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EFFICACY OF PROBLEM BASED LEARNING IN PROMOTING HIGH ACHIEVEMENT OF STUDENTS IN CHEMISTRY

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Abstract

The study investigated the efficacy of Problem Based Learning (PBL) on students' academic achievement in electrochemistry in Enugu Education Zone in Enugu State. To achieve the purpose of the study three research questions were posed and three hypotheses were formulated. The study adopted quasi experimental design specifically pretest post-test non-equivalent control group design. The population of the study comprised of 2042 SSII Chemistry students. Purposive sampling technique was used to select the sample. The sample size was 215 comprising of 124 males and 91 female SSII students. Electrochemistry Achievement Test (EAT) was used to collect data for the study. The instrument was validated by three experts in the Department of Science Education, University of Nigeria, Nsukka. The reliability index of EAT was 0.96, which was determined using Kendall' Coefficient of Concordance. The data obtained were analyzed using mean and standard deviation to answer the research questions and Analysis of Covariance (ANCOVA) to test the hypothesis at 0.05 level of significance. The result of the study showed that PBL instructional approach enhanced students' achievement in electrochemistry better than traditional lecture method. Gender had a significant influence on students' achievement in favor of the male. It was recommended that teachers should teach electrochemistry using PBL instructional approach among others.

Key words: Electrochemistry, Problem Based Learning, Gender, Achievement

Introduction

Chemistry is an incredibly fascinating field of study. Chemistry is receiving much emphasis in education because of its significance and relevance to life and society. The relevance of Chemistry to human living has been greatly acknowledged through Chemistry developments (Martin & Abegaz, 2011). The developments of Chemistry have dramatically influenced every aspect of human life such as our health, quality of life and wealth creation. The developments are based on human activity to explore, invest and utilize the natural resources available in the nation. The rightful application of knowledge and skills acquired from Chemistry helps the individuals and the nation to solve everyday problems (Achumugu, 2016). According to the Nigerian Educational Research and Development Council (NERDC) (Federal Republic of Nigeria, FRN, 2013) Chemistry is crucial for effective living in this modern age of science and technology. Chemistry education is indispensable in this 21stcentury. Despite the acknowledge contribution of Chemistry to the progress of mankind, Chemistry as a subject he taught in secondary school is bedeviled with poor academic achievement West African Secondary School Certificate Examination (WAEC) (2014, 2015, 2016, 2017, and 2018) reported that student achievement in Chemistry show a progressive decline in quality and the number of passes in Senior Secondary Certificate Examination (SSCE). Similarly, the National Examination Council (NECO) (2014, 2015, 2016, 2017, and 2018) reported poor achievement of student especially in Chemistry. Recently, students' poor academic achievement in Chemistry examination is a source of concern to parents and Chemistry educators and these calls for immediate attention.

Electrochemistry is concerned with the transfer of electrons from one chemical species to another and the relationship between the electron transfer and the electrical currents that are generated or used during these processes (Freemantle, 2000). Electrochemistry deals with the chemical changes produced by an electric current and with the production of electricity by chemical reactions. The knowledge of electrochemistry is important in the extraction of metals, production of certain gases and compounds like Chlorine gas, Hydrogen gas, 0xygen gas and Sodium Hydroxide pellets. Considering its applications in the society and industry, the students need to be given enough time to explore and engage actively in the learning of electrochemistry. However, in spite of the importance of electrochemistry, students' achievement in this area is poor. The reason for the poor achievement is the way the concepts are being presented by the teacher (Mihindo, Wachanga & Anditi, 2017). Available research on effective

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instructional approach indicates that Chemistry teaching and learning should focus on instruction that promote student active involvement. The instructional approach should tilt towards engaging students in critical thinking, independent study and checking for their understanding as is done in Problem Based Learning (PBL). This strategy enables students to learn through solving problems and reflecting in their experiences.

Problem Based Learning is an instructional approach where problems serve as the context and the stimulus for students to learn course concepts and metacognitive skills. Learning begins with ill structured problems which students need to solve from their previous knowledge. Therefore, they are required to identify what they need to acquire and apply in order to solve the problem. During the problem solving process, students construct content knowledge and develop problem solving skills as well as self-directed skills while working towards a solution to the problem. PBL takes advantage of social aspect of learning through discussion, problem solving and study with peers though the students are independent The PBL process begins with are the problem, small group creation, self-directed study and exchange of information. According to Wood (2003) as shown below

- The problem (What to do?): Students learn more when instructions centers more on problems that pose cognitive challenges (Hung, Jonassen & Liu, 2008). The problem should progress from simple to complex.
- Small group creation (Where do I start?): Students learn more when they are directed to recall their prior knowledge or given structure for organizing a new knowledge.
- Self-directed study (How to do it?): Students learn more when deep content knowledge is constructed in the context of solving the problem.
- Exchange of information (When to do it?): Students learn more when they are encouraged to integrate their knowledge into their life through reflection, discussion, debate and/or presentation of new knowledge.

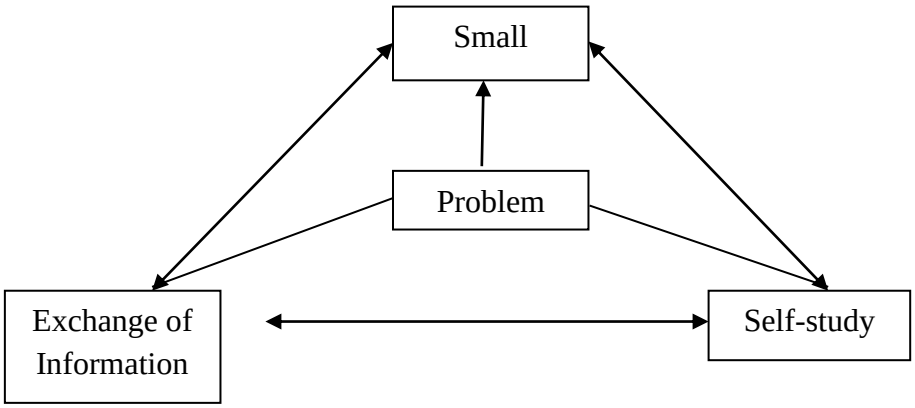

Fig 1: Relationship between the processes of PBL instructional approach (Wood, 2003).

This figure illustrates the PBL instructional approach process. The problem serves as the central theme that influences small group discussion, self-study and exchange of information. Self-study determines the information to be exchanged. Small group discussion, self-study and exchange of information unify to find solution to the given problem. The PBL instructional approach type to be used for this study is the hybrid type specifically the lecture-based case. The PBL instructional approach model employed by Mergendoller, Maxwell and Bellisino (2000) was used for the study. This PBL instructional approach model has six step wise components namely entry point, framing the problem, knowledge inventory, problem log, problem solving and problem debriefing. The six steps are

1. Entry point; Pose problems related to their prior ideas of a given concepts.
2. Problem-framing; Define the problem, explain the problem statement and the things needed for the solution.
3. Knowledge inventory; Explore the learning materials, gather information related to each learning objectives about the problem.
4. Problem-log; Arrange information gathered from knowledge inventory into tentative solutions.
5. Problem-solving; Use the information from knowledge inventory to solve the problem.
6. Problem-debriefing; Transfer the knowledge in a new situation and test the new acquired information by using the answer to solve a follow-up problem.

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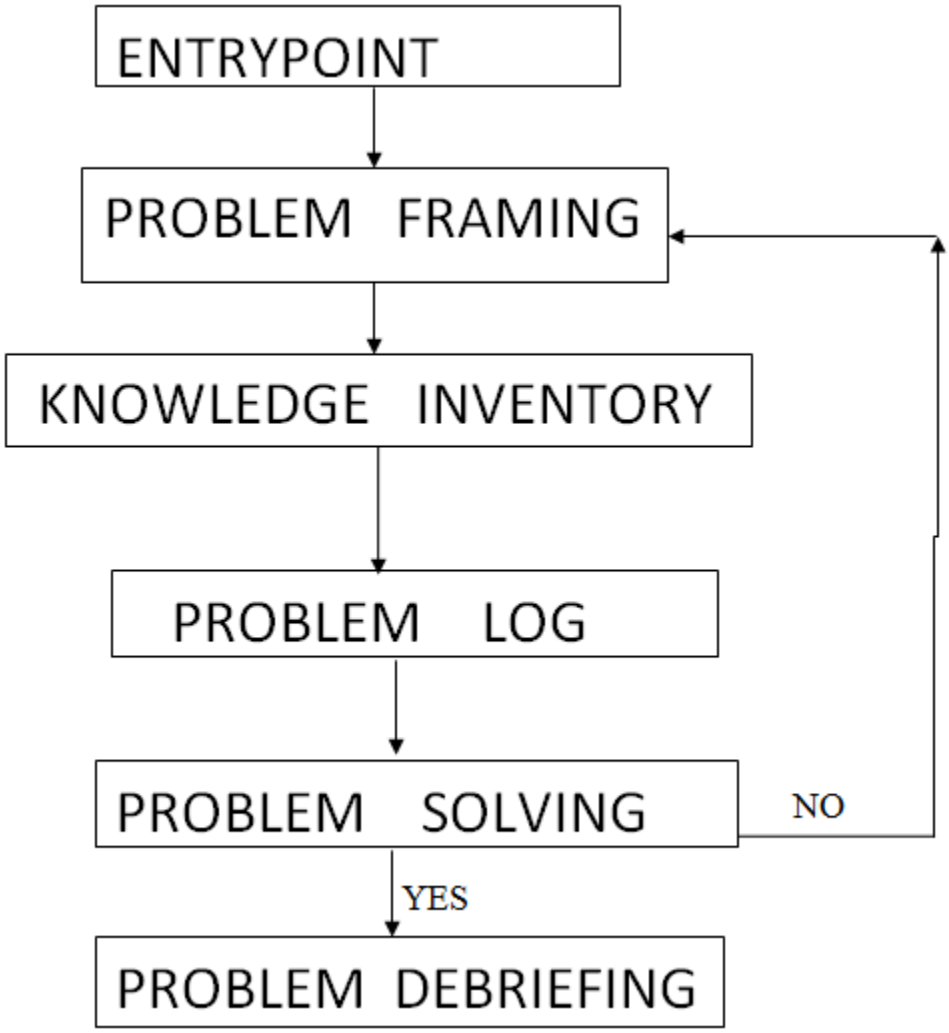

Fig 2: A procedure of the 6 -Step PBL instructional approach Model (Mergendoller et. al 2000)

The figure above illustrates the instructional sequence procedure in PBL instructional approach model as shown in fig 2. The arrows in the flowchart indicates a progression of whole complex task from the same class of tasks. Here the task to be solved is posed as a problem to learners during entry point. Secondly, learners are helped to define the problem by giving them instructions and presentations on what is required to solve the problem. This instruction does not teach all there is to know about the given problem but only what the learners need to know to solve the problem. Thirdly, learners explore many learning materials revisiting the problem. Fourthly, learners construct new knowledge from explored learning materials revisiting the problem statement. Fifthly, the learners apply the constructed knowledge and skills acquired to solve the problem. If the learner is unable to solve the problem, they problem will be reframed and the process repeated but if not learners are asked to transfer their newly acquired knowledge in a follow-up situation.

The following results are achieved by teachers using PBL instructional approach model: acquisition of knowledge and skills. Knowledge building is stimulated by the problem and applied back to the problem. Student centered learning and less tutoring. This is because it makes the students to be actively involved in the teaching learning. According to Agwagah (2015), the greater the students' involvement in the learning process, the greater the learning and the higher the achievement. Self-directed learning is enhanced. This is because it makes the

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students to assume responsibility for their learning. Bruners' theory of instruction (1960) was strengthened. The theory encouraged learners to construct knowledge based on their prior experience. Hence, the need to explore students' achievement in this study. Students' achievement is measured in terms of their passes in Chemistry test and examination administered in public and private examinations. Students' achievement at the secondary school level is a major determinant of their academic career in future. According to WASSCE (2018) and NECO (2018), there is a decline in Chemistry students' achievement despite the use of various instructional models as shown in literature. This poor achievement in Chemistry has been attributed to the nature of Chemistry and ineffective teaching method (Ezechukwu and Ukozor, 2016). However, research evidence has shown that PBL instructional approach model is an effective way to develop a wide range of soft skills (research skills, negotiation, teaming, reading, writing, oral communication), higher order thinking skills (critical thinking, creative thinking and problem-solving skills) and intrinsic motivation to solve an identified problem (Mauffette, Kandibinder & Soucisse, 2012). Some researchers have evaluated the effectiveness of PBL instructional approach in both Chemistry and other subjects these were in the areas of Chemistry (Stochiometry), (Festus & Ekpete, 2012), Mathematics (Olo, Abonyi, Okafor & Omebe, 2015), Economics (Ekweoba & Nji, 2015), Economics (Yidanu, 2018). However, no research has been carried out using PBL instructional approach on electrolysis hence the need for the study. Furthermore, Madu and Ukah (2016) observed that poor achievement in science subjects can be attributed to gender and family background. It is therefore necessary to examine some of these factors which influence achievement in science subjects including Chemistry.

Gender stereotype is one of the factors that influence the development of science and technology in Nigeria. Generally, boys and girls are socialized differently which results in girls learning different roles and attitudes from boys in a society. Gender related difference in Chemistry achievement has been an issue of concern to educationists. Literature on gender and achievement in chemistry exist with different opinions and findings. Some studies conducted by science educators have shown that there exists significant relationship between gender and students' achievement in Chemistry. Researchers like Ezinwa (2021); Okeke and Ikokwu (2017); Ene (2015) found that boys achieve higher than girls in Chemistry. Okorie and Eze (2016); Aniodoh and Egbo (2013) found that females achieve higher than males in Chemistry. While Babale, Lawal, Ibrahim (2019); Adigun (2016); Njoku and Akwali (2016); observed no gender difference in the achievement of boys and girls in Chemistry. The mode of instruction is one of the causes of gender related differences in Chemistry achievement (Egolum & Igboanugo, 2017; Okeke & Ikokwu, 2017). In view of this controversy and inconclusiveness of the male/female influence on students' achievement in Chemistry there is need to include gender in the present study.

Problem of the study

With the onset of the knowledge based era, Chemistry education has become more complex, challenging and competitive. Chemistry students need critical thinking, creativity problem-solving and socialization skill in order to thrive in todays' society. The nature of Chemistry is abstract and difficult thus leading to misunderstanding and misconceptions of fundamental chemical concepts and their relationships. However, most younger students don't learn now without concrete effort through well planned activities. Thus, there is need to assist and motivate these younger students through well planned activities to do self-directed learning for them to delve deeper into key concepts. Chemistry as a subject taught in secondary schools is bedeviled with students' poor academic achievement. Previous studies on students' Chemistry achievement have indicated that students have difficulty in solving electrochemistry problems. As a result of this, students have developed negative attitudes towards Chemistry, fail to achieve academic ambitions and expectations, and are unable to make meaningful progress in terms of students' achievement and selection of career paths requiring Chemistry. The problem of students' poor achievement is not so much with the subject matter contents but more with students' lack of commitment and low work input in the study of the subject. The educational system is deeply affected by this trend. The problem of poor academic achievement is the nature of Chemistry and ineffective teaching method. The nature of Chemistry is abstract and difficult thus leading to misunderstanding and misconceptions of fundamental chemical concepts and their relationships. Also, the teaching method is neither innovative nor sustained by various activities, thereby, making students to lose interest in the teaching process. It is important to find out if PBL instructional approach could enhance achievement in this area of Chemistry curriculum called electrochemistry which students find difficult?

Purpose of the study

The general purpose of the study was to determine the efficacy of PBL instructional approach and gender on students' academic achievement in electrochemistry. Specifically, the study sought to find the:

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1. Achievement mean scores of students in electrochemistry when exposed to PBL instructional approach and traditional (talk chalk) lecture method of teaching.
2. Achievement mean scores of male and female students in electrochemistry when exposed to PBL instructional approach and traditional method of teaching.
3. Interaction mean scores of teaching method and gender on students' achievement mean scores in electrochemistry.

Research Questions

The following research questions were posed to guide the study:

1. What are the achievement mean scores of students taught electrochemistry using PBL instructional approach and those taught with traditional method?
2. What are the achievement mean scores of male and female students taught electrochemistry using PBL instructional approach and those taught with traditional method?
3. What is the interaction effect of teaching methods and gender on students' achievement mean scores in electrochemistry?

Hypotheses

$H0_1$: There is no significant difference in the achievement mean scores of students taught electrochemistry using PBL instructional approach and those taught using traditional method ($P<0.05$).

$H0_2$: There is no significant difference in the achievement mean scores of male and female students taught electrochemistry using PBL instructional approach and those taught using traditional method ($P<0.05$).

$H0_3$: There is no significant interaction effect of teaching method and gender on students' achievement mean score in electrochemistry. ($P<0.05$).

Methods

A quasi-experimental design specifically a pretest post-test non-equivalent control group design was adopted for the study. The researcher adopted quasi-experimental design because there was no randomization of subjects to experimental groups, rather intact classes were used.The population of the study comprised of 2042 senior secondary two (SS2) Chemistry students drawn from 20 public secondary schools in Enugu Education Zone of Enugu State. Multi stage sampling technique was used for the study. Firstly, purposive sampling technique was employed in selecting the ten public co-educational schools which have school laboratory and libraries. Secondly, simple random sampling technique was used to assign the selected schools to treatment and control. The sample of the study was 215 SS2 Chemistry students consisting of 124 males and 91 females. The instrument Electrochemistry Achievement Test (EAT) was used for data collection. The instrument is made up of 20 item short answered structured Questions. The items were adapted from WASSCE Chemistry 2010-2016 which were supposed to have been covered by SS2 students. The reason for adapting items was because the questions have been standardized. The instrument was validated by three experts, two from Chemistry unit and one from Measurement and Evaluation unit, University of Nigeria, Nsukka. Test blue print was used to ensure the content validity. Students in both experimental and control group were pretested before the commencement of the study. The reliability indices of EAT was established by using Pearson Product Moment correlation coefficient suitable for internal values with a coefficient of 0.97. The reliability of the instrument was obtained by scorer reliability index. The inter rater reliability for EAT was found using Kendall' Coefficient of Concordance (w) and was found to be 0.96. Four research assistants were trained on the conduct of the study using PBL instructional approach. After collating pretest scores by the research assistants, the actual study commenced on the two groups based on the subject matter. The data obtained from the study were analyzed using mean and standard deviation to answer research questions. Hypotheses tested at 0.05% level of significance were analyzed using analysis of covariance (ANCOVA).

Results

Research Question 1: What are the achievement mean scores of students taught electrochemistry using PBL instructional approach and those taught using traditional lecture method?

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Table 1: Mean and Standard Deviation of students' Achievement Mean Scores by groups

Variable		Pre-test		Post–test		Mean gain score
	N	$\overline{x}$	SD	$\overline{x}$		SD
PBL	110	19.90	3.90	60.75	7.35	40.85
TM	105	19.04	3.25	58.38	6.56	39.34

Table 1 showed that the overall mean achievement score of the students taught using Problem based learning (PBL) was 60.75 with a standard deviation of 7.35 while those taught with traditional method (TM) had an overall mean achievement scores of 58.38 with a standard deviation of 6.56. This suggested that those students taught electrochemistry using PBL instructional approach performed better than those taught using traditional method. Hence PBL instructional approach seems to have more effect on students; achievement than traditional method.

Ho_1: There is no significant difference in the achievement mean scores of students taught electrochemistry using PBL instructional approach and those taught using traditional method

Table 2: Analysis of Covariance (ANCOVA) of students' Mean Achievement Scores by Method and Gender

Source	Squares	DF	Mean Square	F	Sig	Remarks
Correctedmodel	1235.575	4	308.894	6.393	.000	
Intercept	71224.565	1	7.1224.565	1474.161	.000	
Pretest	7.129	1	7.129	.148	.701	
Method	330.148	1	330.148	6.833	.010	S
Gender	862.017	1	862.017	17.841	.000	S
Method*Gender	6.925	1	6.925	.143	.705	NS
Error	10146.221	210	48.315			
Total	774977.000	215				
Corrected Total	11381.795	214				

Table 2 shows that treatment is a significant factor on the students' achievement in electrochemistry with an associated probability value of 0.010. Since the associated value of 0.00 was less than 0.05 set as level of significance, the null hypothesis (HO_1) was rejected. Therefore, there is a significant difference in the achievement mean of students taught electrochemistry using PBL instructional approach and those taught using traditional method. This suggests that the earlier observed difference between the means of the two groups was not attributed to chance error but due to the treatment in favor of PBL instructional approach

Research Question 2: What is the achievement mean scores of male and female students taught electrochemistry using PBL instructional approach?

Table 3: Mean and Standard Deviation of Male and Female Students' Achievement Mean Scores in Electrochemistry.

Gender	N	Pre-test		Post-test		Mean gain
		$\overline{x}$	SD	$\overline{x}$	SD	
Male	124	20.50	4.20	60.75	7.35	40.25
Female	91	18.19	3.11	58.38	6.37	40.19

Result in Table 3 shows that male students had an achievement mean score of 60.75 with a standard deviation of 7.35 while the female students had an achievement mean score of 58.38 with standard deviation of 6.37. This shows that the male students had higher achievement mean scores than female students at the post-test. This can be seen from slight difference of 2.47 between the two post-test achievement mean scores. Therefore, gender may influence students' achievement in electrochemistry.

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Ho_2: There is no significant difference in the achievement mean scores of male and female students taught electrochemistry using PBL instructional approach and those taught using traditional method

Table 2 shows that gender is significant on the students' achievement in electrochemistry (F=17.84, P=0.000). this is because the probability value of 0.000 is less than 0.05 set as level of significance Thus, the null hypothesis (HO_2) was rejected. Therefore, there is a significant difference in the achievement mean of male and female students taught electrochemistry using PBL instructional approach.

Research Question 3

What is the interaction effect of teaching methods and gender on students' achievement mean scores in electrochemistry?

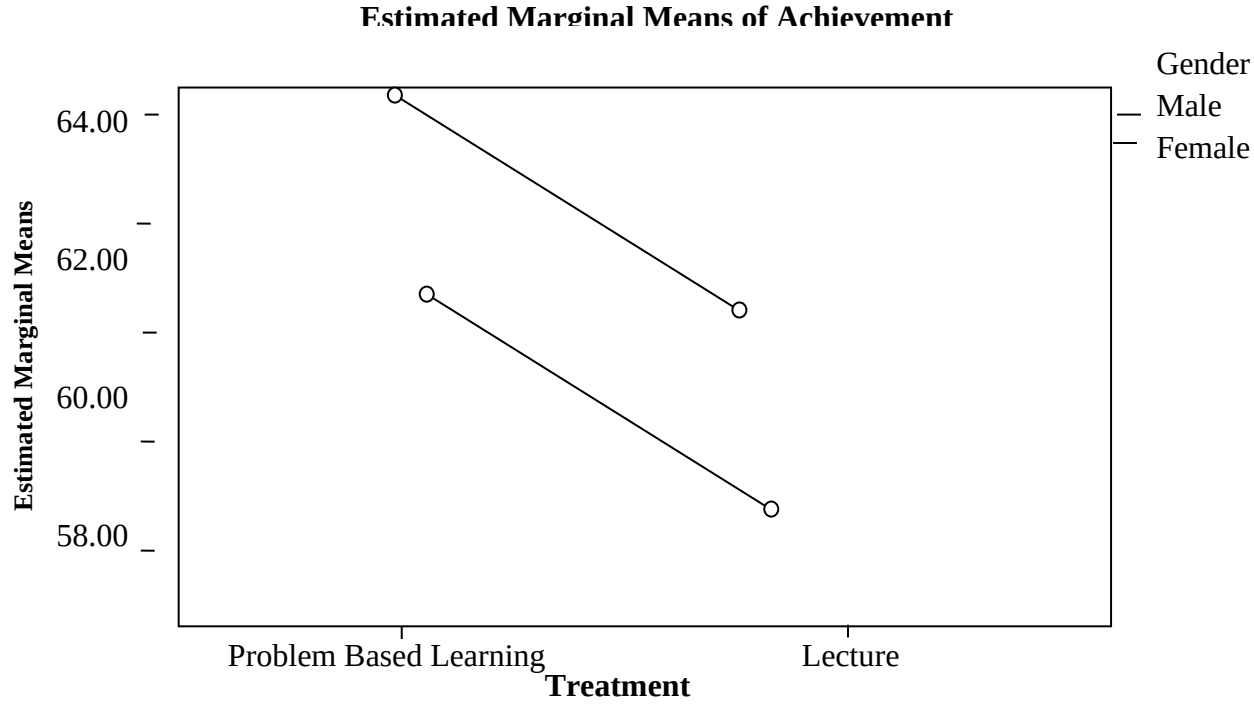
Table 4: Mean and Standard Deviation of Students showing Interaction of Treatment with Gender on Achievement scores in Electrochemistry

Variables			Pre-test		Post-test		
Modes	Gender	N	$\bar{x}$	SD	$\bar{x}$	SD	Mean gain
PBL	Male	64	21. 25	4.24	62.46	7.58	41.21
	Female	46	18.20	3.14	58.98	6.91	40.78
Lecture	Male	60	19.77	3.80	60.24	7.32	40.47
	Female	45	17.03	3.03	58.50	6.89	41.47

Result in Table 4 shows that the male students had an achievement mean score of 62.46 with a standard deviation of 7.58 while the female students had an achievement mean score of 58.98 with standard deviation of 6.91. This shows that the male students had higher achievement mean scores than female students at the post-test. This can be seen from slight difference of 3.48 between the two post-test achievement mean scores. Male and female students in PBL group slightly outperformed their counterpart in lecture group. There is no interaction of treatment with gender on students' achievement mean scores in electrochemistry.

Considering the achievement mean plot of interaction effect of treatment and gender on students' achievement mean score in electrochemistry.

Fig 9: Achievement Mean Plot of Interaction Effect of Treatment and Gender.



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The figure above shows that the students taught electrochemistry using PBL have higher marginal achievement mean score of 62.46 than those of traditional method with mean score of 60.24. This clearly showed that PBL improved students' achievement in electrochemistry better than traditional method. Also, the result in the figure shows that male students performed better than their female counterparts when the two instructional approaches were employed. However, the most effective approach was the PBL. The achievement mean plot of PBL group with gender is parallel to that of the traditional method group with gender. This shows that there is no interaction effect of teaching method and gender on students' achievement mean scores in electrochemistry.

Hypothesis 3

HO_3: There is no significant interaction effect of teaching method and gender on students' achievement mean score in electrochemistry.

Table 2 shows that the interaction between teaching modes and gender is not significant on the students' achievement in electrochemistry (F=0.143, P=0.705). This is because the probability value of 0.705 is greater than 0.05 set as level of significance Thus, the null hypothesis (HO_3) was accepted. Therefore, there is no significant interaction effect of teaching method and gender on student's achievement in electrochemistry.

Discussion

The findings of the study in Table 1 shows that students exposed to PBL had higher achievement scores compared with those exposed to lecture method. The achievement was further strengthened by the analysis of covariance in Table 3 which showed significant difference in the mean achievement scores of students taught electrochemistry using PBL instructional approach and those taught with traditional method. This implies that PBL significantly enhanced students' achievement compared to lecture method. This high achievement may be as a result of active, group learning and task based teaching which PBL provided. PBL instructional approach enabled the students to constructed new knowledge and used them in the problem solving. This finding is in agreement with the findings of Ekweoba and Nji (2015) whose findings revealed that students taught Economics using PBL instructional approach performed significantly better than those taught using traditional method. Also, in support was the findings of Olo, Abonyi, Okafor and Omebe (2015) who reported significant difference in the post-test mean scores of students taught Algebra using PBL mode of instructional approach The finding is in line with the study of Ak (2011), who indicated that PBL instructional approach makes the students to be always active thinking, exploring explaining, drawing and solving problems. The finding is also supported with the study of Agwagah (2015) who indicated that the greater the students' involvement in the learning process, the greater the learning and the achievement.

The result of the findings in Table 2 showed that male students had a higher achievement mean scores than their female counterparts. Further analysis in Table 3 using analysis of covariance (ANCOVA) revealed a significant difference in the achievement mean score of male and female students in electrochemistry. That showed that the higher mean score accrued to male students as earlier seen in Table 2 was due to gender stereotyping about the girls' way of life. The girls' way of life in the society shows that in solving problems, boys take the risk more. These affect educational opportunities because the instructional approach is PBL which must begin with a problem. The result is in agreement with the findings of Yidanu (2018) who reported a significant difference between the mean achievement scores of male and female students taught Economics using PBL instructional approach.

The result of the findings in Table 3 showed there is no interaction of treatment with gender on students' achievement mean scores in electrochemistry. Further analysis in Table 3 using analysis of covariance (ANCOVA) revealed no significant interaction effect of teaching method and gender on the achievement mean score of students in electrochemistry. This may be because the teaching method (PBL) is more structured, characterized by doing and effectively implemented such that it is gender free. That showed that the higher mean score accrued to male students as earlier seen in Table 2 was due chance factor showing that PBL is equally effective for male and female students. The result is in agreement with the findings of Olo, Abonyi, Okafor and Omebe (2015) who reported no significant interaction effect of between teaching method and gender on the mean achievement scores of students taught Algebra using PBL instructional approach.

Conclusion

Based on the findings of the study, it was established that:

1. PBL instructional approach enhanced students' achievement in electrochemistry better than traditional method.

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2. Gender had a significant influence on students' academic achievement in electrochemistry in favor of the male.
3. The interaction effect of teaching method and gender is not significant

Educational implications of the Study

The implications of the study based on the findings are:

1. The instructional strategies are among the variables that improves students' achievement in Chemistry. The problem of poor achievement can be meliorated by the use of PBL instructional approach instead of traditional method.
2. Students' achievement depends on the students' participation in the teaching learning process not gender. PBL instructional approach can create uniform learning conditions for all students irrespective of gender.
3. The superiority of PBL instructional approach in fostering academic achievement was uniform for both male and female students since PBL instructional approach provided equal opportunities in the learning process for male and female students to benefit maximally from this instructional approach.

RECOMMENDATIONS

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

1. Chemistry teachers should adopt the use PBL instructional approach since it has been found to be effective in enhancing students" achievement compared to traditional method.
2. Government in collaboration with Ministry of Education should organize workshops, conferences and seminars to train in-service teachers regularly on the use of PBL instructional approach since it has been found efficacious in classroom instructions.

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