Gender Differences on Students' Self-Efficacy, Academic Performance, and Knowledge Retention Taught Mole Concept using Krall's Five-Step Problem Based Learning Model

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Abstract

Worried by the gender gaps in science, particularly chemistry classrooms, this study investigated the influence of gender on students' self-efficacy, academic performance, and knowledge retention taught mole concept using Krall's five-step problem-based learning (PBL) model in Jalingo Education Zone. Taraba State, Nigeria. A sample size of 135 students (72 males & 63 females) from two intact classes was drawn through purposive sampling. Students' self-efficacy scale (SSES) and Mole concept achievement test (MCAT) were used for data collection. Cronbach alpha was used to estimate the reliability index of 0.815 for SSES; and Kudder- Richardson KR-20 for MCAT with a reliability index of 0.745. Analysis of covariance (ANCOVA) was used to test the null hypotheses at a 0.05 level of significance. Based on the data collected and analyzed, the findings revealed that there was no significant influence of gender on students' self-efficacy, academic performance, and knowledge retention taught the mole concept using Krall's five-step PBL model. The study concluded that the use of PBL facilitated the learning of chemistry, and student's academic performance, knowledge retention, and self-efficacy were not gender-influenced. Thus, chemistry teachers should be trained and encouraged to use PBL in daily class lessons due to its effectiveness in closing gender gaps.

Keywords: Self-efficacy, performance, retention, mole, gender.

Introduction

In 21st-century science classrooms, various teaching-learning strategies have been developed to accelerate the learning process of students which evolved from the learning theories defining the role of teacher, students, and the contents; but most behavioral practices in schools make students passive, and the classroom-dominated by the teacher (Jack, 2022). Hence, for effective teaching to take place, the teacher must stimulate, encourage, and maintain active participation of the students through the selection of appropriate teaching methods. This would require a balance between what is taught and how it is taught. Therefore, the successful teaching of chemistry does not depend only on the teacher's mastery of the subject matter, but also on the instructional method employed. This implies that what students learn is greatly influenced by how they are taught.

As schools begin to shift their academic focus, traditional approaches to learning may not provide enough opportunity for students to develop some of the 21st-century skills. The structure of traditional teaching within science education (specifically, chemistry) focuses primarily on content-driven results and lacks the foundational innovation skills such as problem-solving, collaboration, critical thinking, and communication needed to become an authentic or meaningful learner (Jaack, 2022; Jack 2023). It is therefore critical that students are prepared to question and contribute to scientific and technological public interests by the end of their secondary school. To achieve this, the instructional strategies used in science/chemistry classes must provoke curiosity and a desire to learn. This is because, the students not only need the content, but the skills to use the learned knowledge and an interest in lifelong learning. Hence, educators need to provide opportunities that allow students to learn through inquiry, collaboration, and problem-solving that encourage the learning process both now and in the future through innovative methods. For example, Problem-based Learning (PBL) seems to be an alternative approach to teaching that is not prescriptive and makes use of problems as a focus for student investigation and inquiry (Jack, 2022); mostly for some chemistry difficult and abstract concepts such as mole and stoichiometry. Problem-based learning covers a broad family of schemes that include problem-solving, project-based teaching, inquiry, case-based instruction, and grounded instruction.

Problem-based learning is one possible solution to addressing this complicated problem of providing students with opportunities to develop these important 21st-century skills, while also giving students the freedom to expand and explore their interests in the topics taught (Tighe, 2020). A problem-based learning task is a pedagogical strategy that aims to increase critical thinking, collaboration, creativity, and communication through a student-centered learning task (Brush, 2017; Tighe, 2020). Problem-based learning methods are a cross-curricular approach, supporting students to incorporate all their knowledge into the problem-solving activity, not just an isolated subject. When students engage in these types of activities, their knowledge becomes transferable because they can make connections between materials (Brush, 2017). Problem-based learning allows the freedom for students to explore their interests within the scope of the problem, also impacting motivation and higher levels of thinking (Bagus, 2018; Tighe, 2020). Problem-based learning develops critical life skills such as collaboration, flexible knowledge, self-directed learning, and critical thinking (Brush, 2017; Tighe, 2020).

As noted by Tighe (2020), a key element of PBL tasks is communication and collaboration, and these skills are essential to student learning. These are life skills that students will value, no matter the context of their careers, becoming not only great learners but developing social skills for their society (Brush, 2017); and these skills are valued in the 21st-century workforce (Tighe, 2020). Students who excel in creativity may struggle to think critically; therefore, the social element of communication and collaboration of their ideas creates even stronger solutions (Saputra et al., 2019). With the advancement of technology, accessing platforms to communicate and collaborate has become even easier. With proper guidance, students can be taught to maximize these opportunities and gain strategies to effectively communicate with their peers or even professionals. However, just having opportunities to communicate does not necessarily mean students are utilizing these platforms effectively. Problem-based learning as noted by Bagus (2018) can provide opportunities to practice effective communication and collaboration by utilizing teacher guidance. This makes it even more important for schools to implement problem-based learning to create effective change and advancement for students learning valuable skills to solve problems.

Students' active involvement in trying to solve some problems or answer some questions is central to all the different strategies and students' self-efficacy beliefs using both qualitative and quantitative data. Interviews with the participants indicated that students had higher self-efficacy beliefs in chemistry, for conducting chemistry experiments, and mathematical concepts in chemistry such as the mole and stoichiometry. As noted by Mataka (2014), students felt that PBL provided them with autonomy while exploring phenomena and allowed them to take more responsibility for their learning. The problem of students' underachievement and low self-efficacy as opined by Jimoh and Fatokun, (2020) towards learning especially difficult chemical concepts, can be attributed to some inadequacies in the teaching; and teachers' persistent adoption of conventional instructional approaches have been observed as major challenge to students' proper understanding, assimilation and retention of content taught. The mole concept is fundamental in chemistry, though abstract and mathematically inclined (Jimoh & Fatokun, (2020). Boniface (2018) affirmed that the mole concept is difficult and expressed students' wrong perception and exhibition of negative attitude towards learning before exposure to treatment, which has affected the learning outcomes and understanding of this fundamental chemistry concept.

One of the affective factors that determine the students' achievement and retention in the learning process is self-efficacy. Self-efficacy is described by Masitoh and Fitriyani (2018) as an individual's confidence in completing a variety of tasks, from understanding concepts to

solving problems., Masitoh and Fitriyani (2018) noted that high self-efficacy will encourage the achievement of good learning outcomes, and when students have good learning outcomes, they will be more motivated in the learning process; and that students with high self-efficacy can solve a problem than students with low self-efficacy.

Given the importance of education, it is critical to concentrate on instructors' problem-solving abilities to achieve the necessary increase in students' learning outcomes, particularly in mole concepts in chemistry in senior secondary schools. The student's poor achievement in chemistry could be attributed to many factors. These factors include poor classroom management, use of gender-based instructional materials, inadequate instructional material, inadequate laboratory activities, poor teaching methods employed in teaching chemistry, and lack of competent chemistry teachers. The problem of this study is to find out if the use of a problem-based learning strategy could enhance the self-efficacy, academic performance, and retention of students in mole concepts in chemistry and help close the gender gaps. The study sought to ascertain if PBL could help to close gender gaps in chemistry classrooms. Hence, the study aimed at examining the influence of gender on students' self-efficacy, academic performance, and knowledge retention taught the mole concept using Krall's five-step problem-based learning model.

The study was guided by three null hypotheses tested at 0.05 level of significance, as follows:

$H0_1$: There is no influence of gender on student's self-efficacy taught mole concept using Krall's five-step problem-based learning model.

$H0_2$: There is no influence of gender on students' academic performance, taught mole concept using Krall's five-step problem-based learning model.

$H0_3$: There is no influence of gender on student's knowledge retention taught mole concept using

Krall's five-step problem-based learning model

Problem-based Learning (PBL), is a new pedagogical and realistic approach to learning stemming from a constructivism approach to education that regards learning as an active process in which learner constructs the meaning of subject matter rather passively received the finished product of knowledge based on his/her present and past state of knowledge and experiences or in other word learners are supposed as independent participants and critical inquirers. In PBL, the problem means an open-ended situation and future-facing anticipated problems that the learner needs to know for his/her succession in the present world (Malla, 2020).

For the searching solutions to problems according to mathematics as viewed by Malla (2020), Krall's problem-based learning strategy is new and scientific than conventional problem-solving strategy; and problem-solving is important to both teachers and students for better understanding. Krall's (2012) developed a five problem-based learning cycle as following steps which include:

Posing the problem: Students are presented with a problem that is complex and ill-structured and concerned with real-world phenomena. Such problems engaged the students in an independent critical inquiry.

Work on the problem: Students work in small and interactive groups to share and organize their ideas, including the past and present current state of knowledge and experience related to a given problem.

Intervention as a question arises: Students learn by doing something new, whereas the tutor provides the series of arising conundrums in cordial ways so that students employ the rules to find the proper solutions.

Students apply the instruction: Students share their solutions. Here instructors position again themselves to watch over the student's work and how they are using and misusing knowledge they are trying to achieve and finally, the tutor provides feedback.

A solution reached: Here students reach the solution, which is expected to a new and different, and along with the phase new problem is given problem based learning takes at least three scenarios per unit at once whole learning is focused on the final product.

For the context of stoichiometry and mole concepts which are mathematical chemistry concepts under mass-volume relationships, the Krall five-step problem-based learning model seems to be more appropriate, hence used for this study.

Research Methods

This study adopted a quasi-experimental design, using pre-test, post-test, and post-post-test with control and experimental groups. The study was carried out in Jalingo Educational Zone Taraba State, Nigeria. The population was drawn from Secondary Schools Two (SS2) in the 2023/2024 academic session. A sample of 135 students SS2 students made up of two intact classes (assigned as experimental & control groups) was selected using purposive sampling from the population, due to the nature of the study. The experimental group used an intact class of 71 students (40 males & 31 females); while the control group was an intact class of 64 students (29 males & 35 females).

Two instruments; the Students Self-efficacy Scale toward mole concept (SSES), and the Mole Concept Performance Test (MCPT) adapted from an online questionnaire, and WAEC past questions, were used as tools for data collection; that is a questionnaire and a performance test. The questionnaire was adapted to measure students' self-efficacy in the Chemistry mole concept and was used as a pre-test and post-test for both experimental and control groups. The pre-test was used to measure students' self-efficacy towards the mole concept in chemistry before the exposure of the treatment to the experimental groups. On the other hand, the post-test was used to measure students' self-efficacy toward the mole concept in Chemistry after the treatment. The items of the pre-test (SSES) were re-arranged to form the post-test SSES items. The respondents were required to tick the chosen response representing their viewpoint from several answer categories. This means the structure of the questions was close-ended questions on the five-point likert scale of SA=Strongly Agreed (5 points), A=Agreed (4 points), U= undecided (3 points) D= Disagreed (2 points), and SD= Strongly Disagreed (1 point). The advantage of close-ended questions is that they are manageable since the respondents are restricted to a finite set of responses.

The other instrument for data collection was a performance test tagged Mole Concept Performance Test (MCPT); the performance test was administered to both control and experimental groups to measure their performance in the mole concept in Chemistry. The MCPT was a 40-item 4-option multiple choice question; where the right option is 1 and the wrong option is 0. The MCPT pre-test assessment test was administered to both groups to measure the student's performance in Chemistry before the exposure to the treatment. The questions were generated based on selected Chemistry content of second term SS2 topics: mole concept, oxidation, and reduction reactions, mass-volume relationship, and electrolysis. This was to ensure the equivalence of control and experimental groups. The post-test was used to measure the student's performance in the mole concept in Chemistry for both experimental and control groups after the treatment.

In the validation of both instruments (SSES & MCPT), three experts conducted face and content validation. To ensure both face and content validity; the experts checked for ambiguity of items concerning the research variables, appropriateness of the items, construction, and structure of the items, good reflection of the objectives, clarity of the items and options, and relevance to the issue under investigation. The comments and suggestions made by these three experts were used to review the instruments.

For the reliability of the instruments, a pilot test was conducted with 30 students. In determining the reliability of the questionnaire (SSES), the data obtained from pilot testing was analyzed using Cronbach Alpha's to ensure the level of internal consistency in the responses, which gave a reliability coefficient of 0.82. For the performance test (MCPT), the K-R formula 20 was used, and the reliability coefficient was 0.75. This indicated that the instruments were reliable and suitable for the study. Both instruments were administered, and the data collected were coded and collated.

The administration of the instruments was done in two phases; the first phase was a pre-test, which was administered to the students a week before the treatment. After the administration of the pre-test, the students were taught the selected topics for four weeks in the same intact classes. The teachers who participated in the study were regular teachers who served as research assistants at the selected schools that taught both the experimental and the control groups, respectively. The second phase was a post-test that was being done after the experiment to determine whether the teaching strategy was effective. Both groups were taught for four weeks. At the end of the teaching, a post-test was administered to the students in both the treatment and controlled groups. A retention test (Post-post-test) was administered to the students in the two groups two weeks after the post-test. Data collected at pre-test, post-test, post post-test (Retention) were analyzed.

In the method of data collection, the preliminary stage took place in the first week; this included the presentation of an introductory letter for permission to be granted from the school authorities to use their students and teachers for seven (7) weeks. The training of the research assistants (regular teachers) to handle the experimental and control groups in the various schools lasted for one week. The second week was used for the administration of a pretest using both SSES and MCPT to both experimental and control groups in the school for one week. The third to the six weeks treatment was used, for administration of treatment which lasted for four weeks for teaching the experimental and control groups. The 7^{th} week was used for revision, completion of selected topics, and administration of the post-test using reshuffle MCPT to both the experimental and control groups in the school for one week.

For the method of data analysis for the data collected, the research questions were answered using mean and standard deviation (descriptive statistics); while all the hypotheses were tested at 0.05 level of significance using Analysis of Covariance (ANCOVA). Where the pre-test scores are the covariates to ascertain the entry equivalence. The use of ANCOVA analysis was to "statistically control" for the influence of confounding variables. A p-value of less than 0.05 ($p<0.05$) was considered to be statistically significant.

Results

Testing Hypothesis one

H_{01}: There is no influence of gender on student's self-efficacy in the mole concept using Krall's problem based learning model.

Table 1: ANCOVA of Self-Efficacy of Male and Female Students Taught mole concept using Krall's five-step problem based learning model

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2.501[a]	2	1.250	5.455	.005	.078
Intercept	158.337	1	158.337	690.831	.000	.843
Pre MCPT	2.494	1	2.494	10.880	.001	.078
Gender	.043	1	.043	.188	.665	.001
Error	29.567	69	.229			
Total	1374.738	71				
Corrected Total	32.067	70				

a. R Squared = .078 (Adjusted R Squared = .064)

Table 1 reveals that $F(1,69) = 0.188$; $p = 0.665 > 0.05$. Thus, the null hypothesis is not rejected. This implies that there is no significant difference in the mean belief score of male and female students taught the mole concept using Krall's five-step problem-based learning model. Therefore, there is no significant difference in the effect of problem-based learning on the mean belief score of male and female students. The partial Eta square of 0.001 obtained for gender means that only 0.1 percent (insignificant) of students' mean self-efficacy can be attributed to gender.

Testing Hypothesis two

H_{02}: There is no influence of gender on students' mean performance scores in mole concept, taught using Krall's five-step problem-based learning model

Table 2: ANCOVA of Performance of Male and Female Students taught mole concept using Krall's five-step problem-based learning model

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	130.327[a]	2	65.163	2.119	.124	.032
Intercept	7260.363	1	7260.363	236.062	.000	.647
Pre MCPT	118.308	1	118.308	3.847	.052	.029
Gender	12.294	1	12.294	.400	.528	.003
Error	3967.552	69	30.756			
Total	67810.000	71				
Corrected Total	4097.879	70				

a. R Squared = .032 (Adjusted R Squared = .017)

Table 2 reveals that F(1,69) = 0.400; p = 0.528 > 0.05. Thus, the null hypothesis is not rejected. This implies that there is no significant difference in the mean performance of male and female students taught the mole concept using Krall's five-step problem-based learning model. Therefore, there is no significant difference in the effect of problem-based learning on the mean performance scores of male and female students. The partial Eta square of 0.003 obtained for gender means that only 0.3 percent of students' performance can be attributed to gender.

Testing Hypothesis three

H_{03}: There is no influence of gender on student retention in the mole concept using Krall's five-step problem-based learning model.

Table 3: ANCOVA of Retention of Male and Female Students taught Mole concept using Krall's Five-step Problem based learning Model

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	68.606[a]	2	34.303	3.006	.052	.027
Intercept	2767.388	1	2767.388	242.526	.000	.531
Pre MCPT	29.012	1	29.012	2.543	.112	.012
Gender	57.836	1	57.836	5.069	.025	.023
Error	2441.892	69	11.411			
Total	25386.000	71				
Corrected Total	2510.498	70				

a. R Squared = .027 (Adjusted R Squared = .018)

Table 3 shows that F(1, 69) = 5.069; p = 0.025 < 0.05. Thus, the null hypothesis is not rejected. This implies that there is no significant influence of gender in the retention of students taught the mole concept using Krall's five-step Problem-based learning model. Therefore, there is no significant difference in the effect of problem-based learning on the mean performance scores of male and female students. The partial Eta square of 0.023 obtained for gender means that only 2.3 percent of students' retention can be attributed to gender.

Discussion

The key findings include:

i. There is no significant influence of gender on students' self-efficacy in the mole concept using Krall's five-step problem-based learning model.

ii. There is no significant influence of gender on students' mean performance scores in the mole concept using Krall's five-step problem-based learning model.

iii. There is no significant influence of gender on student retention in the mole concept using Krall's five-step problem-based learning model.

On gender influence on students' self-efficacy using PBL, the finding revealed that there was no significant influence of gender on students' self-efficacy in the mole concept using Krall's five-step problem-based learning model. The difference in the mean self-efficacy of male and female students taught the mole concept using Krall's five-step problem-based learning model was in favour of male students in problem-based learning class; though the difference was insignificant. This study agrees with Dorji (2021), Nenshi et al. (2021), and Wahyu, et al. (2018) whose studies showed that the influence of gender was insignificant.

On gender influence on student's academic performance using PBL, the finding revealed that there was no significant influence of gender on student's academic performance in mole concept using Krall's five-step problem-based learning model. The finding of the present study agrees with Dorji (2021) who revealed the effectiveness of using PBL on the academic achievement of higher secondary school students. The results revealed that the experimental group that used PBL scored higher marks in the class test than the control group. The experimental group had a favorable opinion of the effectiveness of the PBL. Nenshi et al. (2021) also revealed the effectiveness of PBL; the finding revealed among others that students taught with PBL recorded higher achievement. The finding also agrees with Jimoh and Fatokun (2020) who attested that PBL improved the achievement of both male and female students equally. Cwynar (2020) attested to the effectiveness of problem-based learning on academic achievement and the development of skills beyond the academic content. The finding also agrees with Wahyu et al (2018) whose results showed that generally academic achievement and creativity of students increased with PBL and that it can be applied to the learning process for other chemistry topics that are suitable in terms of characteristics between learning materials and PBL stages to develop academic achievement and creativity of students. Also, the results of no significant difference based on gender agree with Itodo (2019) and Agbidye (2017) found that there are no statistically significant differences in the academic achievements of students concerning gender. Oludipe (2012) also found that there was no statistically significant difference in the academic achievement mean scores of male and female students.

On gender influence on students' knowledge retention using PBL, the finding revealed that there is no significant influence of gender on student retention in the mole concept using Krall's five-step problem-based learning model. This study agrees with Dorji (2021) and

Nenshi et al (2021) whose studies showed that the influence of gender on students' retention was insignificant.

The insignificant gender differences in students' self-efficacy, academic performance, and knowledge retention may have resulted from the usage of PBL in mole concept lessons which provoked students' curiosity and desire to learn. Students in chemistry lessons do not only need the content, but the skills to use the learned knowledge and an interest in lifelong learning. The Krall's five-step problem-based learning model also enabled the students opportunities to learn through inquiry, collaboration, critical thinking, and problem-solving, hence developing collaborative, computational, and higher-order thinking skills in the students in a gender-friendly class environment. The structure of traditional teaching within science education focuses primarily on content-driven results and lacks the foundational innovation skills such as problem-solving, collaboration, and communication needed to become a successful professional. This is not healthy for 21st-century chemistry classes for authentic and meaningful learning.

Conclusion

The study findings of this study revealed that the use of problem-based learning (PBL) facilitated the learning and closing of gender gaps in chemistry. Therefore, the study concluded that the PBL strategy, specifically Krall's five-step PBL model enhanced students' academic performance, knowledge retention, and self-efficacy and was very effective in closing the gender gaps. Hence, if Krall's five-step PBL model is adopted in chemistry, it may help improve the academic performance, knowledge retention, and self-efficacy of students in some difficult mathematic concepts in chemistry such as mole and stoichiometry.

Based on the conclusions drawn from the findings of this study, it is hereby recommended that:

i. Chemistry teachers should be trained and encouraged to use PBL, specifically Krall's five-step PBL model in making daily lesson plans in teaching difficult chemistry concepts such as the mole concept because of its effectiveness in closing classroom gender gaps.

ii. Curriculum planners and science teachers may be innovative and adopt a problem-based solving activity (Krall's five-step PBL model) in teacher education instructions; as students are actively engaged and 21st-century skills such as collaborative, critical thinking, and problem-solving are developed. Hence, its use is highly recommended for a gender-friendly class environment in teaching difficult mathematical concepts in chemistry, such as the mole concept and other chemical concepts.

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