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EFFECT OF PROBLEM-BASED LEARNING ON SECONDARY SCHOOL CHEMISTRY STUDENTS' ACHIEVEMENT IN IUPAC NOMENCLATURE OF ORGANIC COMPOUNDS: A GENDER-BASED STUDY IN OYO TOWN

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Abstract

This study investigated the effect of Problem-Based Learning (PBL) on secondary school students' achievement in the International Union of Pure and Applied Chemistry (IUPAC) nomenclature of organic compounds, with a focus on gender differences in Oyo Town, Nigeria. Adopting a 2x2x2 factorial quasi-experimental design, 170 Senior Secondary II Chemistry students from two public schools were selected using purposive sampling. Participants were divided into experimental (PBL) and control (conventional lecture method) groups. The Chemistry Achievement Test (CAT), a validated and reliable instrument, was used to measure academic performance pre- and post-intervention. Results revealed a statistically significant main effect of PBL on students' academic achievement in IUPAC nomenclature ($F_{(1, 114)} = 343.831$, $p < 0.05$, $\eta^2 = 0.765$). Students in the PBL

Keywords: Problem-Based Learning, Chemistry Education, IUPAC Nomenclature, Gender Differences, Academic Achievement, Secondary School.

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group achieved a significantly higher post-test mean score (M = 23.182) compared to those in the control group (M = 13.438), showing a mean difference of 9.744. Additionally, there was a significant main effect of gender on achievement ($F_{(1, 167)} = 4.532$, $p < 0.05$, $\eta^2 = 0.076$), with female students outperforming their male counterparts (M = 21.705 vs. M = 20.353). While the interaction effect of PBL and gender was not statistically significant $F_{(1, 112)} = 1.980$, $p = 0.162$), descriptive statistics showed that both male and female students benefited from PBL, with females in the PBL group achieving the highest post-test mean (M = 23.871). The study concludes that PBL is an effective strategy for improving students' understanding of complex chemistry topics like IUPAC nomenclature and highlights the role of gender in learning outcomes. It recommends the integration of PBL into the chemistry curriculum and teacher training to optimize instructional practices and address gender-related learning differences.

Introduction

The origins of science can be traced back to early humans, whose interactions with nature sparked their interest in studying and comprehending the cosmos. Science can also be thought of as a field of knowledge or research that examines a collection of orderly facts and demonstrates how universal laws operate. Science is a natural process that organizes information to better comprehend the world around us and the forces that shape it. Learning about nature and its benefits, which can enhance human lives, is part of this. The earth sciences and physical science, which study the inorganic world and include astronomy, physics, chemistry, and life science or biological science, which study the organic world of life and its processes, are examples of different scientific disciplines that can be divided into different groups according to the topic of study (Da-Silva, 2022).

Chemistry is widely used to advance technology in the properties of the compounds used in the fabrication process, the materials used, and the process itself. By using chemical processes to create medicines from medicinal plants and animals for a variety of illnesses, humans have effectively applied the concept of chemistry to medicine. Unfortunately, a lot of chemistry students in secondary school struggle to understand some scientific principles. This difficulty has been related to the fact that pupils find these abstract chemical principles hard to

understand. Since the pupils cannot see any of these, they must be able to visualize them to fully comprehend them. Even though chemistry is an essential subject for scientific and technological advancement, students' performance in the Senior School Certificate Examinations (SSCE) has been subpar. Lack of knowledge of balancing chemical equations, inability to answer electrolysis questions, ignorance of oxidation and reduction reactions, and ignorance of IUPAC norms are the main problems (Drew, 2023).

Any knowledge or skills a student has gained in school are considered academic achievements, and they provide an account of their current academic standing. The outcomes of internal or external tests and exams could be used to describe the academic standing. The researcher in the study links students' achievement on the teacher-given test to their academic success. There have been many previous attempts to solve these problems, but they have mostly concentrated on ways to improve the widely accepted conventional approaches to teaching chemistry. To improve students' performance in physical science, the instructor must employ a more engaging teaching strategy. Some educators prefer traditional teaching approaches, which emphasize a teacher-led approach to learning. The lecture technique, discussion method, project method, demonstration method, and discovery method are examples of conventional methodologies. Teachers frequently use these strategies to impart knowledge, skills, and information to their students. The term "conventional approach" refers to the lecture technique in the context of this study (Ebokaiwe, Ajaja and Kpangban, 2023). This strategy was chosen because most chemistry teachers preferred it to more conventional teaching approaches. A single individual, typically a teacher, delivers a spoken discourse about a particular subject in the lecture technique, also known as the didactic approach (Macaranas, 2022).

Lectures include discussions with students about new topics as well as explanations, simplifications, and clarifications. In addition to offering a visually stimulating experience, the materials may offer information or viewpoints on topics and situations that are pertinent to the students. The characteristics of the students, the classroom environment, the subject matter, the lesson objectives, and the qualities and skills of the teacher all affect how effective the lecture approach is. It can spread a lot of information quickly15, and is frequently used by chemistry teachers to instruct their students (Alaagib, Musa and Saeed, 2019). Lectures are the most economical and practical way to teach things. Except for

the chalkboard, scientific equipment, experiments, or tools are rarely required. The lecture method is a content-centric, teacher-directed approach. By using this method, the teacher serves as a resource for role-playing among the pupils. This allows the instructor to talk while the students just listen (Sanchita, 2023).

One particularly effective strategic teaching method is the Problem-based Learning (PBL) paradigm. It is a student-centered teaching strategy that encourages critical thinking through problem-based learning and encourages students to actively participate in their education. Investigation, assessment, and creative thinking should all be incorporated into a successful problem-based learning project or challenge. This method can be used in inquiry-based classrooms for a variety of courses at the start of the year and is essential for encouraging students to apply what they have learnt to practical circumstances (Yu and Zin, 2023). Based on the ideas of adult education, problem-based learning (PBL) is a useful strategy for capturing students' attention. By giving students the ability to set learning goals and make decisions that affect their academic path, problem-based learning increases student motivation and engagement. As a teaching strategy, problem-based learning (PBL) aims to teach students by having them solve real-world problems. This method emphasizes the value of stimulating educational opportunities that foster critical thinking, problem-solving, and teamwork. Additionally, problem-based learning creates an exciting and demanding environment in the classroom, which may have a big impact on students' behaviour. It allows students to leverage existing conceptual knowledge frameworks and activate prior knowledge, fostering transferable skills and attitudes beneficial for their future endeavours, including collaboration, critical assessment, teamwork, communication, respect for peers, self-directed learning, and resource management.

Although Problem-based Learning (PBL) is an effective educational method, it remains questionable if students' responses and gains from it vary according to gender. According to the findings of "Gender in Problem-based Learning: Curiosity Analysis, Problem Understanding, and Problem-Solving Ability", problem-based learning noticeably boosted curiosity and problem-solving abilities, but did not affect problem comprehension. According to a different study, kids' success in mathematics is unrelated to their gender or learning preferences. An investigation into the problem-solving skills of students using problem-based learning approaches about gender inequality was conducted (Yusuf, 2023). The findings

showed that although male students' average completeness increased by 73.5%, female students' average completeness increased by 72.5%. This suggests that male pupils are better than female students. Using reliable sources and academic research (Ameliasari & Wilujeng, 2023), this study will examine how gender affects learning through computer animation and problem-based learning. By investigating the "effect of problem-based learning on secondary school chemistry students' achievement in IUPAC nomenclature of organic compounds: A gender-based study in Oyo Town", this study overcomes the limitations of individual studies.

Statement of the Problem

Secondary school students in science class must study chemistry, especially organic chemistry, since it lays the groundwork for many other scientific and technological disciplines. The IUPAC nomenclature of organic compounds is one of the most important topics in secondary school chemistry, and because of its intricacy, students frequently find it difficult to understand. Lectures and rote memorization are examples of conventional teaching techniques that do not properly engage pupils or improve their comprehension of this complex subject. Because of this, many students are unable to become highly proficient in IUPAC nomenclature, which results in subpar academic achievement and a lack of enthusiasm for the topic. As a cutting-edge teaching method, problem-based learning (PBL) promotes critical thinking, problem-solving abilities, and active learning. The usefulness of PBL in raising students' proficiency in IUPAC nomenclature, however, has not been sufficiently investigated despite its possible advantages, especially when it comes to Oyo Town secondary schools. Moreover, no research has been done on how gender variations might affect PBL's results in chemistry classes. By examining the effect of problem-based learning on secondary school chemistry students' proficiency in IUPAC nomenclature of organic compounds, with an emphasis on gender disparities in Oyo Town, this study aims to close these gaps. Gaining knowledge about how PBL affects male and female students' achievement in this particular domain can help educators better understand how gender affects academic accomplishment in science classes and how to develop more effective teaching methods.

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Objectives of the Study

1. To determine the main effect of problem-based learning on chemistry students' achievement.
2. To evaluate the interactive effect of problem-based learning and gender on chemistry students' achievement.
3. To examine the main effect of gender on chemistry students' achievement.

Hypotheses

Based on the stated problems, the following hypotheses will be tested at a 0.05 level of significance.

$H_{o}1$: There will be no significant main effect of problem-based learning on chemistry students' achievement.

$H_{o}2$: There will be no significant interactive effect of problem-based learning and gender on chemistry students' achievement.

$H_{o}3$: There will be no significant main effect of gender on chemistry students' achievement.

Methods

This study employed a 2x2x2 factorial quasi-experimental design, incorporating pre-test and post-test measures, a non-randomized control group, and non-equivalent intact groups. According to the Teaching Service Commission (2024), the population of senior secondary II students in Oyo Metropolis, Oyo State, Nigeria, is two thousand six hundred thirty-nine (2639). The schools involved in this study are Ladigbolu Grammar School 2 (Oyo West Local Government) and Durbar Senior Grammar School (Oyo East Local Government). It adopted a multistage technique to select the students required, which includes two (2) intact science classes of senior secondary II. A purposive sampling technique was used to select two public co-educational secondary schools, one (1) school each from a Local Government area in the Oyo Educational Zone of Oyo State, using the following criteria:

1. Schools that have been in existence for more than 50 years.
2. Schools that have qualified chemistry teachers with at least five (5) years of working experience and also five (5) years of experience as a West African Examinations Council (WAEC) Examiner.
3. Schools that have a standard, well-equipped laboratory and a laboratory assistant

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In Oyo West Local Government, the school selected was Ladigbolu Grammar School, which has 89 Chemistry students in senior secondary school II. Also, in Oyo East Local Government, the school selected was Durbar Senior Grammar School, which has 28 Chemistry students in senior secondary school II.

Three (3) research instruments were used for this study: The Chemistry Achievement Test (CAT), Lesson Plan Format for Experimental Group 1 (Problem-Based Learning), and Lesson Plan Format for Conventional Group (Control Group). The Chemistry Achievement Test (CAT) was developed to assess both students' initial knowledge of IUPAC nomenclature before any intervention (Pre-test) and after the completion of the teaching interventions to measure improvement (Post-test). The Chemistry Achievement Test comprises thirty multiple-choice questions focused on the IUPAC Nomenclature of Organic Compounds, featuring four answer options. Senior secondary II chemistry students participated in this assessment, which is divided into two sections. The Lesson Plan Format for Experimental Group 1 is a detailed guide for teaching students using problem-based learning. It is a teaching approach in which students gain knowledge by resolving real-world issues. The learning experience segment encompasses identifying the issues and splitting the students into smaller groups to promote cooperation and communication, each group is then allowed to examine the problems by posing queries or having a conversation about it, they then conduct studies on the subject, gathering pertinent data through a variety of sources (books, articles, interviews, etc.), analyzing the data, and coming up with solutions. The Lesson Plan Format for Conventional Group emphasizes guided practice and direct instruction in an organized, teacher-centered manner.

The validity of the instrument was partly established through careful examination, and subsequently submitted for scrutiny to experts for both face and content validity to provide reliable comments. Based on their recommendations, fundamental changes and modifications were then made. To evaluate the reliability of the research tool, the Chemistry Achievement Test (CAT), a pilot study was carried out. Thirty Senior Secondary II Chemistry students from Alaafin High School I, located on Idi-Ose Street in the YID Area of Agunpopo, Oyo, participated in a pre-test of the instrument. Similar to the targeted sample, this coeducational school is used to launch each item's discriminating and difficulty indices. Ultimately, all of the remaining items with discriminating indices of 0.3 and above and difficulty indices ranging from 0.40 to 0.60 were chosen for the study.

Cronbach's Alpha was used to test the reliability coefficient after Kuder Richardson's (KR-20) formula was used to determine the instrument's reliability coefficient value.

The two (2) chosen schools for data collection were visited to obtain permission from the administrators and properly notify them of the research before distributing the instruments to the students. Additionally, permission and collaboration from the chosen chemistry students and research assistants, or teachers (2) were requested. For the experiment, two different teaching philosophies were employed: problem-based learning and the conventional technique. Eight (8) weeks were spent on the experiments. In the first and second weeks, the chemistry teachers received training to become research assistants. They were informed about their intended participation in the trial. A pre-test was given to each group in the third week before the students were taught utilizing the lesson plan for the next four weeks. The post-test was then administered in the final week. The data gathered were examined using analysis of Covariance (ANCOVA) to test the hypotheses at the 0.05 significance level.

Results and Discussion of Findings

The results and discussion of conclusions are given based on the demographic characteristics of the participants, and the hypotheses are as follows:

Demographic Data Analysis

Below are the socio-demographic characteristics of the participants.

Table 1: Distribution of the Participants by Gender

Gender	Frequency	Percent	Cumulative Percent
Female	82	48.2	48.2
Male	88	51.8	100.0
Total	170	100.0	

Source: Field Survey, 2024

Table 1 reveals that 88 (51.8%) participants were females, while 82 (48.2%) were males. This means that most of the participants were females.

Test of Hypotheses

$H_{o}1$: There will be no significant main effect of problem-based learning on chemistry students' achievement.

Table 2a: Analysis of covariance of the main effect of problem-based learning on chemistry students' achievement.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2198.569[a]	2	1099.285	186.000	.000
Intercept	1991.581	1	1991.581	336.977	.000
Pre-Test	232.225	1	232.225	39.293	.000
Group	2032.090	1	2032.090	343.831	.000
Error	673.755	114	5.910		
Total	53883.000	117			
Corrected Total	2872.325	116			

a. R Squared = .765 (Adjusted R Squared = .761)

Source: Field Survey, 2024

Table 2a indicates a notable main effect of problem-based learning on the achievement of chemistry students ($F_{(1, 114)}$ =343.831, $p<0.05$, $\eta 2=0.765$). The null hypothesis, which posits that problem-based learning will not have a significant main effect on the achievement of chemistry students, is consequently rejected. This suggests that utilizing problem-based learning for training chemistry students in the IUPAC nomenclature of organic compounds proves to be more effective than traditional methods. The eta square value of 0.765 indicates a contributing effect size of 76.5%.

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Table 2b: Estimated Marginal Means of Problem-based Learning on the Academic Achievement of Chemistry Students in the IUPAC Nomenclature of Organic Compounds

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Conventional Group	13.438[a]	.440	12.569	14.307
Experimental Group 2	23.182[a]	.247	22.695	23.669

Source: Field Survey, 2024

Table 2b illustrates that in the two-way interactive comparison of the combined groups, participants who experienced the conventional teaching method (control group) achieved a lower posttest mean score of 13.438, whereas those engaged in problem-based learning (experimental group 2) attained a higher post-test mean score of 23.182. This indicates that the participants who engaged in Problem-based learning (experimental group 2) achieved superior results compared to those in the control group. Therefore, problem-based learning may be suggested as a highly effective approach for instructing chemistry students in the IUPAC nomenclature of organic compounds.

H_o2: There will be no significant interactive effect of problem-based learning and gender on chemistry students' achievement.

Table 3a: Analysis of covariance of the interactive effect of problem-based learning and gender on chemistry students' achievement

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2307.834[a]	4	576.959	114.474	.000
Intercept	1993.349	1	1993.349	395.498	.000
Pre-Test	225.386	1	225.386	44.719	.000
Group	1974.251	1	1974.251	391.709	.000
Gender	103.509	1	103.509	20.537	.000
Group * Gender	9.981	1	9.981	1.980	.162
Error	564.490	112	5.040		
Total	53883.000	117			
Corrected Total	2872.325	116			

a. R Squared = .803 (Adjusted R Squared = .796)

Source: Field Survey, 2024

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Table 3a indicates a significant interaction effect of problem-based learning and gender ($F_{(1, 76)}$=12.816, p<0.05, η2=0.781) on the success of chemistry students. The null hypothesis, asserting the absence of a substantial interaction effect of problem-based learning and gender on the success of chemistry students, is thus rejected. This indicates that the implementation of treatment-problem-based learning, in conjunction with gender considerations, greatly influences the academic performance of chemistry students in the IUPAC nomenclature of organic compounds in Oyo State. The eta squared value of 0.781 indicates an effect size contribution of 78.1%.

Table 3b: Estimated Marginal Means of Treatments, problem-based learning, and gender on the academic achievement of chemistry students in the IUPAC nomenclature of Organic Compounds

Gender	Group	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Male	Conventional Group	12.054[a]	.571	10.918	13.191
	Experimental Group 2	22.347[a]	.365	21.625	23.070
Female	Conventional Group	14.930[a]	.570	13.795	16.066
	Experimental Group 2	23.871[a]	.314	23.248	24.494

Source: Field Survey, 2024

Table 4.8b demonstrates that, in the gender comparison between the two groups, males subjected to the conventional approach exhibited a lower post-test mean than those engaged in problem-based learning. Similarly, female individuals subjected to the traditional technique had a lower post-test mean than those engaged in problem-based learning, who demonstrated a higher post-test mean. The males in the control group (traditional approach) achieved a post-test mean score of 12.054, but those in the problem-based learning group attained a post-test mean score of 22.347, resulting in a difference of 10.293. The females in the control group achieved a post-test mean score of 14.930, whereas female participants in the problem-based learning group attained a post-test mean score of 23.871, resulting in a difference of 8.941. A

disparity of 1.352 existed between the two genders. This indicates that, despite a mean difference between the genders of the two groups, the difference was not statistically significant.

H_03: There will be no significant main effect of gender on chemistry students' achievement.

Table 4a: Analysis of covariance of the main effect of gender on chemistry students' achievement

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	234.291[a]	2	117.146	6.854	.001
Intercept	5359.330	1	5359.330	313.572	.000
Pre-Test	151.332	1	151.332	8.854	.003
Gender	77.459	1	77.459	4.532	.035
Error	2854.232	167	17.091		
Total	78437.000	170			
Corrected Total	3088.524	169			

a. R Squared = .076 (Adjusted R Squared = .065)

Source: Field Survey, 2024

Table 4a indicates a significant main impact of gender on the success of chemistry students ($F_{(1, 167)} = 4.532$, $p<0.05$, $\eta 2=0.076$). The null hypothesis, asserting no substantial primary influence of gender on chemistry students' success, is thus rejected. This indicates that gender independently and substantially influences the academic performance of chemistry students in the IUPAC nomenclature of organic compounds in Oyo State. The eta square value of 0.076 indicates a contributing impact size of 7.6%.

Table 4b: Estimated Marginal Means of Gender on the Academic Achievement of Chemistry Students in the IUPAC Nomenclature of Organic Compounds

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	20.353[a]	.457	19.452	21.255
Female	21.705[a]	.441	20.835	22.575

Source: Field Survey, 2024

Table 4b reveals that male participants have an average mean ($\bar{x}$) score of 20.353, while the female participants had a higher post-test mean score of 21.705. This means that overall, the female participants perform better than their male counterparts in the IUPAC nomenclature of organic compounds in chemistry.

Discussion of the Findings

The findings indicated a significant main effect of the treatment (problem-based learning) on the achievement of chemistry students. Participants who engaged with problem-based learning demonstrated superior performance compared to those in the control group, who received instruction through the conventional teaching method. The effectiveness of problem-based learning methods in mastering IUPAC nomenclature in chemistry has been demonstrated through testing.

Problem-Based Learning enables students to draw on preexisting conceptual knowledge frameworks and activate prior knowledge, developing transferable skills and attitudes that will be useful in their future practice, such as cooperation, critical evaluation, teamwork, communication, respect for colleagues, self-directed learning, and resource utilization. Both instructors and students find problem-based learning to be highly interesting since it demands complete student participation in the learning process. In problem-based learning, the student is in charge of directing the learning process.

Though the notions presented in the topic of chemistry are abstract, to establish a solid scientific basis, the theory room's conceptions must be complemented by the laboratory room's practical applications and skills. These two crucial facets of science education complement one another, necessitating the development of strategic intervention plans, protocols, and resources to support educators in encouraging learning and piquing students' interests in chemistry. No matter how complex and abstract the subject is, it is thought that including hands-on activities and other alternatives the likes as problem-based learning and computer animation that combine scientific procedures, instruments, and technological features, will spark students' interest in learning the material (Nwoke, Okorie, and Chile-Agada, 2021).

Also, there was a significant interactive effect of the treatment (problem-based learning) and gender on chemistry students' achievement. This implies

that the introduction of the treatments (problem-based learning) as a method, with consideration of gender, significantly affects the academic achievement of chemistry students in the IUPAC nomenclature of organic compounds, Oyo State. Gender comparisons among the two groups indicate that females had higher posttest means in the two different groups. This implies that female participants performed better in the IUPAC nomenclature of organic compounds using conventional methods and problem-based methods.

A notable main effect of problem-based learning on the achievement of chemistry students was observed. The implementation of problem-based learning as a training approach for chemistry students in IUPAC nomenclature of organic compounds demonstrates greater effectiveness compared to traditional methods. The group subjected to the traditional teaching approach exhibited a lower mean score on the post-test, whereas the group engaged in problem-based learning demonstrated a higher mean score on the post-test. The participants who engaged in Problem-based learning (experimental group 2) demonstrated superior performance compared to those in the control group. Therefore, problem-based learning may be suggested as a valuable approach for instructing chemistry students in the IUPAC nomenclature of organic compounds. Problem-based learning focuses on education that centers around the student, promoting the resolution of real-world issues and the enhancement of critical thinking abilities. Studies show that PBL fosters a deeper understanding by necessitating that students apply their knowledge in practical ways (Hmelo-Silver, 2004).

The significant impact of PBL observed in the study aligns with findings that PBL enhances retention and engagement compared to conventional teaching methods (Schmidt, Loyens, Van Gog, and Paas, 2011). The study's data showing higher posttest means for students exposed to PBL supports this evidence. Problem-based learning (PBL) continues to be validated as an effective pedagogical approach for fostering critical thinking and deep understanding. The literature confirms that PBL encourages active student engagement and enhances knowledge retention by applying concepts to practical scenarios (De Graaff and Kolmos, 2022). The study's findings revealed that students exposed to PBL had higher achievement scores, also aligns with findings that observed improved problem-solving skills and academic outcomes in students using PBL in STEM courses (Liu, W. Zhang & S. Yu, 2023).

The findings indicate a notable interactive influence of problem-based learning and gender on the academic performance of chemistry students. The introduction of the treatment problem-based learning method, in conjunction with gender consideration, has a significant and combined impact on the academic achievement of chemistry students in the IUPAC nomenclature of organic compounds in Oyo State. The analysis of gender differences between the two groups revealed that males who underwent the conventional method had a lower post-test mean compared to those who experienced problem-based learning. Similarly, female participants who experienced the conventional method exhibited a lower post-test mean in contrast to those engaged in problem-based learning, who demonstrated a higher post-test mean. The males in the control group, utilizing the conventional method, exhibited a post-test mean that was lower than that of their counterparts in the problem-based learning group. The females in the control group exhibited a post-test mean score that was lower than that of the female participants in the problem-based learning group. While there was an average difference observed between the genders of the two groups, this difference did not reach statistical significance.

The results revealed a significant primary influence of gender on the performance of chemistry students. This suggests that gender plays a significant and noteworthy role in the academic performance of chemistry students concerning the IUPAC nomenclature of organic compounds in Oyo State. The mean value for male participants is less than that of female participants. This suggests that, overall, the female participants demonstrate better performance than their male counterparts in the IUPAC nomenclature of organic compounds in chemistry. Recent discussions have underscored the changing influence of gender on educational outcomes. A study highlights that differences in academic performance between genders could be affected by the learning context and the particular subjects at play. In STEM fields, females often demonstrate enhanced performance in structured and collaborative settings, while males generally excel in visual-spatial tasks and competitive scenarios (Cheng & H. Li, 2022). The study's observation that female students outperformed males in chemistry aligns with current research emphasizing the importance of considering gender dynamics in educational strategies.

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Conclusion

The findings provide more evidence that a new teaching method, in particular problem-based learning, is successful in improving students' academic achievement in the subject of chemistry. The findings also emphasize the fact that gender might have an effect on the outcome of such teaching approach, which suggests that individualized educational tactics can be advantageous.

Recommendations

Based on the foregoing, the following recommendations were suggested:

1. Schools should adopt PBL as a core teaching strategy to enhance students' understanding and achievement, especially in complex topics like IUPAC nomenclature.
2. Regular professional development programs should be organized to equip chemistry teachers with the skills needed to effectively implement PBL and foster gender-inclusive classrooms.
3. Curriculum developers and policymakers should revise existing guidelines to include modern, student-centered teaching methods and establish systems for ongoing evaluation and improvement

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