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Investigating the Effectiveness of Flipped Classroom Strategy on Secondary School Students' achievement of chemical equilibrium in Chemistry

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Abstract. Looking at the tremendous impact that advancement in technology has made in the educational sector, this research investigated the effectiveness of flipped classroom strategy on secondary school students' achievement of chemical equilibrium in Chemistry. The research employed a quasi-experimental design featuring a pre-test post-test non-equivalent control group. The study comprised 85 Senior Secondary School, 11chemistry randomly selected from two secondary schools. The assessment tool utilised was the Chemistry Chemical Equilibrium Test (CCET). The instrument had a reliability index of 0.79, as determined by the Kuder-Richardson (k21) formula analysis. The data were analysed using descriptive statistics of the mean to address the study issues, while independent sample t-tests was employed to evaluate the proposed hypotheses. The study's findings indicated that Chemistry students instructed using a flipped classroom instructional strategy achieved higher scores than those instructed with lectures method; additionally, no significant difference in the performance of male students taught with the flipped classroom instructional strategy. The study concluded that the flipped classroom instructional strategy is more effective in enhancing chemistry students' achievement compared to the lecture method. It is recommended that both teachers and students receive adequate training to develop the necessary skills for implementing this strategy and that they be encouraged to utilise it in teaching and learning.

Keywords: Flipped Classroom Instructional Strategy, Sex, Chemical Equilibrium, Achievement, Quasi-Experimental Design.

1. Introduction

Chemistry is one of the important science subjects that is made compulsory for all science students at the secondary school level in Nigeria. A credit pass in Chemistry is a requirement for those who wished to study Chemistry related courses at the higher institution of learning in Nigeria. Chemistry is a subject that deals with the study of matter, the substances of which matter is made up of; the investigation of their properties, the reactions which matter undergo, how they behave during reactions and the changes which occurs during reaction to form new substances. It is a fundamental scientific discipline that plays a crucial role in various aspects of human life, including health, industry, agriculture, and environmental sustainability. According to Ogunleye & Adebayo, (2019) chemistry as a core science subject is essential for technological advancement, industrial growth, and the development of critical sectors such as pharmaceuticals, petroleum, and manufacturing.

Beyond education, chemistry plays a crucial role in Nigeria's industrial and economic sectors. For example, in the petroleum industry which is a major contributor to Nigeria's economy, the knowledge of Chemistry is required since the petroleum sector heavily relies on chemical processes for refining crude oil and producing petrochemicals. Additionally, Ogunleye & Okoro, (2022) are of the view that the knowledge of chemistry is fundamental in addressing environmental challenges, such as pollution control, waste management, and sustainable Agricultural practices.

Despite its significance, chemistry education in Nigeria faces several challenges, including inadequate laboratory facilities, a shortage of qualified teachers, and students' negative attitudes toward the subject due

to its perceived difficulty (Ajayi et al., 2020) and the use of inappropriate teaching methods. Research findings have shown that poor performance in chemistry among Nigerian students is often linked to ineffective teaching methods, lack of hands-on experiments, and reliance on rote memorization instead of conceptual understanding (Agboro-Eravwoke, 2024). The study of chemistry also requires students to possess good level of science process skills to be able to conduct experimental verification into natural phenomena. These challenges have been reflected in the achievement of secondary school Chemistry students which over the years is greeted with several appalling remarks from Chief Examiners.

The reports of the West African Secondary School Certificate Examination (WASSCE) Chief Examiner's shows that from 2007-2012, the percentage of students who obtained a credit pass in chemistry was below 50% except in 2010. The reports further revealed a continual decline in the achievement of students from 2013 to 2016 from 72.34% to 57.74% of the percentage number of students with credit passes and further decline below 50% in 2018 and 2019. In 2020, the failure rate was 42.61%; in 2021, the failure rate was 33%; in 2022, indicated that only 38.68% of students passed chemistry (WASSCE, 2022).

One of the ways through which students' achievement is to be improved on in Chemistry is through the use of instructional teaching strategies which will promote hands on activities, social interaction and collaboration during the teaching and learning of Chemistry since most of the concepts in Chemistry are abstract like the concept of Chemical Equilibrium.

Chemical equilibrium is a fundamental concept in chemistry that describes the state in which the rates of the forward and reverse reactions are equal, leading to constant concentrations of reactants and products. This concept is crucial in understanding various chemical processes, including industrial reactions, biological systems, and environmental Chemistry. In Nigeria, chemical equilibrium plays a significant role in industries such as petroleum refining, fertilizer production, and pharmaceutical manufacturing. The country's oil and gas sector, which is a major contributor to the economy, relies heavily on equilibrium principles in refining crude oil and producing petrochemicals. Additionally, the production of ammonia and urea fertilizers, essential for Nigeria's agricultural sector, depends on the Haber process, a well-known example of chemical equilibrium.

Despite the importance of chemical equilibrium, studies have shown that many students in Nigerian secondary schools and universities struggle with understanding this concept due to inadequate laboratory facilities, insufficient instructional materials, and ineffective teaching methods (Ajayi & Adebayo, 2020). Furthermore, environmental concerns such as air pollution and water contamination in Nigeria can be better managed through an understanding of chemical equilibrium. For instance, equilibrium concepts are applied in controlling the emission of gases from industrial processes and in water treatment technologies (Eze & Uche, 2022). This has led to a growing concern about the quality of Chemistry education and the need for improved teaching strategies that will promote hands on and minds on activities in order to make concept learnt to be concrete through learning experiences. One of such strategies that could achieve this is the flipped classroom instructional strategy.

The flipped classroom instructional strategy is a student-centered teaching approach that reverses the lecture method of instruction. Instead of delivering lectures in class, students access instructional materials—such as pre-recorded videos, online resources, and assigned readings—before and during classes, while classroom sessions are used for discussions, problem-solving, and collaborative activities. This method promotes active learning, deeper understanding, and better student engagement compared to the lecture-based teaching (Ogunleye & Adeyemi, 2020), through the learning experiences that the students are engaged in. When flipped classroom instructional strategy is employed, the various activities that students are exposed to fosters critical thinking skills, improve their participation in the teaching and learning process, and encourages independent learning. These are essential factors that promotes academic success. Looking out the difference between the pattern of content presentation of the flipped classroom instructional Strategy and that of the lecture method which is teacher centered and widely used in the teaching of Chemistry in Nigeria, it becomes necessary to try out the method and determine if it will improve students' achievement in the concept of Chemical equilibrium in Chemistry. It is against this background that this study seeks to investigate the effectiveness of flipped classroom strategy on secondary school students' achievement of chemical equilibrium in Chemistry.

1.1 Statement of Problem

One of the challenges that have been found in today's chemistry education is the usage of ineffective

instructional strategies (Agboro-Eravwoke, 2020) and this has accounted for the decline in chemistry students' examination as yearly reported by external examination bodies. In order to overcome this challenge and improve students' achievement in Chemistry, it becomes necessary to try out teaching methods that are student centered. One of such methods is the flipped classroom instructional strategy. When the flipped classroom instructional strategy is employed, the various activities that students are exposed to fosters critical thinking skills, improve their participation in the teaching and learning process, and encourages independent learning which are essential factors that promotes academic success. Base on this, the statement of problem therefore is "What effect will the use of flipped classroom instructional strategy have on chemistry students' achievement in chemical equilibrium?

1.2 Research Questions

- What is the difference in the mean achievement scores of students taught using flipped classroom instructional strategy and lecture method?
- What is the difference in the mean achievement scores of male and female students taught using flipped classroom instructional strategy?

1.3 Hypotheses

$H0_1$: There is no significant difference in the mean achievement scores of students taught using flipped classroom instructional strategy and lecture method.
$H0_2$: There is no significant difference in the mean achievement scores of male and female students taught using flipped classroom instructional strategy.

2. Methodology

The study adopted pre-test posttest non-equivalent control group quasi-experimental. In this design, there was no randomization of subjects in to groups rather intact classes were used to avoid disruption of the school activities. The Independent variables for this study are the teaching methods which are flipped classroom strategy (FCS) and lecture method (LM) while the Dependent variable (DV) is students' academic achievement and the intervening variable is sex. The population of the study is made up of 1,206 senior secondary year two (SS2) students offering chemistry in all the 29 public secondary schools in Akoko-Edo local government area of Edo state for the 2024/2025 academic session. The sample for the study were 85 students Senior Secondary School 2 students, comprising of 55 males and 30 females from two intact classes using sampling. In doing this, the names of the schools in the local government were listed in a blind bag from which two schools were selected. The instrument for data collection was the Chemistry Chemical Equilibrium Test (CCET). The CCET is made up of two sections. Sections A and B. Section A elicits information on students' bio-data while section B is made up of 20 items drawn from West African Secondary School Certificate Examination (WASSCE) past questions with multiple choice options of option A-E. These options contained one right answer and four distracters. For the instrument, each correct answer was scored 2.5, the maximum score is 50.

The face validity of the instrument was done by three experts: One experienced Chemistry teacher, one Science Educator and one measurement and Evaluation expert. They were given the instrument alongside the research question and hypotheses to determine if the items will be able to generate data needed to answer the research questions and test the hypotheses. They all agreed that the instrument will be able to generate data needed to answer the research questions and test the hypotheses. The content validity of the instrument was ensured through the use of table of specification based on blooms taxonomy to ensure content coverage and were rightly represented.

The reliability of the instrument was determined after the instrument were administered on twenty students who were not part of the study and the data collected were analyzed using Kuder-Richardson 21 formula which yielded an r –value of 0.79. With these values high than 0.70, this instrument is judged reliable.

Treatment Procedure

In implementing the flipped classroom strategy in the classroom, the experimental group teachers followed these steps:
Step 1: Introduction: Teacher introduced the concepts to be taught using Pre-recorded videos
Step 2: Engagement: Students were made to surf the net to access online audio-visual resources
Step 3: Explanation: Teacher ask students to explain the concept base on the understanding from the pre-recorded and online –visual resources.
Step 4: Extension: Teacher gives elaborate explanation of the concept taught citing examples from the online materials and also making references to activities in the environment
Step 5: Evaluation: Teacher asks students question to determine if they understood the concepts taught and also give room to students to ask their questions.
Step 4: Elaboration: Teacher further group the students into various groups and asked them to give a written explanation of what they have learnt.

3. Results

Table 1: Mean and Stand deviation statistics showing chemistry secondary students' achievement in Chemical Equilibrium.

Teaching Methods	N	Mean	Mean Diff	SD
Flipped Classroom	48	26.38		6.06
			2.69	
Lecture Method Classroom	37	23.69		5.18

Table 2 shows that the chemistry students taught in the flipped classroom instructional strategy had a mean score of 26.38and a standard deviation of 6.06 while their counterpart taught with the lecture method had a mean score of 23.69 with a standard deviation of 5.18. There exists a mean difference of 2.69 in favour of the flipped classroom instructional strategy. To determine if this difference was significant, independent sample t-test statistics was used to test $H_{01}$and the result is shown in table 2.

$H0_1$: There is no significant difference in the mean achievement scores of students taught using flipped classroom instructional strategy and lecture method.

Table 2: Independent sample t-test statistics showing chemistry secondary school students' achievement in Chemical Equilibrium.

Teaching Methods	**N**	**Mean**	**Mean Diff**	**SD**	**df**	**tcal**	**Sig (2-tail**
Flipped Classroom	48	26.38		6.06			
			2.69		83	1.200	0.003
Lecture Method Classroom	37	23.69		5.18			

Table 2 shows that the observed difference in table 1 is significant since the calculated sig value of 0.003 which is less than 0.05 was obtained. With this, $H0_1$ there is no significant difference in the mean achievement scores of students taught using flipped classroom instructional strategy and lecture method is therefore rejected.

Research Question 2: What is the difference in the mean achievement scores of male and female students taught using flipped classroom instructional strategy?

Table 2: Independent sample t-test statistics showing male and female chemistry secondary school students' achievement in Chemical Equilibrium.

Sex	N	Mean	Mean Diff	SD
Male	26	20.98		3.81
			0.43	
Female	22	21.41		6.04

Also, the table shows that the male students had a mean score of20.98 and a standard deviation of 3.81while their female counterpart had a mean score of 21.41 with a standard deviation of 6.04. There exists a mean difference of 0.31 in favour of the females. To determine if this differences are significant, independent sample t-test statistics was used to test H_{02}

$H0_2$: There is no significant difference in the mean achievement scores of male and female students taught using flipped classroom instructional strategy.

Table 3: Independent sample t-test statistics showing male and female chemistry secondary students' achievement in Chemical Equilibrium.

Sex	**N**	**Mean**	**Mean Diff**	**SD**	**df**	**tcal**	**Sig (2-tail**
Male	26	20.98		3.81			
			0.42		46	0.660	0.520
Female	22	21.41		6.04			

Table 3 shows that the difference between the male and female chemistry students' achievement is not significant since the calculates significant value of 0.520 is greater than 0.05 alpha level of significant with this, H_{02} which states that there is no significant difference in the mean achievement scores of male and female students taught using flipped classroom instructional strategy was not rejected.

4. Discussion of Findings

The first finding of the study as seen in table 2 shows that there is a significant difference between the mean achievement scores of students taught Chemistry Chemical equilibrium with flipped classroom instructional strategy and Lecture Method. The students taught with flipped classroom instructional strategy had higher mean scores than their lecture method group counterparts (Table 1). This difference may be as a result of the enriched technology learning environment that the students were exposed to. This must have made them have concrete learning experience in the teaching and learning environment more than their counterparts in the lecture method groups. This findings aligned with the findings of Chado et al. (2024) Makinde (2024), George and Osuafor (2023), Omeje (2023) Bukar and Isa (2023), Ibenegbu and Ugwu (2022) whose studies showed that the usage of flipped classroom had significant influence on students achievement and also collaborate with the finding of Agboro-Eravwoke (2024) whose study showed that students exposed to computer assisted instruction performed better than their counterparts taught with lecture method.

The second finding of the study as seen in table 4 shows that there is non-significant difference between the mean achievement scores of male and female students taught Chemistry Chemical equilibrium using flipped classroom instructional strategy. This lack difference shows that the enriched technology learning environment that the male and female chemistry students were exposed to had equal impact on them irrespective of their sex. This finding collaborates those of Udu and Unwaha (2024) and Bello (2023) whose findings showed a is significant difference between the mean achievement scores of male and female students taught using flipped classroom and that of Agboro-Eravwoke (2024) whose study showed that male and female students exposed to computer assisted instruction did not significantly outperform one another,

5. Conclusion

Looking and the tremendous impact made by advancement in technology in every sphere of life, and the positive impact it has in educational sector in terms of lesson delivery, one will conclude from the findings of this study that the flipped classroom instructional strategy is more suitable for the teaching of chemical equilibrium in Chemistry than the lecture method.

6. Recommendations

It is there recommended that governments in Nigeria should make available facilities that will foster the usage of clipped classroom in schools and also train teachers through organization of seminar and workshop for them to acquire the skills needed for its usage.

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