REPOSITIONING 21ST CENTURY CHEMISTRY EDUCATION THROUGH INNOVATIVE TEACHING STRATEGIES: THE CASE OF PROBLEM-BASED LEARNING TEACHING STRATEGY IN NIGERIA

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ABSTRACT

The advancement in science and technology has ushered the 21st century education into a new era characterized by a lot of innovation that promotes the reform of practices and methodologies of teaching and learning at all levels of education. This is to ensure the proper understanding by student to cope with the current trend in the chemistry community. The world is undergoing series of reformations geared towards recovery from aftermath of the traumatic experiences of COVID-19 pandemic that ravaged the world between 2019 and 2020. In chemistry education sector, the main focus is expected to center around curriculum reform processes geared towards provision of best practices that enhance individuals thinking, towards their physical and mental development as an imperative for the 21st century chemistry education in the post COVID-19 era. This study therefore, explored the usage of innovative teaching approaches in chemistry pedagogy, particularly, problem-based learning and the effect of students' achievement in chemical reactions in Nigeria. Quasi-experimental research design was adopted using 79 Senior Secondary 2 Chemistry Students as sample. The instrument was a 25-item Chemical Equilibrium Performance Test Two validated by science education lecturers with reliability coefficient of 0.79 determined by test-retest method. Findings of the study revealed that problem-based learning approach enhanced critical thinking and problem-solving skills of students in Chemical Equilibrium. Students taught with problem-based learning approach performed significantly better with higher achievement scores than those taught with lecture teaching method. Significant difference in achievement of students taught with problem-based learning and lecture teaching method was obtained while there was no significant gender related difference in students' performance. It was recommended among others that teachers should adopt problem–based learning as an effective strategy in teaching Chemical Equilibrium. *[African Journal of Chemical Education—AJCE 13(2), June 2023]*

INTRODUCTION

Developing and underdeveloped nations of the world are constantly engaged in dynamic approaches towards advancement in science and technology to measure up with the developed economies of the word by providing the basic needs and improving the standard of living of the populaces. The growth of any nation is a product of its advancement in science and technology and the crucial role of education as "the bedrock of the development of any notion" in this process cannot be undermined in this process. Considering this essential role, science teaching and learning requires proper reformations to meet the 21st century demands of the "digital age" where the introduction of mobile technology has provided electronic devices that has the ability to transform the system of information processing to support effective lesson delivery. This is anchored on the development of innovative student-centered teaching and learning strategies that could enhance proper understanding of abstract scientific concepts.

Problem based learning is one of the innovative strategies for teaching science. This strategy ca be considered as type of learning where problems that give students opportunity to design and investigative activity using problem-solving to arrive at a conclusion is given to the student. [1] however, defined problem-based learning as "the learning that results from the process of working toward the understanding or resolution of a problem". Form the above, problem-based learning can be viewed as an instructional method that challenges learners to learn by working cooperatively in

groups to seek solutions to real world problems This approach covers many teaching strategies which include problem solving, project-based teaching, inquiry, case-based teaching and grounded instruction.

Problem-based learning is a student-centered teaching strategy where the problem drives the learning with the central focus on students' active involvement in trying to solve some problems or answer some questions. The problem drives the learning while the teachers plays the role of a facilitator coaching the students to acquire knowledge and to become "self-directed learners". One of the outstanding characteristics of this strategy is that the students work in smaller groups to critically discuss the problem and possible ways of exploring and reflecting the problem as well as content. Similarly, they try to source for information, access learning material and share ideas among themselves while working in small groups. Moreover, they research, explain, and cooperate in order to find meaningful solutions to real life problems [2,3,4].

Furthermore, problem-based learning is a constructivist teaching strategy that emphasizes on learner's active participation in the process of "knowledge construction" and "making meaning". It recognizes the fact that learners possess preconceived ideas which are usually different from the acceptable scientific ideas as a result of interaction with their peers, teachers, and the environment. They construct understanding or meaning by making sense of their experiences and fitting their own ideas into reality. Due to the outcome of this, learners come to learning situations with a variety of

knowledge, feelings, and skills which exists within the learner and is developed as individuals [5, 6].

Scientifically, the process leading to answer is more important than the answer itself, therefore, problem-solving, emphasizes on the use of information from different sources to arrive at multiple solutions rather than the solution itself. This process makes knowledge more relevant to learners and also enhance its retention [7]. Also, problem-based learning aims at teaching learners how to carry out analysis of the problem in consideration, assess the importance of various pieces of information, and to decide which information should be used to understand, explain, or solve the problem and plan subsequent study actions. Problem-solving skills are the processes used to reach the solution to a problem [8].

The theoretical underpinning of this study hinges on constructivist learning theory. The emphasis of constructivism lies on construction of knowledge from prior knowledge. Accordingly, knowledge cannot be transferred from one individual to another. Knowledge construction is greatly influenced by individuals' prior experiences and learners make sense of the world by integrating or synthesizing new ideas or experiences into the previous ones. Consequently, each learner constructs meaning for himself by connecting new information or idea to his already existing knowledge, experiences, or conceptualizations in other to make interpretations. The teacher therefore plays the

role of creating an enabling environment for learners to think and make their own connections in order to arrive at valid internalized meaning

Problem-based learning has numerous applications in teaching especially science concepts. Problem-based learning promotes better understanding of course concepts and improves the problem- solving skills of students as well as their communication, presentation and teamwork skills. Students are more engaged in class because they recognize that they are acquiring important skills which will help them succeed in their future careers [9,4]. Furthermore, it provides learners with opportunities to develop conceptual and practical skills and practically apply them as they process knowledge and information from various sources. Problem-based learning provides learners with opportunities to develop conceptual and practical skills and practically apply this as they process knowledge and information from various sources,

Problem-based learning offers students the opportunity to appraise their own understanding, and detecting their learning needs as they play an active role in the teaching and learning process. Higher order thinking skills can be developed by students through logical thinking and probing questions can encourage retrieval of prior knowledge and discussion with group members which enhance accumulation, organization, storage and retrieval of information [10]. As a technique that in-corporate advanced levels of thinking, it helps learner acquire problem solving skills in addition to the skills of communicating, analyzing, researching and accepting others. Furthermore, Problem-

based learning enhances self-confidence, boost students‟ self-efficacy and encourages critical thinking skill irrespective of gender. It also instills perseverance in students for reaching their set targets, 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 [11].

There are seven phases involved in developing a good problem-based learning which forms what is popularly known as the “Problem-Based Learning Cycle”. The steps are:

1. The teacher presents a real like problem to the students.
2. Students discuss the problem and formulate hypothesis.
3. Students first retrieve prior knowledge and experience relative to the problem
4. They identify knowledge deficiencies
5. Start making their research;
6. Students apply their knowledge to check the validity of their hypotheses in light of what they have learned
7. At the finish of each problem, students make their own reflection on the knowledge acquired [2, 12].

Moreover, center for teaching recommended the following seven steps for designing problem-based learning that can help teachers in preparing lessons.

Step 1: Explore the issue: Get required information; study new ideas, principles, and skills about the projected topic.

Step 2: State what is known: Individual students and groups list what they already know about the scenario and list what areas they are lacking information.

Step 3: Define the issues: Frame the problem in a context of what is already known and information the students expect to learn.

Step 4: Research the knowledge: Find resources and information that will help create a compelling argument.

Step 5: Investigate solutions: List possible actions and solutions to the problem, formulate and test potential hypotheses

Step 6: Present and support the chosen solution: Clearly state and support your conclusion with relevant information and evidence.

Step 7: Review your performance: Students must evaluate their performance and plan improvements for the next problem.

In developing a good problem-based instruction, the teacher must ensure that the problem is complex, open-ended, ill-structured, has multiple solutions with none clearly superior, be realistic and resonate with the students' experiences, support intrinsic motivation, lead students to generate hypotheses and defend them to others in their group, challenge students to develop higher order

thinking skills, afford feedback that permits students to evaluate the effectiveness of their knowledge, reasoning, and learning strategies. An ill-structured problem is the problem that is not completely defined and not easily resolved with a degree of certainty [13].

It is imperative to note that, problem-based learning when well-designed provide students opportunities to develop related skills connected to working in team, handling projects and holding leadership role, oral and written communication, working independently, critical learning and analysis, applying content to real world examples, and problem solving among disciplines [13]. However, the teacher needs to articulate the learning results of the project, create a problem, create ground rules at the commencement, consider students playing different roles establish how to evaluate and assess the assignment and introduce the students to their groups

There are several studies on the use of problem –based learning in various chemistry concepts apart from other science concepts.[14] examined the effects of Problem-Solving teaching strategy on secondary school students' academic performance and retention in Chemistry in Obio-Akpor Local Government Area of Rivers State, Nigeria. It also examined the effect of Problem-Solving teaching strategy on gender of Chemistry school students. Purposive and stratified random sampling techniques was used to select a total sample of 85 SS II Chemistry students (this sample was divided into 40 students in experimental and 45 students control group) from two Senior Secondary schools in Obio-Akpor Local Government Area of Rivers State, Nigeria. Three research questions and two

hypotheses null hypotheses were formulated and tested at 0.05 level of significance. The instrument for this study was Chemistry Achievement Test (CAT). The data collected were analysed using t-test statistical analysis package. The results of the analyses revealed that no significant difference between academic achievement of learners in experimental group and control group involved in the study at pretest (this showed initial academic homogeneity of the groups). However, students' academic performance in the experimental group and control group at post-test level was establish to be significantly different in favour of the experimental group. This indicated that Problem-Solving teaching strategy significantly affects students' academic performance in Chemistry in Senior Secondary School. The performance of male and female students exposed to Problem-Solving teaching strategy did not differ significantly as female students were found to have similar achievement in Chemistry as their male counterparts Founded on the findings of the study, conclusion and recommendations were made.

[11] investigated the influence of problem-based learning approach on chemistry students' performance and interest in Mole concept using quasi-experimental pre-test, post-test, control group design. The sample comprise 110 SS 2 chemistry students from the seven public co-educational schools in Abuja Municipal Area Council (AMAC), Karshi Zone of Abuja, while the instruments were: Mole Concept Achievement Test (MCAT) and Mole Concept. Interest Scale (MCIS) with reliability coefficient of 0.96 and 0.95 respectively. Findings shown that, students taught mole

concept with problem based learning strategy performed better and expressed better interest than those taught using lecture method. Problem-based learning improved the achievement of both boys and girls equally but fostered more interest in male students. [10] studied the effect of problem-based learning on students' academic achievement in chromatography and science learning activation. The study adopted quasi-experimental design and mixed research method and the sample comprised 92 grade 10 learners of Nyamphande boarding secondary school in Petauke, Eastern province, Zambia. The instruments were: chromatography achievement and problem-solving skills test and science learning activation questionnaire. Results from the achievement test and a science learning activation questionnaire survey revealed that problem-based learning approach contributed positively to learners' achievement and science learning activation and had a positive impact on learners' academic achievement and science learning activation.

[15] examined problem solving method and Brainstorming technique on learners achievement in Chemistry in Obio-Akpor Local Government Area of Rivers State. Two research questions and one hypothesis guided the study. Quasi-experimental design specifically non-equivalent control group design was used. 150 senior secondary II (SS2) Chemistry students was the sample size gotten via simple random sampling technique. One intact class were assigned to experimental group (problem solving method and one intact class to control group brainstorming method). The research instrument comprised of Chemistry Achievement Test (CAT) . The reliability

coefficient of the instrument is 0.71. The data was scrutinized using mean, standard deviation and analysis of covariance (ANCOVA). The finding shows that students taught Chemistry with problem solving teaching method performed better than the learners taught with brainstorming instructional method. Therefore, the researcher recommends the use of problem solving method in all senior secondary schools that offer Chemistry in Rivers State and other state in Nigeria, also teachers should be sponsored by Governments to attend special workshops and conferences on effective use problem solving method

[16] conducted research on problem-solving technique of teaching on students' academic achievement in Physics and Chemistry in Calabar Municipality, Cross Rivers State Nigeria. Quasi experimented design was the research design. The sample size consisted of 200 senior secondary 11 students. The instruments for data gathering was Physic/Chemistry Performance Test (PPT and CPT) the reliably coefficient for PPT and CPT were 0.85 and 0.89 via the Kudar Richardson. The data gathered were scrutinized using mean difference. The finding of the research revealed that learners in the experimental group performed better in Physics and Chemistry than the control group. The researchers recommend among others that problem-solving strategy to be applied in teaching Physics and Chemistry.

[17] studied the influence of problem-based learning method on senior secondary school students interest and performance in physics in Bauchi State, Nigeria. The study adopted a quasi-

experimental research design, specifically, non-randomized pre-test post-test research design. The sample comprised to students in four intact science classes from two equivalent co-educational secondary schools. The tools used for the data collection were Physics Achievement Test (PAT) and Electricity Interest Inventory (EII). The results also showed that the problem-based learning approach had a more positive effect on students' achievement than the conventional approach. Male students had a marginally higher mean interest rate when they learnt electricity using problem-based learning method than their female colleagues, but the difference was not significant.

[18] studied problem solving instruction on middle school students' physical science learning interplay of knowledge, reasoning and problem solving. The quasi-experimental design specifically the on factorial design and 126 students constituted the sample. The instrument for data gathering was a science achieved test. Data gathered were scrutinized using Analysis of Variance (ANOVA) and MANCOVA. The result shows that problem solving group achieved better than the conventional group and rate of retention was significant. The study recommends that problem solving is an effective method and must be incorporated in school curriculum as a means of instruction for high school students.

[3] investigated the effect of problem-based learning on students' achievement in chemistry. Quasi-experimental design was employed for the study. 101 equivalent students in KwaZulu-Natal province in South Africa were designated for the study. The control group was taught with the

traditional lecture method while the experimental group were taught with problem-based learning. Findings revealed that there was significant difference in chemistry performance of students between control and the experimental group after teaching. This confirms that problem-based learning is an efficient technique to teach chemistry as it improves students' critical thinking and problem-solving skills.

Abanikannda [2] investigated the influence of problem-based learning in chemistry tutelage on academic achievement of school students. The study adopted a descriptive survey design. Purposive sampling method was used to select 300 senior secondary two (S.S.2) science students of ten (10) high schools in Oriade local Government Area of Osun State in Nigeria which served as the sample. The instrument was questionnaire on the effect of problem-based learning in Chemistry education on academic achievement of school students. The findings of this study revealed various activities engaged in by students during PBL lessons.

[19] investigated the effect of problem-based learning on the science academic performance of prospective science teacher and the stability of knowledge in terms of the boiler stone problem. The design was pretest and post-test control group design of quasi experimental design. The sample comprised 74 3rd grade students in Department of Science Education and the instrument was Science Academic Achievement Test (SAAT). Finding of the study revealed that there was a significant difference between the experimental and control group students in favor of the experimental group.

Problem based learning had a positive influence on students' science achievement and the permanence of knowledge**.**

[20] carried out a study on students problem-solving skills and their understanding of chemical rate and their performance on this issue. The sample size consisted of 122 students in the department of Science Education Gazi University. The instrument for data collections was Logical Reasoning Test (LRT) and Scientific Process Skill Test (SPST). The reliably coefficient of LRT and SPST was 0.79 and 0.82 respectively. The data generated were scrutinized using mean, standard deviation, t-test and ANOVA. The findings of study revealed that there was significant difference in achievement between the experimental and control group. The problem-solving group achieved better in chemical concept than the control group. The effect of problem-solving in performance of male and female undergraduates was in favor of the females.

STATEMENT OF THE PROBLEM, OBJECTIVES AND RESEARCH QUESTION

Statement of the Problem

Science teaching and learning over the years has been confronted with myriad of problems pointing towards students' poor performance in examinations at all stages of education and its attendant adverse effect on the quality of education in Nigeria. This unwelcomed development has attracted stakeholders" concerns and triggered the quest geared towards ongoing researchers in

chemistry and other disciplines with a view to proffering answer to the problem. Ideally, the availability of instructional materials and conducive learning environment in an educational setting only cannot guarantee the anticipated good performance of students in examinations without proper harnessing of these facilities and blending them with appropriate teaching strategies. Therefore, the teachers' method of lesson delivery which is a means of realization of instructional objectives or learning outcomes usually measured in terms of students' performance in examinations becomes an imperative that must be prioritized in exploring the problem of students' poor performance in examinations, mostly, chemistry which is abstract in nature. From available studies, although many teaching methods has been considered in different research, problem-based learning as a teaching strategy has not been fully explored. In Nigeria, there are limited studies on this strategy in other states with none in Rivers State. Therefore, it is not clear whether the results obtained in these studies are applicable to other states in the country particularly, Rivers State where there appears to be no available study in this regard. To address this gap in knowledge this study is carried out in Port Harcourt metropolis of Rivers State.

Objectives of the Study

This study explored the effect of problem-based learning teaching strategy on academic performance of students in senior secondary schools in Port Harcourt Metropolis, Nigeria. Specifically, the study tends to determine:

1 students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method.

2 male and female students' performance in chemical equilibrium when taught with problem-based learning teaching strategy.

3. private and public-school students' performance in chemical equilibrium when taught with problem-based learning teaching strategy.

Research Questions

1 What is the difference between students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method.

2 What is the difference between male and female students' performance on chemical equilibrium when taught with problem-based learning teaching strategy.

3. What is the difference between private and public school students' performance on chemical equilibrium when taught with problem-based learning teaching strategy.

Hypotheses

HO1 There is no significant difference between students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method.

HO2 There is no significant difference between male and female students' performance on chemical equilibrium when taught with problem-based learning teaching strategy.

HO3. There is no significant difference between private and public-school students' performance on chemical equilibrium when taught with problem-based learning teaching strategy.

METHODOLOGY

This study adopted quasi-experimental design, specifically, the pretest posttest nonrandomized design. The sample comprised 79 SS2 chemistry students in intact classes of two senior secondary schools in Port Harcourt Metropolis purposively selected for the study. The instrument was a 25-item Chemical Equilibrium Performance Test (CEPT) developed by the researcher and subjected to face and content validity by two lecturers in Department of Science Education and one expert in Measurement and Evaluation in Rivers State University. The reliability coefficient of the instrument was 0.76 determined by test-retest method using Pearson Product Moment Correlation Coefficient formula. The research questions were answered using mean and standard deviation while the hypotheses were tested using Analysis of Covariance (ANCOVA). The hypothesis was accepted when the calculated value of t is less than the table or critical value and accepted when the calculated value of t is greater than the table or critical value.

RESULTS

Research Question 1

What is the difference between students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method?

Table1: Mean and standard deviation of students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method

		Mean			Standard Deviation		
Group	**N**	**Pre-test**	**Posttest**	**Diff.**	**Pre-test**	**Post-test**	**Diff.**
Problem-based learning Strategy	41	42.09	74..22	32.13	11.04	9.12	1.92
Lecture Teaching Method	38	37.64	44.62	6.98	9.97	8.54	1.43
Diff. between		4.45	29.60	25.15	2.74	0.58	0.49

Research Question 2

What is the difference between male and female students' performance in chemical equilibrium when taught with problem-based learning teaching strategy?

Table2: Mean and standard deviation of male and female students' performance in chemical equilibrium when taught with problem-based learning teaching strategy.

		Mean			Standard Deviation		
Group	**N**	**Pre-test**	**Posttest**	**Diff.**	**Pre-test**	**Post-test**	**Diff.**
Male	55	40.21	78.11	37.90	0.99	1.78	0.79
Female	24	39.15	73.41	34.26	1.22	1.01	0.21
Diff. between		1.06	4.7	3.64	0.23	0.77	3.98

Research Question 3

What is the difference between private and public-school students' performance in chemical equilibrium when taught with problem-based learning teaching strategy?

Table 3: Mean and standard deviation of private and public senior school students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method

		Mean			Standard Deviation		
School type	**N**	**Pre-test**	**Posttest**	**Diff.**	**Pre-test**	**Post-test**	**Diff.**
Private	45	56.45	76.67	20.22	1.12	1.45	0.33
Public	49	24.23	53.23	31.00	0.88	1.43	0.55
Diff. between		32.22	23.44	9.22	0.24	0.02	0.22

Hypothesis1

There is no significant difference between students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method.

Table 4: Analysis of Covariance private and public senior secondary students' performance in chemical equilibrium when taught with problem-based learning and lecture teaching method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1172.054[a]	2	8121.531	106.769	.000
Intercept	247.441	1	273.450	3.654	.010
Pre	10426.186	1	10478.187	146.730	.000
Groups	714.871	1	654.881	9.549	.003
Error	7668.846	76	76.432		
Total	334771.001	79			
Corrected Total	22054.011	78			

a. R Squared = .697 (Adjusted R Squared = .690)

Table 4 shows that F1, 76 = 9.545, $P<.05$, the null hypothesis which states that there is no significant difference in students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method is rejected. This infer that **t**here is a significant difference in students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method.

Hypothesis 2

There is no significant difference between male and female students' performance in chemical equilibrium when taught with problem-based learning teaching strategy.

Table 4: Analysis of Covariance of male and female students' performance in chemical equilibrium test when taught with problem-based learning and lecture teaching method

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1260.111[a]	2	6178.443	105.789	.000
Intercept	342.365	1	269.365	3.657	.010
Pre	22131.096	1	123567.098	1345.675	.000
Groups	705.762	1	567.652	0.067	.865
Error	4466.563	76	84.541		
Total	124563.123	79			
Corrected Total	12153.051	78			

Table 5 shows that F (1, 76) = 0.067, *P*>.05. For that reason, the null hypothesis which states that there is no significant difference in male and female students' performance in chemical equilibrium when taught with problem-based learning teaching strategy is accepted. This infer that there is no significant difference between the performance of male and female students on chemical equilibrium when taught with problem-based learning teaching strategy.

Hypothesis 3

There is no significant difference between private and public-school students' performance in chemical equilibrium test when taught with problem-based learning teaching strategy.

Table 4: Analysis of Covariance private and public senior school students' performance in chemical equilibrium when taught with problem-based learning

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	12067.033[a]	2	7978.531	118.769	.000
Intercept	354.225	1	167.450	2.452	.030
Pre	11315.215	1	12357.187	234.531	.000
Groups	823.965	1	632.881	9.549	.003
Error	6798.897	76	66.432		
Total	387654.010	79			
Corrected Total	11123.023	78			

Table 6 shows that F (1, 76) = 9.549, *P*>.05. Therefore, the null hypothesis which states that there is no significant difference in private and public students' performance in chemical equilibrium

when taught with problem-based learning teaching strategy is rejected. This infer that there is a significant difference between private and public-school students' performance in chemical equilibrium when taught with problem-based learning teaching strategy.

DISCUSSION OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Discussion

Results of research question 1 and test of hypothesis 1 (Tables 1 and 4) revealed a significant difference between the performance of students' performance in chemical equilibrium when taught with problem-based learning teaching strategy and lecture teaching method. The students taught with problem-based learning obtained higher performance test scores than those taught with lecture teaching method. This result agrees with that of [11] which showed that students taught mole concept using problem-based learning strategy performed well and showed interest than those taught using lecture technique in Abuja Municipal Area Council (AMAC), Karshi Zone of Abuja.

This result further agree with that of [15,17] which showed that problem-based learning approach had a more positive effect on students achievement and interest than the conventional approach in Bauchi state of Nigeria and that of [19] which showed a significant difference between the experimental and control group students' in favor of the experimental group. Problem based learning had a positive impact on students' science achievement and the permanence of knowledge.

Furthermore, it agrees with the results of [10] in Eastern province of Zambia which showed that that problem-based learning approach contributed positively to learners' achievement and science learning activation and had a positive impact on learners' academic achievement in chromatography and science learning activation as well as that of [14,16,17] where similar results was obtained showing that the problem based learning approach had a more positive effect on students' achievement than the conventional approach.

Results of research question 2 and test of hypothesis 2(Tables 2 and 5) showed no significant difference between the performance of male and female students on chemical equilibrium when taught with problem-based learning teaching strategy. Male students obtained similar higher performance test scores compared to their female counterparts implying that the teaching strategy is not gender selective. This results agree with that of [11,14] which showed that problem-based learning improved the achievement of both male and female students equally but fostered more interest in male students but disagree with that of [17] where male students had a slightly higher mean interest rate when they learnt electricity using problem-based learning approach than their female counterparts but the difference was not statistically significant. The results of research question 3 and test of hypothesis 3 (Tables 3 and 6) showed that there is a significant difference between private and public-school students' performance on chemical equilibrium when taught with problem-based learning teaching strategy.

Conclusion

Problem-based learning teaching strategy is more effective and enhance students understanding of chemical concepts than lecture teaching method. Moreover, the strategy is not gender and class level selective.

Recommendations

1 Teachers should embrace problem-based learning teaching strategy in teaching chemistry at all stages of education.

2. Enabling environment that promote collaboration of knowledge among students should be created by teachers

3. Teaches should endeavor to ensure that classroom activities are dominated by the students while he or she plays the role of a facilitator.

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Contributions to knowledge

1. Findings of this study expands the existing knowledge on the application of problem-based learning in teaching science.
2. It offers teachers unlimited alternatives to selecting suitable teaching strategies to arrive at effective lesson delivery.