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Collaborative Classrooms: The Impact of Peer Instruction on Secondary School Students' Learning Outcomes in Chemistry

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A B S T R A C T

This study investigated the impact of peer instruction on students' achievement in senior secondary school chemistry in Lagos State, Nigeria. The study population comprised secondary school chemistry students in the state. It adopted a quasi-experimental design and used the Chemistry Achievement Test and questionnaire to obtain information from the students. The data collected were analysed using mean, percentages and standard deviation, while inferential statistics were used to test the hypotheses. The findings showed a positive impact on the academic achievement of students who received peer instruction compared to those who did not. The study further deduced that students have a positive perception and attitude toward using peer instruction strategy in the learning of chemistry. It was recommended that secondary school teachers should adopt the use of peer instruction strategy.

1. Introduction

Education is undeniably one of the cornerstones of society, serving as the bedrock on which progress and development are built. Education is an important part of the human development process as it signifies the acquisition of knowledge, skills and competencies that are pivotal for change in individuals and society. Therefore, every person needs to receive quality education (Sustainable Development Goal 4), and learning that will enable him or her to succeed in life and contribute to society (UNESCO, 2016; UNESCO, 2020; Filmer & Rogers, 2019).

Science education has been the main focus of modern education, whereby students are equipped with the relevant knowledge, skills and attitudes for them to know how to respond to many scientific and technological situations in the world of today. To achieve this, knowledge of science must be pursued to build students' capacity to think scientifically and solve real-life problems (Schwarz et al., 2017; Oguoma et al., 2019). Thus, there is the need to always consider the two essential

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components of scientific education, which are the process and the contents. Many approaches of passing scientific knowledge to students lack the essential processes that can make them master the content. If the process or method of teaching is not efficient, the learner will be shallow in knowledge and this has affected the output of science education. Therefore, scientific education needs to be reinforced (Adebayo et al., 2020; Oladejo et al., 2022). On the other hand, the scientific content, which the learner must be equipped with must include scientific theories, concepts, laws, principles and equations.

Chemistry is a central science and is required for several professions including medical science, pharmacy, engineering, food science, and agriculture. Therefore, chemistry education plays a vital role in preparing students for careers in science, technology, engineering, and mathematics (STEM). It also informs citizens about critical issues like environmental sustainability and public health. However, it has been observed that students' performance in chemistry is below the expectation considering the unique nature of chemistry and the critical role it plays in the development of any country. There is a need for science educators to come up with strategies for encouraging their students to have a positive attitude towards science and science-related subjects. They should also use effective teaching strategies that best fit particular objectives to facilitate the transfer of knowledge (Brown, 2017; Njoku & Ugwu, 2017). Okunuga (2021) also noted that a host of challenges affect the effective teaching and learning of chemistry in secondary schools such as lack of, or non-equipped chemistry laboratories, and instructional materials. Therefore, effective chemistry education must address the challenges of student disengagement, difficulty in conceptual understanding, and inadequate teacher preparation.

To ensure that all chemistry students have access to high and quality learning opportunities that will enhance their conceptual understanding, the methodologies for teaching the subject must take diversity, equity, as well as inclusion learning strategies into consideration (Kind, 2016; Hanson, 2017). Also, the learning of chemistry requires that students are taken through both the theoretical and the practical aspects of the subject and they are engaged in inquiry, exploration and experimentation for a comprehensive understanding and assimilation. This is not easily achieved by the lecture method only but requires some other novel methodologies that must engage the students' thinking and involvement in the class activities. It has been established that strategies of learning delivery are central to improving learner's performance, achievement, and the acquisition of learning skills (Igboanugo, 2021). Education is the most important factor in a person's life, because it can distinguish a person's ability to think (Bella, 2023).

All science teaching approaches are categorized into two, namely; teacher-centred and student-centred approaches. Therefore, the teaching approach adopted by any science educator must have a defined overall plan of action, guiding philosophy and methodology with the view of enhancing students' knowledge. While there are varieties of approaches to teaching science, the choice of the teaching approach is largely determined by matching the teaching and learning objectives with students' cognitive level and learning conditions in the classroom

(Lehesvuori et al., 2018; Okebukola et *al.*, 2020). Teaching approaches differ across countries based on the subject matter, the skills being imparted, and the students' ability and eagerness to learn. The instructional strategy a teacher selects is influenced by factors, such as the material to be covered, the objectives the teacher aims to reach, the availability of educational resources, the language of instruction, the teacher's capacity and readiness to adapt when conventional teaching tools are lacking (Ibrahim, Hamza et al., 2018; Darling-Hammond, 2017; Minstrell, & van Zee, 2017). In Vocational High Schools in the field of tourism expertise, chemistry subjects are not studied directly as subjects, but are integrated into applied science subjects (Afinda, 2023).

The lecture teaching method, which is the earliest known teaching method, is concentrated on the teacher's involvement alone. The teacher typically addresses the learners without interruption and the main task of the learners is to listen carefully (Serin, 2018; Muganga & Ssenkusu, 2019; Okebukola et *al.*, 2020). However, Nwosu & Okeke, (2019) argued that the lecture method is highly effective in instructing scientific procedures such as reading a thermometer, preparing gases like hydrogen and carbon dioxide, conducting salt analysis, performing volumetric analysis, etc. It helps students develop abilities by giving them instructions on what to do and how to do it consistently until they understand and become proficient in the procedures (Igwe, 2018; Cakir & Crawford, 2017). Nevertheless, findings from different studies revealed that students taught with the lecture method perform woefully in chemistry and other science subjects (Udu, 2018; Byusa et al., 2020; Oladejo, 2020).

Peer Instruction is closely linked to the flipped lecture method and is especially well-researched in mathematics, biology, and the physical sciences (Han & Bhattacharya, 2017; Knight & Brame, 2018). According to Gok (2018), when students discuss and share ideas, it helps them to arrange these ideas and they are able to recall the ideas they find difficult to remember on their own. Hence, peer instruction is a technique where students work with each other in explaining contents, and as a result, they can gain a better understanding of the content area in question (Randle & Overbaugh, 2016; Harrison et al., 2018). Peer instruction emphasizes knowledge and empowers students to take ownership of their education. It is one of the educational strategies that has the potential to enhance the acquisition of social skills among secondary school students (Okunuga & Nwafor, 2022).

Lev Vygotsky's in his theory posits that culture and society a play part in the cognitive networking of learners (Veraksa & Veraksa, 2018). He believed that children acquire knowledge through social interactions. He sees an opportunity to help them increase and enrich their demand activities. The structure of engagement based on this theory of learning and development has a strong connection to the peer instruction strategy in the following ways:

1. Zone of Proximal Development (ZPD): The instruction that came with the ZPD, suggests that learning of children is only effective when done somewhat

over their head, and beyond their current ability. Peer instruction does this because it puts the students together with other students who can help out.
2. Collaborative Learning: In scaffolding learning for the general achievement of course objectives, students work collaboratively to achieve the intended learning outcomes as envisaged by the peer education approach.
3. Language and Dialogue: According to Vygotsky’s theory of development, language plays a significant part in the development of cognitions. This is in line with Vygotsky’s postulations since the peer instruction technique makes the students talk amongst themselves, reason, and explain in their own words.

By aligning with Vygotsky's theory, peer instruction strategy provides an environment where students can learn successfully, build on each other's strengths, and develop critical thinking and communication skills. The main purpose of this study is to examine the effect of peer instruction on student’s achievement in secondary school chemistry.
The specific objectives are to:

i.) investigate the effect of peer instruction on students’ achievement in chemistry.
ii.) examine students’ perception towards using peer instruction based on gender and previous experience.
iii.) examine the attitudes of students towards using peer instruction based on gender and previous experience.

2. Methodology

The study employed a quasi-experimental research design. The participants were 244 chemistry secondary school students selected from five public schools in an Education District in Lagos State. Three schools served as the experimental group while two served as control. The Chemistry Achievement Test (CAT) consisting of twenty multiple-choice tests was developed by the researcher to effectively measure students' knowledge in organic chemistry. Pre-tests and post-tests were administered to both the experimental and control groups, but only the experimental group received the peer instruction intervention while the control group was taught by the lecture method. The questionnaire was administered to only the experimental group after the intervention. The CAT was given under a standardized environment to both the control and experimental groups so that the pre-test, as well as post-test achievement, would reflect the effect of using peer instruction.

Peer Instruction Attitude Survey (PIAS), explored students' perceptions, experiences, and attitudes towards peer instruction as a teaching methodology. which made use of a 5-level Likert scale; where 5 represents "Strongly Agree, 4 - “Agree”, 3 - “Neither agree nor disagree”, 2 - “Disagree”, and 1 represents "Strongly Disagree". The outcome of the chemistry achievement tests and the data collected from PIAS were subjected to statistical analyses. The study made use of Eric Mazur's peer instruction approach. The students in the class were divided into groups with five students in a group. The intervention consisted of six stages.

First, the teacher asked a conceptual question on organic chemistry, which is the topic selected for this study. Second, the students were allowed to think for some minutes. Third, the students responded individually by writing the answer to the question on a piece of paper and then submitted the paper to the teacher. The teacher takes a poll, if the majority of the students get the answer correctly, the teacher goes back to stage one. However, if the responses show that the concept is not well understood, the teacher moves to the fourth stage. Figures 1 and 2 show the classroom activities of the students.

Figure 1. Peer Instruction Classroom Figure 2. Group Discussion

Figures 1 and 2 show the classroom activities of the students. The fourth stage is the collaborative classroom where the students can discuss their answers with their peers in the group. They are allowed to justify their answers and reason together. In response to this, students rewrite their answers according to their group findings and then the group present the teacher with revised answers. This is stage five and it proves to be useful in reiterating some concepts as well as encouraging students to work in groups among themselves. The sixth stage is where the teacher shares the answers given by the groups with the whole class and further explains the answers as well as the reasoning behind them. This stage can help to guarantee that the students have understood the concept without any misunderstanding.

3. Results and Discussion

Research Question 1: What is the effect of peer instruction on students' achievement in chemistry? The means of both the experimental and control groups are compared as shown in Table 1.

Table 1. Comparison Between The Means of Control and Experimental Groups

	Pre-test			Post-test		
Group	**Mean**	**Std. Deviation**	**N**	**Mean**	**Std. Deviation**	**N**
Control	6.5231	2.09991	65	9.154	3.1237	65
Experimental	6.5000	2.05027	168	11.946	3.8571	168

Dependent Variable: Post-test

From Table 1, the mean of the experimental group (11.946) is higher when compared with that of the control group (9.154), showing that there is an improvement and positive effect in students' achievement after exposure to peer instruction. The mean gain of the experimental group is 5.446 (83.8%) as against the mean gain of 2.6309 (40.4%) by the control group. We deduce from the percentage mean gain that the effect of peer instruction treatment on students in chemistry achievement test is as twice that of the lecture method.

Furthermore, the effect of the peer instruction strategy is tested with the following hypothesis. Ho_1: There is no significant difference in academic achievement between students who received peer instruction treatment and those who did not. To test this hypothesis, we first test to see whether the covariates meet the requirements to run the ANCOVA. The pre-test cannot be statistically significantly different across the level of the independent variables, that is, between the control and the experimental groups, the pre-test should not be significantly different. The analysis in ANOVA takes the Pre-test as the dependent variable and the result is shown in Table 2.

Table 2. Tests of Between-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	.025[a]	1	.025	.006	.939
Intercept	7948.660	1	7948.660	1865.588	.000
Group	.025	1	.025	.006	.939

a. R Squared = .000 (Adjusted R Squared = -.004)

b. Dependent Variable: Pre-test

The ANOVA analysis in Table 2 gives a p-value of 0.939, which is non-significant. That is, there is no statistically significant difference between the control and the experimental group in the pre-test scores, which satisfies the first requirement to use ANOVA. The second test to be satisfied is to check the homogeneity of regression. The p-value is also expected not to be statistically significant. To test for this, Tables 3a and 3b are generated.

Table 3a: Test for homogeneity of assumption of regression
Levene's Test of Equality of Error Variances[a]

Dependent Variable: Pre-test			
F	**df1**	**df2**	**Sig.**
.016	1	231	.900

Table 3a gives the Levene's test of equality of variance with a non-significant p-value of 0.900 which is also confirmed in Table 3b with the p-value of the group as 0.171, which is non-significant.

Table 3b: Tests of Between-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	64.083[a]	2	32.042	8.009	.000
Intercept	607.055	1	607.055	151.738	.000
PostTest	64.058	1	64.058	16.012	.000
Group	7.537	1	7.537	1.884	.171
Error	920.157	230	4.001		
Total	10848.000	233			
Corrected Total	984.240	232			

1. R Squared = .065 (Adjusted R Squared = .057)
2. Dependent Variable: Pre-test

Hence, the assumption of homogeneity is satisfied. We therefore examine the ANCOVA of the chemistry achievement test scores between the groups as given in Table 4.

Table 4. Tests of Between-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	567.843[a]	2	283.921	22.467	.000	.163
Intercept	1192.291	1	1192.291	94.345	.000	.291
PreTest	202.350	1	202.350	16.012	.000	.065
Group	368.227	1	368.227	29.138	.000	.112
Error	2906.629	230	12.638			
Total	32532.000	233				
Corrected Total	3474.472	232				

a. R Squared = .163 (Adjusted R Squared = .156)
b. Dependent Variable: Post-Test

Table 4 shows the ANCOVA test on the pre-test and the post-test. The Group gives a p-value of 0.000 which is statistically significant. Furthermore, about 11.2% represent the partial Eta squared. That is, the movement in one group over the other is explained by the 11.2% of the dependent variable. Hence, we reject the null hypothesis and conclude that there is a significant difference between the pre-test and post-test scores with higher mean as adduced in Research Question 1. This implies that students who are exposed to Peer Instruction significantly had higher and better academic achievement than those not exposed to such treatment.

Perception and Attitude of Students

A survey conducted among the experimental group through questionnaire gave the perception and the attitude of the students towards peer instruction in chemistry class after they have gone through the Peer Instruction treatment. Two research questions and two corresponding hypotheses were raised to determine the perception and attitudes of the students.

Research Question 2: What perception do students have towards the use of peer instruction in the chemistry classroom? Tables 5-7 show the analysis of students' perception towards peer instruction in chemistry class.

Table 5. Descriptive Statistics on Perception

Item no	Item on Questionnaire	N	Min	Max	Mean	Std. Deviation
6	PI enhances my understanding of chemistry concepts	168	1	5	3.67	1.052
7	PI in chemistry enhances my ability to solve chemistry problem	168	1	5	3.79	1.157
8	PI in chemistry improves my engagement in the class.	167	1	5	3.70	1.111
9	PI in chemistry enhances my active participation in the class.	168	1	5	3.88	1.120
16	PI in chemistry effectively improved your understanding of the subject.	168	1	5	4.19	.985
17	PI in chemistry helps you retain and apply chemical concepts more effectively.	168	1	5	3.95	.917
18	PI in chemistry encourages your reasoning and intelligent development	168	1	5	4.22	.836
19	I believe that PI in chemistry encourages my questioning skills	168	1	5	4.14	.928

From Table 5, all the mean values are higher than 3.50 on a scale of 1 to 5, which shows that the students agree that peer instruction enhances their performance in the learning of chemistry. Also, the following hypothesis is tested to determine the effect of these mean values. Ho_2: There is no significant difference in students' perception towards the use of peer instruction based on gender and their previous experience of peer instruction. Table 6 gives a sample t-test on students' perception of peer instruction based on gender.

Table 6. Independent Samples T-Test of Gender and Perception

Item no	Gender	N	Mean	Std. Deviation	Std. Error Mean	t	Df	Sig. (2-tailed)
6	Male	39	3.67	1.060	.170	-.040	166	.968
	Female	129	3.67	1.054	.093			
7	Male	39	3.44	1.095	.175	-2.216	166	.028
	Female	129	3.90	1.158	.102			
8	Male	39	3.69	1.195	.191	-.053	165	.958
	Female	128	3.70	1.089	.096			
9	Male	39	3.59	1.332	.213	-1.866	166	.064
	Female	129	3.97	1.038	.091			
16	Male	39	4.28	.759	.122	.662	166	.509
	Female	129	4.16	1.044	.092			
17	Male	39	3.85	1.014	.162	-.778	166	.438
	Female	129	3.98	.888	.078			
18	Male	39	4.28	.857	.137	.525	166	.600
	Female	129	4.20	.833	.073			
19	Male	39	4.10	1.046	.168	-.2	166	.793
	Female	129	4.15	.894	.079			

Table 6 shows that there is no significant difference between males and females in their perception towards using peer instruction in all the question items except item 7, as all the p-values are higher than 0.05. However, for item 7, there is a significant difference in the perception of males and females with a p-value of 0.028. Table 7 gives an independent sample t-test on whether the students have previous knowledge of peer instruction before treatment.

Table 7. Independent Samples T-Test of Previous Experience in PI and Perception

	Previous experience in PI	N	Mean	Std. Deviation	Std. Error Mean	t	Df	Sig. (2-tailed)
6	NP in PI	73	3.67	.958	.112	-.015	166	.988
	YP in PI	95	3.67	1.125	.115			
7	NP in PI	73	3.93	1.171	.137	1.376	166	.171
	YP in PI	95	3.68	1.142	.117			
8	NP in PI	73	3.75	.997	.117	.540	165	.590
	YP in PI	94	3.66	1.196	.123			
9	NP in PI	73	4.08	.968	.113	2.061	166	.041
	YP in PI	95	3.73	1.207	.124			
16	NP in PI	73	4.07	1.122	.131	-1.412	166	.160
	YP in PI	95	4.28	.859	.088			
17	NP in PI	73	3.88	.881	.103	-.863	166	.389
	YP in PI	95	4.00	.945	.097			
18	NP in PI	73	4.04	.920	.108	-2.470	166	.015
	YP in PI	95	4.36	.743	.076			
19	NP in PI	73	4.12	.957	.112	-.166	166	.868
	YP in PI	95	4.15	.911	.093			

Key: NP in PI = No Previous Experience in PI, YP in PI = Yes Previous Experience in PI

The result showed that for all the variables, there is no significant difference at 0.05 significance level between those with no previous experience of peer instruction and those who have previous experience except in items 9 and 18. On the other hand, items 9 and 18 gave p-values of 0.041 and 0.015 respectively which are significant.

Research Question 3: What is the attitude of students towards peer instruction in chemistry class? A suitable hypothesis for this research question is stated as follows: Ho_3: There is no significant difference in students' attitudes towards the use of peer instruction based on gender and their previous experience of peer instruction. As it was done for students' perception, Table 8 gives the attitude of students after exposure to peer instruction towards chemistry teaching.

Table 8. Descriptive Statistics on Attitude

Item No	Attitude Items	N	Min	Max	Mean	Std. Deviation
10	PI in chemistry allows for deeper study and discovery of chemistry knowledge.	168	1	5	3.86	1.088
11	PI in chemistry allows the use of chemistry knowledge.	168	1	5	3.84	1.046
12	PI in chemistry promotes cooperation among students	168	1	5	3.86	1.160
13	PI helps me to develop effective communication skills.	168	1	5	3.96	1.085
14	PI helps me to develop helpful participation among students.	168	1	5	3.89	1.052
15	PI motivates me to take more responsibility for my learning.	167	1	5	3.93	1.122

Key: PI = Peer Instruction

From Table 8, we observed that all the mean values are very high as none is below 3.80 on a scale of 1 to 5, which shows that the students agree that peer instruction affected their attitude positively towards learning chemistry. This is further subjected to inferential statistical analysis to determine the extent these mean values vary based on gender and previous experience on peer instruction as given in Tables 9 and 10.

Table 9. Independent Samples T-Test on Gender and Attitude

Item No	Gender	N	Mean	Std. Deviation	Std. Error Mean	T	Df	Sig. (2-tailed)
10	Male	39	3.51	1.254	.201	-2.323	166	.021
	Female	129	3.97	1.015	.089			
11	Male	39	3.64	1.063	.170	-1.354	166	.177
	Female	129	3.90	1.037	.091			
12	Male	39	3.64	1.224	.196	-1.331	166	.185
	Female	129	3.92	1.136	.100			
13	Male	39	3.87	1.151	.184	-.567	166	.571
	Female	129	3.98	1.068	.094			
14	Male	39	3.51	1.233	.197	-2.576	166	.011
	Female	129	4.00	.968	.085			
15	Male	39	3.82	1.167	.187	-.683	165	.496
	Female	128	3.96	1.111	.098			

Table 9 shows that there is a significant difference between males and females in their attitude towards peer instruction in items 10 and 14 with p-values of 0.021 and 0.011 respectively. However, for other items 11, 12, 13 and 15, non-significant p-values are recorded, meaning that irrespective of the gender of the students their attitude is the same on those items.

Table 10. Independent Samples T-Test on Previous Experience in PI and Attitude

Item No	Previous experience in PI	N	Mean	Std. Deviation	Std. Error Mean	T	Df	Sig. (2-tailed)
10	NP in PI	73	3.88	.942	.110	.142	166	.887
	YP in PI	95	3.85	1.194	.122			
11	NP in PI	73	3.95	1.053	.123	1.152	166	.251
	YP in PI	95	3.76	1.039	.107			
12	NP in PI	73	3.97	.957	.112	1.132	166	.259
	YP in PI	95	3.77	1.292	.133			
13	NP in PI	73	4.05	1.104	.129	1.010	166	.314
	YP in PI	95	3.88	1.071	.110			
14	NP in PI	73	3.86	.887	.104	-.257	166	.797
	YP in PI	95	3.91	1.168	.120			
15	NP in PI	73	3.96	1.111	.130	.311	165	.756
	YP in PI	94	3.90	1.137	.117			

Key: NP in PI = No Previous Experience in PI, YP in PI = Yes Previous Experience in PI

Similarly, from Table 10, with or without previous knowledge of peer instruction, the attitude of all the students is the same as non-significant values ($p > .05$) are recorded for all the variables 10-15. The positive effect of peer instruction on achievement has shown that a collaborative classroom will enhance performance among secondary school students as previous studies have suggested. According to Randle & Overbaugh, (2016); and Gok, (2018), when students discuss and share ideas, they can arrange ideas, explain contents better, and clear their doubts, which they may not be able to share with the teacher and the class as a whole. This is also seen in their positive perception and attitude to the peer instruction strategy.

4. Conclusion

The findings revealed that there is a positive and significant impact on the achievement of the students exposed to peer instruction compared to the achievement of those exposed to lecture method. This suggests that using peer instruction in chemistry classrooms will expand achievement for students as well as improve students' performance. The results also showed that chemistry students have a positive attitude towards the use of peer instruction in the classroom. This positive attitude is independent of gender and previous experience in the use of peer instruction. Hence, the need for secondary school teachers to engage in the use of this strategy not only in the teaching of chemistry but in all secondary school subjects. More findings revealed that there is no significant difference between males and females in the use of peer instruction in chemistry learning.

The use of peer instruction will not only enhance understanding and good performance, it will promote social interactions among students and foster collaborative living among them. This can help reduce friction and unhealthy relationships, thereby promoting safety and good communal living. Peer instruction can also help the students to develop the ability and skills such as teamwork, and communication, which are necessary for higher education and the workplace.

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