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Effect of Problem-Based Learning Strategy on Chemistry Students' Achievement and Interest in Mole Concept in Federal Capital Territory, Abuja

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ABSTRACT

Background: The problem of students' underachievement and negative attitude towards learning, especially difficult chemical concepts, can be attributed to some inadequacies in the teaching. Teachers' persistent adoption of conventional instructional approaches have been observed as a major challenge to students' proper understanding, assimilation and retention of content taught.

Objectives: This study investigated the effect of Problem-Based Learning (PBL) strategy on chemistry students' achievement and interest in Mole concept.

Method: The study adopted a quasi-experimental pre-test, post-test, control group design. The population of the study comprised all Senior Secondary Two chemistry students of Karshi Zone. Two schools were randomly selected from the seven co-educational public secondary schools in the study area and one intact class was randomly selected from each of the two sampled schools. One of the schools served as the experimental group while the other as the control group. 110 students participated in the study. Mole Concept Achievement Test (MCAT) and Mole Concept Interest Scale (MCIS) were instruments used for data collection. MCAT was a 40 items multiple choice test on Mole concepts, drawn from past WAEC examination questions while MCIS was a 24-item interest scale. The instruments were validated by experts and pilot tested. A reliability coefficient of 0.96 was obtained for MCAT using Kuder-Richardson's K-21 and 0.95 for MCIS using Cronbach Alpha. The experimental group was exposed to the treatment while the control group was taught using the conventional method. Data obtained were analyzed using mean, standard deviation and ANCOVA. Four null hypotheses were tested at 0.05 level of significance.

Results: Findings revealed that students taught mole concept using PBL strategy perform better and expressed better interest than those taught using lecture method. PBL improved the achievement of both male and female students equally but fostered more interest in male students.

Conclusion: Based on the findings of this study, it is recommended that chemistry teachers should be encouraged to adopt PBL strategy in teaching Mole concept during their instructional practices.

Keywords: Problem Based Learning (PBL) Strategy, Achievement, Interest, Mole Concept, Gender

INTRODUCTION

With the current diversities in the academic world and the complexities of learning procedures, especially in the sciences, it is imperative that alternative and effective teaching/learning strategies be employed by science educators and learners in handling difficult concepts. Fatokun et al., (2019) asserted that despite the acclaimed benefits of innovative teaching strategies and several efforts made for their adoption by science educators, conventional teaching methodologies are still emphasized in most educational settings, because of some "so called impediments" often envisaged as major hindrances to successful implementation of those approaches by few that are conversant with them. Achieving meaningful learning is a subject of growing controversy, some believe on mere 'improved' conventional teaching methods but others advocate for innovative, active learning strategies, such as problem-based learning (PBL). Some chemical concepts are often referred to as being difficult both to teach and to learn, this is evident in the learners' phobia and poor achievement in both internal assessment and external examinations in such concepts (WAEC, 2015-2018). Students' low achievement in chemistry which is mostly traceable to pedagogical issues (WAEC, 2017) is a

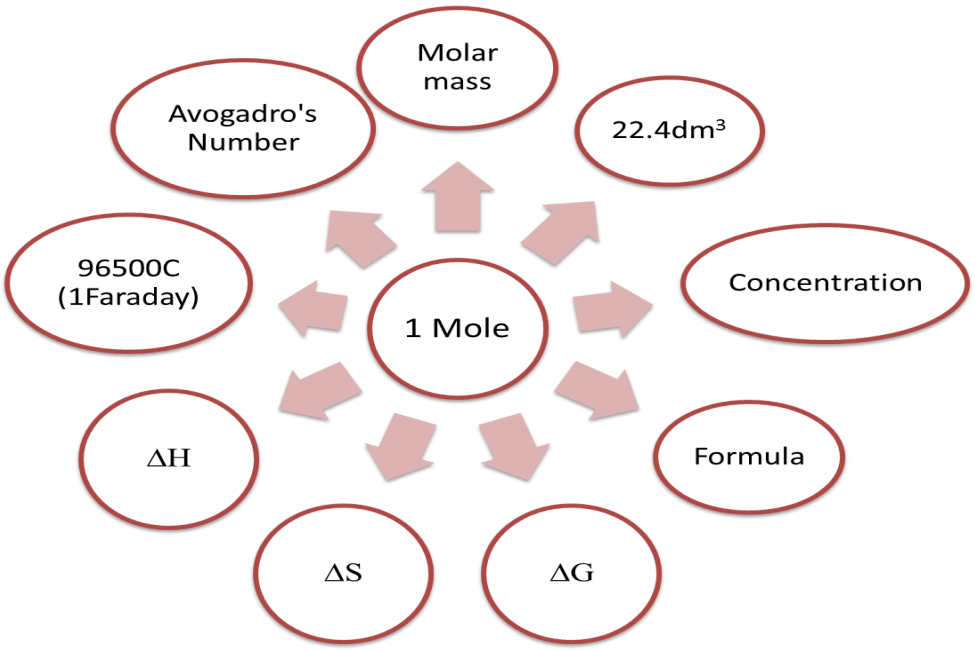

Figure 1: An abridged representation of Mole chemical significance (Researchers)

serious concern to teachers, parents and other stakeholders. Boniface (2018) affirmed Mole concept as a difficult concept and expressed students' wrong perception and exhibition of negative attitude towards its learning before exposure to treatment.

Mole concept is a fundamental concept in chemistry though abstract in nature and mathematically inclined. A mole is defined as the amount of a substance which contains the same number of specified particles or units, as atoms contained in 12.00grams of carbon 12 (^{12}C). The mole concept develops quite naturally from the idea of relative atomic mass and the definition of an atomic mass unit. If one atomic mass unit (a.u) is equivalent to 1.6603 X $10^{-24,}$ then 1 gram of matter contains 1 /1.6603 x 10^{-24} a.u. i.e. 6.023 x 10^{23}a.u. This number is of great importance in Chemistry. It is called the Avogadro's number. One mole of any material contains Avogadro's number of particles i.e. 6.023 X 10^{23}. The mole is simply a collective term similar to kilometer, litre, gross, etc. 12g of ^{12}C isotope is a standard for one mole and it contains 6.023 X 10^{23} atoms and a definite amount of carbon.

PBL is considered from extant literature as one of the most innovative instructional methods to date (Maryellen, 2017; Sihaloho et al., 2017; Aidoo et al., 2016; Fatokun and Fatokun, 2018; Tarhan et al., 2008; Jegede and Fatoke, 2014). These beliefs are anchored in PBL's instructional processes and components which includes; learning initiated by problems, self-directed learning, and collaborative learning in small groups. PBL is a technique that incorporate higher levels of thinking, it helps learner acquire problem solving skills in addition to the skills of communicating, analyzing, researching and accepting others. Adopting this method, students are independent learners and teachers are just facilitators who guide the learning process. These components are very different from traditional instructional methods. Most students find PBL enjoyable and satisfying as it encourages greater understanding, develops lifelong learning skills and retention (Eberly Centre, 2014). Interest as an important variable in learning is referred to as an intrinsic motivation or driving force behind students' participation in any academic activity (Goulart and Bedi, 2011; Achuonye, 2010; Fatokun, 2012). Lack of interest in a subject discourages students from staying in class and working hard to achieve good grades. It equally prevents them from being enthusiastic, which often leads to an increased failure rate and anti-social vices in some instances.

Studies (Pinar et al., 2011; Fatokun and Fatokun, 2013; Valdez and Bungihan, 2019) have also revealed that PBL enhances self-confidence, boost students' self-efficacy and encourages critical thinking skill irrespective of gender. It also instill perseverance in students for reaching their set targets. PBL promotes curiosity in learners and make them yearn to know the details of what they are engaged in and it de-emphasizes memorization of content. Abanikannda (2016) investigated the Influence of PBL on academic achievement of students in chemistry education in Osun State, Nigeria. The study adopted a descriptive survey design and the findings revealed that PBL was more effective and enhanced students'

achievement in chemistry. Cemal and Yavuz (2012) conducted a study on the effect of PBL on students' motivation towards chemistry classes and learning strategies in Ataturk University Turkey. The post-application findings of the research revealed that PBL method had positive contributions to some of the sub-dimensions of motivational belief which are target orientation, topic value and self-efficacy. Boniface (2018) experiment on the effectiveness of Problem-Based Learning approach to Mole concept among students of Tamale College of Education revealed that the PBL resulted in significantly higher students' achievement in Mole concept than the TLB. The outcome of Valdez and Bungihan (2019) study which was aimed at investigating the effectiveness of PBL approach in enhancing the problem-solving skills of Grade 9 students in chemistry in a public high school in the Philippines confirmed that PBL enhances the problem solving-skills of high school students in chemistry.

Purpose of the study

The problem of negative attitude due to lack of interest in learning some difficult chemical concepts which often results in underachievement in chemistry generally, and consequently low enrolment in chemistry related courses at a higher educational level, necessitated this study. Therefore, this study was specifically designed to investigate the effect of PBL strategy on the achievement and interest of male and female chemistry students in Mole concept.

Research Questions

The following research questions were raised to guide the study:

1. What are the mean achievement scores of students taught Mole concept with PBL strategy and those taught using conventional method?
2. What are the mean interest scores of students taught Mole concept using PBL strategy and those taught using conventional method?
3. What are the mean achievement scores of male and female students taught Mole concept using PBL strategy?
4. What are the mean interest scores of male and female students taught Mole concept using PBL strategy?

Research Hypotheses

The following null hypotheses were formulated:

$\mathbf{H_{O1}}$: There is no significant difference in the mean achievement scores of students taught Mole concept using PBL strategy and those taught using conventional method.

$\mathbf{H_{O2}}$: There is no significant difference in the mean interest score of students taught Mole concept using PBL strategy and those taught using conventional method.

$\mathbf{H_{O3}}$: There is no significant difference in the mean achievement scores of male and female students taught Mole concept using PBL strategy

$\mathbf{H_{O4}}$: There is no significant difference in the interest scores of male and female students taught Mole concept using PBL strategy.

MATERIALS AND METHODS

Population, Sample and Sampling Technique

The target population of the study was made up of 477 SSS Two chemistry students from the seven public co-educational schools in Abuja Municipal Area Council (AMAC), Karshi Zone of Abuja, F.C.T. These students were 278 males and 199 females in all the schools. Simple random sampling technique was used. Two schools were randomly selected from the population and one intact class was randomly selected from each of the two sampled schools. The sample consisted of 110 students, 58 students from the first school served as the experimental group and 52 students from the second school which served as the control group.

Research Design

The study adopted pre-test, post-test quasi experimental control group design.

Instrumentation

Two instruments were developed by the researchers and used for data collection. The instruments were; Mole Concept Achievement Test (MCAT) and Mole Concept Interest Scale (MCIS). MCIS was a 24 item Likert-type scale for assessing students' interest; it was adapted from Baggaley (1973) and modified to focus on Mole concept. MCAT which served as both the pre-test and the post-test was a 40 items multiple-choice questions drawn from past WAEC and UME examination questions on Mole concept. This was used to assess students' achievement of knowledge gained during the experimentation. A Table of specification was drawn for MCAT to ascertain appropriate content coverage. The

instruments were given to three experts in Science Education for validation. The reliability indices of 0.96 and 0.95 were established for both MCAT and MCIS respectively using Kuder-Richardson ($K\text{-}R_{21}$) formula and Cronbach Alpha after a trial testing.

Administration

The pre-test MCAT and MCIS were administered to both the experimental and control groups before the teaching of Mole concept to the two groups commenced. Researchers adhered strictly to the lesson delivery procedures developed. The study was conducted during the normal school periods and the normal school time table was followed. The teaching lasted for five consecutive weeks for the two groups with similar content coverage. The control group was taught by their regular teacher (research assistant) using the conventional approach or lecture method while the experimental group was also taught by their resident chemistry teacher (research assistant) who was previously trained by the researchers on PBL implementation. The experimental group was exposed to treatment using PBL during their instructional session twice a week in a double period of 80 minutes. At the end of the fifth week, the post-test MCAT was re-administered to the two groups and the MCIS was also repeated.

The PBL strategy for the experimental group involved the following steps:

Induction and grouping: The first day was used for introducing PBL strategy and familiarization of students with the research procedures. PBL process was briefly described and its objectives; and a copy of the expected students' role during PBL instruction was given to each of the students. The students were randomly assigned to discussion groups of ten (10) each except one with eight members. In each group, the students were asked to introduce themselves and appoint a leader and a record keeper.

Problem presentation and group discussions: Before presenting the problems on each topic considered, the research assistant reviewed the objectives of the lesson to guide the group's thought and discussion to ensure that they did not go off track. In each group, the students were asked to seat closely and establish eye contact with each other. Thereafter, copies of compiled problems on the first topic in Mole concept were distributed to the students. Each group discussion began with one of the students reading the PBL problems. The students discussed the problem, listed out what they knew, what they did not know and what they needed to know to arrive at the solution. These learning issues stimulated them to proceed on the research process and self-directed learning activities where they clarified and ranked learning issues; they delegated learning tasks to each member of the group. The research assistant (facilitator) supported this process by questioning, probing, encouraging critical reflection, suggesting and challenging in helpful ways only where necessary as she moved around the six groups. Afterwards the students and the facilitator discussed the resources needed for studying the learning issues, and their availability.

Subsequent meetings: When the students reconvened, the research assistant encouraged them to re-examine the problems, learn on the need for a change of thoughts and analysis of the problem. This re-examination gave them insights into what they should have hypothesized and what they should have asked. Thus, they explored the previous learning issues, integrating their new knowledge into the context of the problem; summarized their knowledge and connected new concepts to old ones through verbal expression and group concept maps. They followed these procedures for all the outlined topics for the five weeks.

RESULTS

The research questions were answered using mean scores and standard deviation. Analysis of Covariance (ANCOVA) was employed to further analyze the data and test the hypotheses. All hypotheses were tested at 0.05 level of significance. Tables on each research question and the corresponding hypothesis were presented in serial order.

Table 1 answers the first research question, it shows that the experimental group had an achievement mean gain of 12.79 while the control group had a mean gain of 3.87 indicating a difference of 8.92 in the mean gain.

Table 2 shows the summary of the one-way ANCOVA result of students' achievement scores in MCAT for testing the first hypothesis. This result revealed that the noted differences between the mean achievement score of students taught using PBL strategy and those taught with conventional method is significant at 0.05 alpha level. This is from the fact that $F_{(1,107)} = 575.96$ and $p = 0.00 < \alpha = 0.05$. The

null hypothesis was therefore rejected. This implies that PBL is more effective than the conventional method (H_{O1}).

Table 3 answers the second research question, it shows that the experimental group had an interest mean gain of 11.06 while the control group had an interest mean gain of 1.31. This reveals a gap of 9.75 in their interest mean gain.

Table 4 reflects the testing of the second hypothesis as it shows the summary of the one-way ANCOVA on students' interest score from MCIS. This result revealed that there is a significant difference in the mean interest scores of students taught mole concept using PBL strategy and those taught using LTM. Since $F_{(1,107)} = 35.34$ and $p = 0.00 < \alpha = 0.05$. Hence, the null hypothesis was rejected. This implies that PBL enhances students interest in learning Mole concept.

Research Question 1: What are the mean achievement scores of students taught Mole concept using PBL strategy and those taught using the conventional method?

Table 1: Mean and Standard Deviation in MCAT for the Experimental and Control Group

Group	Pre-test			Post-test			
	N	Mean	SD	N	Mean	SD	Mean Gain
PBL	58	19.74	2.87	58	32.53	1.71	12.79
LM	52	20.98	2.51	52	24.85	2.43	3.87

Table 2: Result of ANCOVA on Students' Achievement Mean Score in MCAT for testing Hypothesis 1

Source	Type III Sum of squares	df	Mean Square	F	Sig.	Result
Corrected Model	1761.78	2	880.89	289.02	0.000	S
Intercept	755.81	1	755.81	247.98	0.000	S
Group	1755.44	1	1755.44	575.96	0.000	S
Pretest	141.08	1	141.08	46.29	0.000	S
Error	326.12	107	3.05			
Total	93961.00	110				
Corrected Total	2087.90	109				

S = Significant at $p < 0.05$

Research Question 2: What are the mean interest scores of students taught Mole concept using PBL strategy and those taught using conventional method?

Table 3: Means and Standard Deviation in MCIS of Students in the Experimental and Control Groups

Group	Pre-treatment Interest			Post-treatment Interest			
	N	Mean	SD	N	Mean	SD	Mean Gain
PBL	58	75.34	7.70	58	86.40	6.00	11.06
LM	52	49.85	7.83	52	51.16	7.96	1.31

Table 4: Result of ANCOVA on Students' Interest Mean Scores in MCIS

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Result
Corrected Model	20877.182[a]	2	10438.591	338.559	.000	S
Intercept	2459.756	1	2459.756	79.778	.000	S
Pre-treatment interest	1989.037	1	1989.037	64.511	.000	S
Group	1089.743	1	1089.743	35.344	.000	S
Error	3299.068	107	30.832			
Total	626548.090	110				
Corrected Total	24176.250	109				

S = Significant at $p < 0.05$

Research Question 3: What are the mean achievement scores of male and female students taught Mole concept using PBL strategy?

Table 5: Means and Standard Deviation in MCAT of Male and Female Students in the

Gender	Pre-test			Post-test			
	N	Mean	SD	N	Mean	SD	Mean Gain
Male	32	20.29	1.72	32	24.82	2.46	4.53
Female	26	21.79	3.04	26	24.88	2.44	3.09

Table 6: Result of ANCOVA on Male and Female Students' Achievement Mean Scores in MCAT

Source	Type III Sum Of Squares	df	Mean Square	F	Sig.	Result
Corrected Model	10.099	2	9.049	.250	.772	NS
Intercept	1290.430	1	1290.430	66.453	.000	S
Pretest	8.779	1	8.779	.194	.503	NS
Gender	3.765	1	3.765	.194	.661	NS
Error	2077.801	107	19.419			
Total	93961.000	110				
Corrected Total	2087.900	109				

Research Question 4: What are the mean interest scores of male and female students taught Mole concept using PBL strategy?

Table 7: Mean Interest Scores and Standard Deviation of Male and Female Students Taught with PBL Strategy

Gender	Pre-treatment			Post-treatment			
	N	Mean	SD	N	Mean	SD	Mean Gain
Male	2	53.68	3.38	32	70.35	6.32	16.67
Female	26	67.72	4.06	26	81.49	3.88	13.77

Table 8: Result of the one-way ANCOVA on Male and Female Students' Interest Scores in MCIS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Result
Corrected Model	20672.317[a]	2	10336.158	315.636	.000	S
Intercept	2195.878	1	2195.878	67.056	.000	S
Gender	884.877	1	884.877	27.022	.000	S
Pretest	16724.596	1	16724.596	510.721	.000	S
Error	3503.933	107	32.747			
Total	626548.090	110				
Corrected Total	24176.250	109				

S = Significant at $p < 0.05$

Table 5 answers the third research question. It shows that the male students had an achievement mean gain of 4.53 while their female counterparts had a mean gain of 3.09, indicating a difference of 1.44 in their mean gain.

Table 6 shows the testing of the third hypothesis. It gives the summary of the one-way ANCOVA on male and female students' achievement scores in MCAT. This result indicates that the difference between the mean achievements scores of male and female students taught Mole concept with PBL strategy is not significant at 0.05 alpha level since $F_{(1,107)} = 3.765$ and $p = 0.194 > \alpha = 0.05$. The null hypothesis was therefore not rejected indicating that there is no significant difference in the mean achievement scores of male and female students taught using PBL strategy. From the results presented, both male and female students taught with PBL strategy had higher achievement scores indicating that the use of PBL strategy enhances equal achievement in male and female students learning of Mole concept.

Table 7 answers the fourth research question. It shows that the male students had a mean gain of 16.67 while the female had 13.77 with a difference of 2.9 interest mean gain.

Table 8 shows the testing of the fourth hypothesis. This Table reveals that the noted difference between the mean interest scores of male and female students taught with PBL strategy is significant at 0.05 alpha level. This is from the fact that $F_{(1,107)} = 27.022$ and $p = 0.000 < \alpha = 0.05$. The null hypothesis was therefore rejected indicating that there is a significant difference in the mean interest scores of male and female students taught using PBL strategy. This implies that the male students developed more interest in learning than the female students.

DISCUSSION

There is a statistically significant difference in the achievement of students exposed to PBL and those taught with the traditional lecture method. This result confirms the findings of Abanikannda (2016), Aidoo *et al*. (2016) and Boniface (2018) which concluded that PBL is more effective than any conventional method as it promotes students' achievement in chemistry. Particularly in this era of unlimited information, the making of critical thinkers and lifelong learners is crucial through efficient teaching and learning processes which PBL offers. The findings of this study further revealed that teaching method has a significant effect on interest as PBL enhanced students' interest in learning Mole concept. This result is consistent with Achuonye (2010) assertion that PBL improved students' motivation in learning; and Cemal and Yavuz (2011) also reported that PBL sustained students' interest in learning and enhanced their motivation in self-directed learning.

Furthermore, it was discovered that gender has no significant effect on students' exposure to PBL since both male and female students had achieved equally. This result is in support of Omoniyi (2016) earlier submission that both male and female student perform equally when taught Mole concept with Problem Solving Approach and it is also in line with Okoh *et al* (2011) assertion. Finally, it was equally noted that there is a significant difference in the interest gain of male and female students. The male students had higher interest than the female students. This finding is in consonant with Okoye *et al*. (2015) but contradict Fatokun (2012) who reported that gender does not affect students' interest in learning chemistry.

CONCLUSION

All the null hypotheses were rejected except one. In conclusion, students taught Mole concept using PBL strategy achieved higher and gained more interest in learning than those taught using the conventional (lecture) method. Also gender has no influence on the achievement of students exposed to PBL as both male and female students performed at par but the male students showed more interest in learning through PBL than their female counterparts.

Based on the findings of this study, it is recommended that chemistry teachers should be encouraged to adopt PBL strategy in teaching Mole concept during their instructional practices. Capacity building programmes should be provided for secondary school chemistry teachers by relevant agencies to sensitize and properly train them on instructional implementation of PBL.

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