.68 for TTM. To verify the difference between the two means in both groups in the post-test was statistically significant, an independent t-test statistic was used to test hypothesis two and Table 5 showed the result.

Ho_2: There is no significant difference in the mean achievement score of male and female students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method.

Table 5 showed that, the t-value of 1.24 and 1.38 was obtained and the p-value observed was 0.185 and 0.211 respectively for guided-inquiry laboratory experiments and traditional teaching method. The p-value of both groups (GILEM and TTM) was .185 and 0.211 which is greater than the alpha value of; 0.05 level of significance. This indicated that there is no significant difference between male and female students taught volumetric analysis using guided-inquiry laboratory experiments and traditional teaching method. Based on this result, the null hypothesis two is therefore not rejected.

Ho_3: There is no significant interaction effect of treatment and gender on students' academic achievement in volumetric analysis.

After the instruction, post-test was applied to all groups to determine students' understandings of the concepts and subjects related to volumetric analysis. As seen in Table 6, the ANCOVA results indicated that there was no significant interaction effect between method of instruction and gender on students' academic achievement in volumetric analysis (F (1, 137) =32.46, p = 0.113). The null hypothesis was therefore not rejected.

4. Discussion of Findings

From Table 2 and Table 3, it was seen that the experimental group that used laboratory experiments that was student-activity-centred performed significantly better than the control group who were taught the same contents with traditional teaching method that was teacher-activity-centred. Evidence from the finding showed that guided-Inquiry laboratory experiments have significant effect on students' academic achievement in volumetric analysis than the traditional teaching method. The higher achievement of the experimental group can be attributed to the laboratory work that led to the development of the students' scientific and practical skills in science classrooms. This finding is in agreement with the work of Ensaf [7] who demonstrated that that the use of laboratory experiments are significantly more effective in science concepts than those who used the traditional lecture method in developing the skill of scientific thinking. The findings also supported Blanchard et al [4] whose works revealed that students who participated in an inquiry-based laboratory unit showed significantly higher posttest scores; had the higher scores, had stronger implementation of inquiry methods; and tended to have better outcomes than those who learned through traditional methods. The findings also supported other science educationist whose results showed significant increase in students' academic achievement when guided inquiry laboratory experiments were applied as an instructional approach [2,8,17,18]. The finding is also in agreement with other previous studies in the science literature using laboratory method whose works revealed that laboratory method had great contribution to learn the solubility subject and to eliminate the mistakes, wrong ideas etc [6,30,33]. The findings are also in line with the works of Ensaf who concluded that laboratory method has much greater significant in students' academic achievement than the traditional method which revealed that there was a significant difference on students' retention of chemistry concepts and recalling them when needed [7]. The method motivated the students and fostered the spirit of competition which was positively reflected in their achievement scores.

The findings related to gender were shown in Table 3 and Table 4. The findings revealed that gender has no significant difference or effect on students offering chemistry' academic achievement which showed that males and females benefited significantly from the instructional approach (laboratory experiments) since it was student-activity oriented which engaged them in in-depth critical thinking skills. This result supported the work by Ensaf [7] whose result indicated that the laboratory teaching method has an equal effect on both male and female students. This result also supported the works by Eze [9] asserted that gender had significant effects on students' achievement in chemistry, and showed that male students achieved higher than their female counterparts did; and that of Ifeakor [19] that showed a significant gender-related difference in students' cognitive achievement in favour of male students over their female counterparts. But, the result of this present study contradicts the findings by Aniodoh & Egbo [3] who found that the female students performed better than their male counterparts when taught using inquiry role instructional model. The findings from this study also contradict the results of Owoyemi [28] who asserted that student's achievement in chemistry course has 'nothing to do with whether the student is male or female'; and also that of Agbir [1] who found that gender was not a significant factor in the overall mean achievement rating of students in practical skills on acid-base titration. The findings from Table 6 also revealed that there was no significant interaction effect between method of instruction and gender on students' academic achievement in volumetric analysis.

The guided-inquiry laboratory experiments have positive effects on both male and female students, too. The laboratory experiments differ from other teaching strategies in that it augments achievement of the students who use this method. Moreover, this result indicates that the laboratory teaching method has an equal effect on both male and female students; indicating that it was gender friendly and not bias. It therefore showed that with the right instructional approach like guided-inquiry laboratory experiments, both male and female students can have positive academic achievement in chemistry in general and volumetric analysis in particular. This finding agreed with the work of Ensaf [7] and the reports from Hofstein & Lunetta [15,16] whose findings revealed that the laboratory has been given a central and distinctive role in science education, and science educators have suggested that there are rich benefits in learning from using laboratory activities.

5. Conclusion and Recommendations

In conclusion, the usage of guided-inquiry laboratory experiments that was student-activity centred had great role for increasing positively students' academic achievements in Volumetric Analysis more than the traditional teaching method which was teacher- activity centred. For this reason, guided-inquiry laboratory experiments should be developed based on students' lab activities for senior secondary school chemistry curriculum and usage in chemistry classes more intensively. Since traditional laboratory experiments force students to follow a lab manual, students learn scientific information with difficultly and they cannot notice the relationship between the experiment and scientific theory. As a result, students cannot reach the goals of scientific laboratory which may affect students' chemistry achievement negatively.

This study investigated the effectiveness of guided-Inquiry laboratory experiments based on constructivism played great role on increasing students offering chemistry' academic achievement in volumetric analysis. The finding indicated that guided-Inquiry laboratory experiments method can enhance more students' academic achievement in volumetric analysis than the traditional teaching method. The higher achievement of the experimental group can be attributed to the laboratory work that led to develop scientific attitudes in the students towards the learning of chemistry especially volumetric analysis, which aided in developing scientific skills for problem solving and critical thinking in students amongst others.

It also led to the students' quick understanding, recalling and retention of chemistry concepts in volumetric analysis. The guided-Inquiry laboratory experiments motivated the students and fostered team spirit among them which was positively reflected in their achievement scores. The laboratory experiments differs from other teaching strategies in that it augments achievement of the students who were all actively engaged whose results showed an equal positive effects on both male and female students.

More also, when students offering chemistry participate in experimental processes actively, their self-confidence increases and have better understanding of chemistry concepts since they are concretized. Students' active participation in laboratory work would also enhance their learning and acquisition of science process skills, critical thinking skills. One of the major problems of chemistry teachers in Nigeria in general and Jalingo in particular is the usage of the traditional teaching method continuously which makes chemistry to be abstract and perceived as difficult to students.

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

i. The use of guided-inquiry laboratory experiments which is student-activity oriented should be adopted for effective teaching and learning volumetric analysis instead of the traditional lecture approach or demonstrations which are teacher-activity oriented.
ii. The teachers should therefore be encouraged to prepare experiment for every topic and use the experiments in chemistry textbooks recommended by the ministry of education.
iii. Most teachers avoid entering laboratories and conducting experiments since they see it as too

cumbersome or time-consuming. In order to prevent this, students offering chemistry should be actively engaged in chemistry and participate in inquiry-based laboratory experiments from the beginning of senior secondary one.

iv. The teachers' should also be given adequate time for the students to perform these experiments themselves rather than demonstrations so as to enable them acquire scientific skills such as measuring, weighing, observing, etc. and also scientific attitudes such as honestly, objectivity, perseverance, etc.

References

[1] Agbir, J. D. (2004). Development and validation of an instrument for evaluating chemistry practical skills for senior secondary schools. Unpublished M.Ed thesis, University of Nigeria, Nsukka.

[2] Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: Are there differences?. *International Journal of Science Education*, *29*(14), 1745-1765. http://www.tandfonline.com/doi/abs/10.1080/09500690601075629

[3] Aniodoh, H.C.O & Egbo, J.J. (2013). Effect of Gender on Students' Achievement in Chemistry Using Inquiry Role Instructional Model, *Journal of Educational and Social Research MCSER Publishing, Rome-Italy,* 3(6): 17-21.

[4] Blanchard, M., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability? : A quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction. *Science Education*, *94*(4): 577-616.

[5] Chang, K. E., Sung, Y. T., & Lee, C. L. (2003).Web-based Collaborative Inquiry Learning. *Journal of Computer Assisted Learning,19*, 56-69.

[6] Dermircioglu, G. (2003). Preparation and implementation of guide materials concerning the unit Aids and Bases at Lycee II Level, PhD Thesis. Karadeniz Technical University. Trabzon, Turkey.

[7] Ensaf, G.S.E. (2013). The effect of Laboratory experiments on the upper Basic stage students Achievement in Physics. *Journal of Education and Practice* 4 (8) 62-71. Honorarium.

[8] Evrim U. (2016). The Effect of Guided-Inquiry Laboratory Experiments on Science Education Students' Chemistry Laboratory Attitudes, Anxiety and Achievement. *Journal of Education and Training Studies*, 4 (4): 217-218.

[9] Eze, C.C. (2008). Comparative effects of two questioning techniques on students' achievement, retention and interest in chemistry. M.Ed. project report. Department of Science Education, University of Nigeria, Nsukka.

[10] Ezeh, D.N. (2013). *Science without women: a paradox.* 75th Inaugural Lecture of the University of Nigeria, Nsukka delivered on 30th May, 2013. Nsukka: University of Nigeria Senate Ceremonials Committee.

[11] Federal Republic of Nigeria (2013). National Policy on Education (4th edition). Lagos: NERDC Press.

[12] Gaddis, B. A., & Schoffstall, A. M. (2007). Incorporating guided inquiry learning into the organic chemistry laboratory. *Journal of Chemical Education*, *84*(5), 848-851.

[13] Hart, C., Mulhall, P., Berry, A., Loughran, J. & Gunstone, R. (2000). What is the purpose of this Experiment? Or can students learn something from doing experiments? *Journal of Research Science Teaching* 37(7): 655-675.

[14] Hendrickson, T. L. (2015). Integrating responsible conduct of research education into undergraduate biochemistry and molecular biology laboratory curricula. *Biochemistry and Molecular Biology Education*, *43*(2): 68-75.

[15] Hofstein, A. & Lunetta, V.N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Education Research*, 52 (2): 201-217.

[16] Hofstein, A., & Lunetta. V. N., (2003). The Laboratory in Science Education: Foundations for the Twenty-First Century, *Science Education*, 88 (1): 28-54.

[17] Hofstein, A., Levi-Nahum, T. & Shore, R. (2009). Assessment of the learning environment of inquiry-type laboratories in high school chemistry, *Learning Environment Research*, 4, 193-207.

[18] Hofstein, A., Shore, R., & Kipnis, M. (2004). Research report: Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: a case study. *International Journal of Science Education*, *26*(1), 47-62.

[19] Ifeakor, A.C (2005). Effects of commercially produced computer assisted instruction package on students' achievement and interest in secondary school chemistry. Unpublished Ph.D Thesis. University of Nigeria, Nsukka.

[20] Irinoye, J., Bamidele, E. F., Adetunji, A. A., & Awodele, B. A. (2014). Relative Effectiveness of Guided and Demonstration Methods on Students' Performance in Practical Chemistry in Secondary Schools in Osun State, Nigeria. *Advances in Social Sciences Research Journal*, *2*(2), 21-30.

[21] Jack, G.U. (2005). A comparative study of teachers' and students' perceptions of difficulty levels of topics in secondary school chemistry. An unpublished M.Ed. thesis: Delta State University, Abraka.

[22] Jack, G. U. (2013): *Analysis of Senior Secondary School Students' experienced difficulty in science process skills acquisition in chemistry*. Unpublished PhD Thesis, DELSU, Abraka.

[23] Kanno, T. N. (2008). Gender neutral nature of modern careers. Paper presented at a workshop organised by Federal Ministry of Education for women and girls, at Owerri from 26th -28th August, 2008.

[24] Leman, T. & Burcin, A.S. (2010). Investigation the effectiveness of laboratory works related to "acids and bases" on learning achievements and attitudes toward laboratory. *Procedia Social Behavioural Science*. 2 (2010): 2631-2636.

[25] Odutuyi, M.O. (2015). Effects of laboratory learning environment on students' learning outcomes in secondary school chemistry. *International Journal of Arts and Science*, 8 (2): 507-525.

[26] Okorie, E.U. & Ezeh, D.N. (2016). Influence of Gender and Location on Students' Achievement in Chemical Bonding. *Mediterranean Journal of Social Sciences MCSER Publishing, Rome-Italy* 7 (3): 309-317.

[27] Omiko, A. (2007). Job orientation and Placement: The role of Science Education in a Developing Economy. Abakaliki: Larry and Caleb Publishing House.

[28] Owoyemi, T. E. (2007). Mathematics and chemistry senior school certificate results, gender and attitude as predictors of achievement in a physical chemistry course. *African Journal of Educational Research*, 11 (1&2), 27-34.

[29] Oyedokun, M.R. (2002). Identification of difficult topics in the senior secondary school certificate Biology syllabus as perceived by students. *The Nigerian Teachers Today*, 10(1&2): 109-118.

[30] Ozmen, H., Demircioglu, G. & Coll, R. (2009). A comparative study of the effects of a concept mapping enhanced laboratory experience on Turkish High School Students' Understanding of Acid-Base Chemistry. *International Journal of Science, Mathematics and Education*, 7(1): 1-24.

[31] Taitelbaum, D., Mamlok-Naaman, R., Carmeli, M., &Hofstein, A. (2008). Evidence for teachers' change while participating in a continuous professional development program and implementing the inquiry approach in the chemistry laboratory. *International Journal of Science Education*, *30* (5): 593-617.

[32] Tatli, Z. & Ayas, A. (2011). Effect of a visual Chemistry laboratory on students' academic achievement. *Education, Technology and Society*, 16 (1): 159-170.

[33] Tessier, J.T., & Penniman, C. A. (2006). An inquiry-based laboratory design for microbial ecology. *Bioscene*, *32*(4): 6-11.

[34] Thompson, J. & Soyibo, K. (2006). Effect of lecture, teacher demonstrations, discussion and practical work on 10th grader's attitude to chemistry and understanding of electrolysis, *Research Science and Technology Education*, 20: 25-37.

[35] WAEC. (2013). Chief examiner's report. Lagos: WAEC Press Ltd

[36] WAEC. (2014). Chief examiner's report. Lagos: WAEC Press Ltd.

[37] WAEC. (2015). Chief examiner's report. Lagos: WAEC Press Ltd.