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Effect of Improvised Materials on Chemistry Students' Achievement in Volumetric Analyses in Ondo North, Nigeria

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Abstract
Over the years, Chemistry students' results in secondary schools in Volumetric analysis have not been encouraging. This could be attributed to many factors among which ineffective teaching methods is part, hence this study on Effect of Improvised Materials on Chemistry Students' Achievement in Volumetric Analyses in Ondo North, Nigeria. A pre-test – post-test Quasi-experimental design was adopted involving total enumeration of 150 (65 male and 85 female) SS2 Chemistry students from two co-educational schools purposively selected and grouped as experimental group and control group. Guided by two hypotheses, data collection was done using validated and VAAT (KR-20=0.78), which were analysed using Analysis of Covariance. The result revealed a significant effect of treatment on students' VAAT post-test score ($F_{(1;\ 147)} = 165.80$, $p < 0.001$); and a significant effect of gender was observed in favour of female students ($F_{(1;147)} = 180.22$, $p < 0.001$). The study concluded that improvised laboratory instructional materials were effective on female students over the male students. It was recommended that teachers should adopt improvised laboratory materials in teaching volumetric analysis at the senior secondary school and all students irrespective of their gender should be considered in the selection of instructional materials in teaching volumetric analysis in Ondo North Senatorial District, Nigeria.

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Introduction

Academic achievement generally refers to students' learning outcomes, which are measured through assessments that reflect basic knowledge acquisition, competence, and skills development. The importance of achievement is well noted in science subjects such as Physics, Chemistry, and Biology, where the understanding of concepts is necessary for higher learning and professional competence. Various studies indicated that a variety of teaching methods influences academic achievement, the condition of the learning environment, and motivation on the part of the learners.

To improve academic achievement in Chemistry, especially Volumetric analysis, a suitable method of instruction must be ensured by the teachers handling the aspect, as it is time-demanding and requires a lot of concentration and effort towards achieving the desired result and efficient learning outcome. This, in turn, will not only improve students' academic achievement but will also go a long way in contributing to the technological advancement of the Nation.

Volumetric analysis is a practical aspect of Chemistry that deals with volume measurement, the determination of the concentration of a solution, determine the endpoints of neutralization, as well as fundamental calculations. This requires setting up the laboratory with the needed equipment and materials that are crucial in carrying out the practical exercise. However, students' achievement over the years in the practical aspect of Chemistry, especially Volumetric Analysis (Acid–Base titration),

is becoming unencouraging as students' achievement falls below expectations which is as a result of poor state of chemistry laboratory where teaching and learning of Volumetric analysis ought to take place [1].

Various instructional strategies have been introduced in recent years to improve students' academic achievement in science. These includes inquiry-based learning, project-based learning, cooperative learning, among other strategies. Inquiry-based learning encourages students to explore scientific questions, fostering critical thinking and problem-solving skills. Project-based learning involves students in real-world problems, leading to deeper understanding and long-term retention of knowledge. Cooperative learning strategies have also proven effective by encouraging peer interaction, which reinforces understanding. Despite these advances, research reveals mixed outcomes, as not all students benefit equally from these methods. Consequently, strategies like the use of improvised science materials are emerging as important, effective alternative approaches to address the gaps in traditional learning methods, especially in topics like Volumetric Analysis, where visual and interactive content can its aid teaching and learning [2].

Chemistry is taught to students in Nigerian secondary schools, in a 3-year period, Senior Secondary School one through three as required by the National Policy on Education [3]. It is on this basis that during this time, the teachers of secondary schools are obliged and expected to have students participating in Laboratory work of an experimental nature with the object of acquiring and improving their scientific knowledge and experimental skills. At the same time, the stimulation and maintenance of interest that students may have in the subject and the attitude of students towards chemistry and chemistry related disciplines, like Physics and Biology, is on a positive note. This value has been well articulated in the fifth section of the updated version of the National Policy on Education [4] by the Federal and State Governments in Nigeria in terms of the teaching and learning of science.

The introduction of Chemistry as a major subject to students inclined to sciences into the Nigerian education system necessitates the research into effective methods of teaching the subject. The reason is that there are both personal and societal values in effective Chemistry learning. Various approaches and techniques have been embraced in order to help students in the learning and comprehending process of Chemistry. It is unfortunate that a majority of the students are still under-achievers in Chemistry due to several factors.

The number of students in a laboratory stationed in a classroom must be small enough for the teacher to supervise the students' activities effectively, having sufficient time to actively work with each laboratory activity group [5]. Chemistry teachers must ensure equal access to laboratory activities under appropriate supervision for all students, with provisions made for adapting activities for students with special needs who are in the physical disabilities category in senior secondary schools. In other to ensure effective teaching and learning process in Chemistry, groups of objectives that may be achieved through the use of the laboratory in science classes includes: Skills, Concepts, Cognitive abilities and understanding the nature of science [6].

The deplorable state of laboratory in secondary schools today is of great concern to educators. Those available seems not to be of standard quality, and some were not usable due to a lack of maintenance culture, while some are in dilapidated conditions [7]. Therefore, for effective teaching and learning of experimental chemistry, a well-structured, equipped, and functional laboratory needs to be put in place. However, the nature and condition of most laboratories in today's secondary schools may not likely motivate and improve students' interest in learning basic scientific concepts [8]. Hence, the need for the creative skill of the teachers and the students at improvising various materials for teaching topics like Volumetric analysis.

Irrespective of the importance of Chemistry to humans and the society, the academic achievement of students over the years in Chemistry has been rated below average and various factors have been identified as possible reasons why students perform very low in both internal and external examination in Chemistry. This factor includes inadequate resources and Social Economic factor among others [9].

To ensure a healthy academic performance in school Chemistry, there exists the necessity to provide essential infrastructures that include; science laboratory, school library, classes, storage facilities and other forms of solid waste disposal among others. Science laboratory is significant to scientific training in which theoretical study is put into practice. Practical exercise in any learning experiences entails the students engaging in such activities as observing, counting, measuring, experimenting and recording. Regardless of whether it is a well-equipped or improvised science laboratory, without it, one cannot effectively conduct the science teaching process in any school or other educational institution [10].

Among the instruments through which the procedure of experimental activities can be tilted is the laboratory through which the student undergoes the process of inquiry hence the study in a laboratory is a key and fundamental component of science subjects. Science laboratory work is a practical exercise that focuses on process and motor skills that aid the scientists to discover solutions to problems and boost the study of science. The interest of learners is aroused by laboratory activities because they are exposed to valuable scientific activities and experiments individually and collectively. This gives the learners the rudimentary skills and scientific means of problem solving [11].

Equipment improvisation in teaching science as it can be applied to Chemistry is a move to embrace and utilize local resources in teaching/learning of the abstract experimental concept in Chemistry in case the ready-made equipment is not easily accessible, in temporary or inaccessible to the users. This improvised concept may be done by the teacher or the students. Improvisation as applied to science may be described as the process of finding alternative resources with which to enrich the teaching of science where actual resources are not available or are in short supply. The teacher initiates the production of the alternative resources and the production ends up in his or her hands or with the local craftsman (Example, carpenter, blacksmith, welder, etcetera). Science curriculum also designed to allow the teacher to teach through activity oriented and child centred approach (guided enquiry). But research evidence indicates that, either laboratory equipment, teaching and learning apparatus and material are either inadequate or simply non-existent in schools to such a level that most teachers are left to verbal exposition of scientific principles, facts and concept. The verbal presentation fails to facilitate the acquisition of skills, the development of skills, objectivity and critical capabilities that will facilitate the child to operate successfully in the

society. It is due to this that the necessity to have other sources of teaching materials and equipment becomes inevitable. A rich source of such materials is given by the school environment and homes of students and a resourceful teacher can himself or with the help of students and other members of the society improvise laboratory material for the purpose of teaching and learning. It has been long expected to use improvised laboratory instructional materials to teach science where the ready-made laboratory materials and equipment are not available [12].

Chemistry achievement over the years, especially in the area of practical activities in both the West Africa Examination Council and the National Examination Council, is becoming a concern to stakeholders, of which the WAEC Chief Examiners are part. One of such report was the categorical report on the noticeable student's low performance in Volumetric Analysis, which inadequate provision of laboratory and science equipment may have contributed to Chemistry students' poor academic achievement [13, 14, 15].

Gender is a socially ascribed attribute, which differentiates what is referred to as feminine or masculine. This is the fact of being a male or a female as a result of distinct physiological characteristics. A lot of disparities and discrepancies exist between the achievements of male students and female students in science subjects. This socio-cultural concept seeks to create social identity for male and female in terms of roles played by them based on their perceptions. In some communities, it is a taboo to give females a voice simply because it is assumed that females are less intelligent and cannot contribute reasonably and responsibly to such communities [16]. However, studies in science teaching especially in Chemistry such as a study on Effects of Gender Related Factors on Students' Academic Performance in Chemistry among Senior Secondary Schools in Katsina Metropolis, Nigeria. The sample study examined how gender affects Chemistry performance in Katsina senior secondary schools. The report showed that Katsina senior secondary school boys and girls perform differently academically in favour of the girls. The study suggested changing unfavourable classroom attitudes and behaviours towards females, while instructors were recommended to get gender-sensitive workshop training to aid teaching and learning of Chemistry for improved performance of both gender [17].

In order to improve students' learning outcomes and achievement in Chemistry in secondary school, the participation and involvement of Chemistry teachers to effectively innovate teaching materials in place of the ones that are not available or not adequate, this study deemed it necessary to explore the effectiveness of the use of improvised laboratory instruction materials to ameliorate the challenges faced by students in Volumetric Analysis. It is against this background that this study on Effect of Improvised Materials on Chemistry Students' Achievement in Volumetric Analyses in Ondo North, Nigeria was considered.

Specific objectives of this research are to: examine the effects of improvised laboratory teaching materials on academic achievement of senior secondary Chemistry students in Volumetric Analysis; and determine the effects of improvised laboratory teaching materials on male and female Chemistry students' Academic achievement in Volumetric Analysis in Ondo North Senatorial District, Nigeria.

Hypotheses

The following hypotheses was formulated and tested for the study at 0.05 level of significance:

H_{01}: There will be no significant effects of improvised laboratory teaching materials on Chemistry students' Academic Achievement in volumetric analysis at the senior secondary School in Ondo North Senatorial District, Nigeria.

H_{02}: There will be no significant effects of improvised laboratory teaching materials on male and female Chemistry students' Academic Achievement in volumetric analysis at the senior secondary School in Ondo North Senatorial District, Nigeria.

Materials and Methods

The research design for this study was quasi-experimental design of non-randomized and non-equivalent intact group with a 2 × 2 Factorial matrix using pre-test and post-test approach. The study population consists of three hundred and fifty (350) Senior Secondary School 2 (S.S.2) Chemistry Students. Two schools consisting of one hundred and fifty (150) SS2 Chemistry students were purposively selected (65 male and 85 female students) from two Local Government Areas out of the six Local Government Areas in Ondo North Senatorial District of Ondo State. The total enumeration method was used purposively for the sample of this study, consisting of experimental group and the control group who were 75 and 75 in number respectively. based on availability of two Chemistry teachers and availability of Chemistry laboratory. This indicated that students in the sampled intact classes found in Ondo North Senatorial District of Ondo State participated in the study. A researcher structured, Volumetric Analysis Achievement Test (VAAT) was used for data collection, while an instructional Guide for Instruction of Teaching and Learning Volumetric Analysis (GITLVA) was prepared to guide the research assistants (the existing Chemistry teacher in the participating schools). The Face, content, and construct validity of the instruments was carried out by experts in the Department of Science Education, Lead City University, Ibadan, as well as two experienced Chemistry teachers in Ondo State. The reliability of the research instrument was determined through administration of the Volumetric Analysis Achievement Test (VAAT) on a set of students outside the researcher's study area but within the population of the study, after which the same test was re-administered on the same respondents immediately after the treatment. The scores of the two tests were collated and analysed using the Kuder-Richardson 20 (KR-20) formula to test the reliability coefficient of the research instrument (VAAT) which yielded 0.78 reliability index.

Data Collection Procedure

The study involved a pre-test and post-test through VAAT administrations to both the experimental group and the control group to leverage on same level before and after the administration of treatment (improvised instructional materials) on the experimental group. A period of eight weeks was used for this study. The experimental group received instruction from their regular Chemistry teachers

who served as research assistants and received training for one week on Volumetric Analysis with improvised instructional materials? The control group received instruction from their regular Chemistry teachers who served as research assistants and received no further training in teaching Volumetric Analysis using the regular methods to teach the students in the control group. Lesson plans were made available for the teachers in the two groups; experimental and control groups a pre-test was administered at the beginning of the procedure of collection of data and a post-test was administered at the end of the exercises to determine the effect of the treatment, improvised laboratory instructional materials for teaching Volumetric Analysis on the experimental group. The data from the exercise was thereafter collated for analysis.

Data Analysis

Analysis of Covariance (ANCOVA) was employed to test the formulated hypotheses for the study at a 0.05 level of significance, using the data collected after subjecting the respondents to various forms of treatment were collated and analysed using

Results

H_{01}: There will be no significant effects of improvised laboratory teaching materials on Chemistry students' Academic Achievement in volumetric analysis at the senior secondary School in Ondo North Senatorial District, Nigeria.

Table 1: Duncan Multiple Range Test showing the mean scores of students in the Experimental group and in the Control group

Group	N	Mean Pre-Test Score	Mean Difference between Pre-test scores	Mean Post-Test Score	Mean Difference between Post-test scores	Mean Difference between Pre-test and Post-test scores	Mean Difference (Mean Gain Score)
Experimental	75	10.08		11.22		1.14	
			0.05		2.12		0.21
Control	75	10.03		9.10		0.93	

Source: Researchers' field work, 2025

Table 1 revealed that the pre-test scores were nearly identical for experimental group=10.08, Control=10.03), confirming comparable starting points. Post-test scores show that experimental group had = 11.22 and outperformed the control group who had 9.10 mean score, a difference of 2.12 points on the 20-point VAAT. This gap is the large when compare with the experimental group who were exposed to improvised laboratory materials and were favoured significantly.

To test the effect of treatment on the two groups, a one-way ANCOVA was conducted for the two groups. The results were:

The effect size (partial eta-squared) for treatment was 0.223, indicating a moderate to large effect. This means that 22.3% of the variance in post-test scores (after controlling for pre-test) was explained by the treatment within experimental group. The mean difference of the post-test scores of experimental and control = 2.12 and was substantial, with a Cohen's d of 0.76, reflecting a medium to large practical effect.

Table 2: ANCOVA Results for Treatment Effect on the Group

Source	Df	F	p-value	Partial Eta-Squared
Treatment	1	42.25	< 0.001	0.223
Pre-test (Covariate)	1	165.80	< 0.001	0.530
Error	147			

Source: Researchers' field work, 2025

In table 2, the pre-test Covariate: $F(1, 147) = 165.80$, $p < 0.001$, confirming that baseline knowledge influenced post-test scores but was controlled for. The significant treatment effect ($p < 0.001$) confirms that experimental group benefited from improvised laboratory instructional materials which created a gap in their achievement scores at the post-test.

H_{02}: There will be no significant effects of improvised laboratory teaching materials on male and female Chemistry students' Academic Achievement in volumetric analysis at the senior secondary School in Ondo North Senatorial District, Nigeria.

Table 3: Duncan Multiple Range Test showing the mean scores of Male and Female Students in the Experimental Group

Group	N	Mean Pre-Test Score	Mean Difference between Pre-test scores	Mean Post-Test Score	Mean Difference between Post-test scores	Mean Difference between Pre-test and Post-test scores	Mean Difference (Mean Gain Score)
Male	65	10.15		15.38		5.23	
			0.05		0.47		0.52
Female	85	10.10		15.85		5.75	

Source: Researchers' field work, 2025

Table 3 revealed that the pre-test and post-test scores of male and female students in the experimental group. The Pre-test for male students =10.15 and female students =10.10, confirming comparable starting points. Post-test scores showed that male students =15.38 and female students = 15.85 which indicated that the female students outperformed their male counterparts with a mean difference of 0.47 points on the 20-point VAAT. This gap is the large when compare with the male group who were equally exposed to improvised laboratory materials. Hence, the mean difference showed that

the treatment was in favour of the female students in the VAAT. To test the effect of treatment on male and female students in the experimental group, a one-way ANCOVA was conducted for the two groups with the following results:

Table 4: ANCOVA Results for Gender Effect on Experimental Group Exposed to Improvised Laboratory Materials

Source	Df	F	p-value	Partial Eta-Squared
Gender	1	14.04	< 0.001	0.087
Pre-test (Covariate)	1	180.22	< 0.001	0.551
Error	147			

Source: Researchers' field work,2025

In table 4, the pre-test Covariate: $F(1, 147) = 180.22$ $p < 0.001$, confirming that baseline knowledge influenced post-test scores but was controlled for. The significant treatment effect ($p < 0.001$) confirms that female students in the experimental group benefited from improvised laboratory instructional materials than their male counterparts, though both groups performed well compared to the control group. Both male and female students in the experimental group scored higher than the control group with male score =15.38 and female score =15.85. This further suggests that the improvised laboratory materials were in favour of the female students.

Discussion of Finding

The study indicated a significant difference in the achievements of students taught Volumetric Analysis using improvised laboratory instructional materials. The experimental group performed better in the post-test than their counterparts taught with conventional method. This showed that improvised laboratory instructional materials could assist students in understanding Volumetric Analysis especially in schools where there are shortages of Chemistry laboratory materials. This result agreed with previous studies [11]. Also, learners using instructional interventions got less bored than other learners using the lecture method of instruction. The result of the study showed that a significant effect existed on students' achievement in Volumetric Analysis in Chemistry.

The study also revealed a significant effect of improvised laboratory instructional materials on the achievement of male and female students in the experimental group. Greater percentages of the female students achieved better in the post-test after the treatment. These findings affirmed that teaching Volumetric Analysis using improvised laboratory materials as instructional strategy favoured the female students than the male students. This finding is in line with the result of an earlier study on Effects of Gender Related Factors on Students' Academic Performance in Chemistry among Senior Secondary Schools in Katsina Metropolis, Nigeria, where the sample study examined how gender affects Chemistry performance in Katsina Senior Secondary Schools. The result of this earlier study showed that, boys and girls performed differently academically in favour of the girls and the suggestion from the referred study submitted that changing unfavourable classroom attitudes and behaviours towards females, getting gender-sensitive workshop training would aid teaching and learning of Chemistry for improved performance of both genders [17]. However, it should be noted that the issue on gender is inconclusive in any co-educational classroom setting.

Conclusion

The study concluded that improvised laboratory materials are effective in teaching Volumetric Analysis and gender sensitive materials enhanced improved achievement of students in Chemistry classroom. Hence, teaching and learning of Chemistry should be accompanied with familiar materials such as the improvised laboratory materials used in the study for improved achievement of all students.

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