Effects Of Problem-Solving And 7E Learning Instructional Strategies in Enhancing Students' Attitude Towards Stoichiometry Curriculum Concepts in Chemistry

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Abstract
The research examined the impact of problem-solving and 7E learning strategies on students' attitudes towards stoichiometry in chemistry within the Delta Central Senatorial District. A quasi-experimental design, specifically the pre-test post-test control group approach, was employed. The study targeted a population of 19,874 SSII chemistry students from public secondary schools in the district. Using a stratified random sampling method, a sample of 218 students from four co-educational secondary schools was selected. Five research questions and corresponding hypotheses were formulated to guide the investigation. Data collection was carried out using the Stoichiometry Attitude Scale (SAS), which was validated by experts. Data analysis involved the use of mean, standard deviation, and t-tests. Findings indicated that students taught using the 7E learning strategy had a higher mean attitude score compared to those taught through traditional lecture methods. Additionally, no significant interaction between teaching methods and gender was observed in terms of student attitudes. The results further demonstrated that gender did not influence the effectiveness of the constructivist learning cycle. The study concluded that the 7E learning strategy is a more effective approach for improving students' attitudes towards stoichiometry in chemistry. Based on these findings, it was recommended that chemistry teachers receive training on implementing this teaching strategy in their classrooms.

Keywords: *Problem-solving, 7E Learning Strategy, Stoichiometry, Attitude*

Introduction

Science forms the backbone of technological advancements, making its curriculum essential at all educational levels. It must align with global standards and address the Millennium Development Goals to ensure countries like Nigeria actively participate in global progress. Economic growth depends significantly on fostering a strong commitment to science education (Oyovwi, 2012). According to Oyovwi and Iroriteraye-Adjekpovu (2021), inadequate foundational knowledge at the secondary school level can undermine efforts to improve science achievement and hinder the production of scientists and technologists essential for development.

Chemistry plays a critical role in national progress by enabling the effective management and utilization of natural resources, supporting scientific literacy, ensuring food security, and contributing to industrial development. As a core subject, it is a prerequisite for professional fields such as medicine, nursing, pharmacy, engineering, and geology. Okafor (2018) emphasized that a nation's scientific development depends on the quality of chemistry education offered in schools. Furthermore, chemistry underpins industries like pharmaceuticals, food processing, agriculture, textiles, petrochemicals, and metallurgy (Gongden, 2018).

The National Policy on Education (NPE, 2013) outlines specific objectives for teaching chemistry in secondary schools. These include helping students transition from integrated science concepts to fundamental chemistry principles, highlighting chemistry's interdependence with other sciences, demonstrating its relevance to industry and daily life, and preparing students for higher education and future careers. Achieving these objectives relies heavily on the instructional strategies employed by teachers and the attitudes of students.

Research has shown that students often find certain chemistry topics challenging, with stoichiometry being particularly difficult (Naah & Sanger, 2021). Poor performance in chemistry among Nigerian secondary school students is frequently linked to difficulties in solving stoichiometric problems (Omobolanle, 2022). Teachers and examiners have observed that many students struggle with numerical calculations related to the mole concept and the balancing of chemical equations.

Stoichiometry involves the quantitative relationships between substances in chemical reactions, including calculations of mass, volume, and the limiting reactant. Often referred to as "chemical mathematics," stoichiometry is essential for ensuring efficient reactions, minimizing waste, and avoiding harmful by-products. However, its abstract and conceptually demanding nature leads many students to develop negative attitudes toward it (Adesoji, Omilani, & Dada, 2017; Agogo & Onda, 2018; Childs & Sheehan, 2019; Kamisah & Nur, 2020). According to Biglin (2020), these challenges stem from factors such as insufficient prior knowledge, mathematical anxiety, visual limitations, and the instructional methods used.

To address these issues, educators need to adopt effective teaching strategies that enhance problem-solving skills, foster positive attitudes, and build students' capacity for tackling stoichiometric problems. Promising approaches include the 7E learning cycle and problem-solving instructional strategies. The learning cycle is a constructivist, student-centered teaching method where students explore concepts independently before receiving guidance from instructors. Developed based on Piaget's constructivist theory, the learning cycle has evolved through stages such as 3E, 4E, 5E, 6E, and now 7E. This study focuses on the 7E learning cycle, which incorporates eliciting, engaging, exploring, explaining, elaborating, evaluating, and extending phases (Gok, 2014). The 7E learning model encourages collaboration among students, facilitating peer interactions that enhance conceptual understanding. This method has been shown to improve students' satisfaction, engagement, achievement, and attitudes toward learning (Achor, Otor, & Umoru, 2013; Balta & Sarac, 2016). By fostering meaningful discussions and collaboration, the 7E strategy promotes better academic performance and attitudes across different intellectual abilities.

Problem-solving as a teaching method emphasizes active, student-driven learning, where learners take a central role in exploring, analyzing, and addressing challenges. This approach goes beyond rote memorization, encouraging students to think critically, ask questions, and seek solutions through their own efforts. It fosters critical thinking, enhances intrinsic motivation, and promotes a deeper understanding of the subject matter by connecting new knowledge to existing concepts. According to Adeniran (2011), problem-solving requires students to reorganize their prior knowledge and experiences to effectively address new and unfamiliar challenges. This process often involves trial-and-error exploration, where students test various approaches to find what works, as well as insightful strategies that encourage them to think creatively and discover meaningful, practical solutions. The iterative nature of problem-solving helps students develop resilience and a growth mindset, as they learn to see setbacks as opportunities for improvement. By engaging in these activities, students not only develop essential problem-solving skills but also cultivate independence, initiative, and self-confidence as learners. Problem-solving strategies equip students to become more resourceful and self-reliant, preparing them for real-world challenges. Furthermore, this method nurtures a sense of curiosity and adaptability, enabling them to embrace continuous learning throughout their lives (Basil, 2015). In a rapidly evolving world, the ability to think critically and solve problems is a cornerstone of lifelong learning and personal growth.

Teachers' instructional strategies significantly influence students' attitudes toward chemistry. Attitude, a psychological construct, reflects how individuals think, feel, or act toward certain objects or situations. Positive attitudes can drive academic success, while negative attitudes often lead to reduced interest and lower achievement (Okafor & Agboghoroma, 2023; Kingir & Aydremir, 2012). Factors influencing attitudes include teaching methods, student gender, among others.

Gender has also been identified as a factor influencing students' achievement and attitudes toward science. However, studies show mixed results on whether teaching strategies like 7E and problem-solving disproportionately benefit one gender over the other. Thus, this study seeks to explore the interaction between instructional strategies, gender, and students' attitudes toward stoichiometry in chemistry. Given these considerations, this study investigates the effects of problem-solving and 7E learning strategies on students' attitudes toward stoichiometry in chemistry. It also aims to determine whether these strategies favor one gender in influencing students' attitudes.

Purpose of the Study

The primary aim of this study is to examine the impact of the 7E learning cycle and problem-solving strategies as tools to improve students' attitudes toward stoichiometry in chemistry. Specifically, the study seeks to:

i. Analyze the effects of the 7E learning cycle, problem-solving approach, and traditional lecture method on students' mean attitude scores toward stoichiometry in chemistry.

ii. Compare the mean attitude scores of students taught stoichiometry using the 7E learning cycle, problem-solving approach, and lecture method.
iii. Determine the differences in mean attitude scores between male and female students taught stoichiometry using the 7E learning cycle.
iv. Investigate the differences in mean attitude scores between male and female students taught stoichiometry using the problem-solving approach.
v. Examine the interaction effects of teaching methods and gender on students' attitudes toward stoichiometry in chemistry.

Research Questions

The following research questions will guide the study:

1. What are the differences in mean attitude scores of students taught stoichiometry using the 7E learning cycle, problem-solving strategies, and lecture method?
2. What are the differences in mean attitude scores between male and female students taught stoichiometry using the 7E learning cycle?
3. What are the differences in mean attitude scores between male and female students taught stoichiometry using the problem-solving approach?
4. What are the effects of the interaction between teaching methods and gender on students' attitudes toward stoichiometry in chemistry?

Research Hypotheses

The study tested the following hypotheses:

1. There is no significant difference in the mean attitude scores of students taught stoichiometry using the 7E learning cycle, problem-solving strategies, and lecture method.
2. There is no significant difference in mean attitude scores between male and female students taught stoichiometry using the 7E learning cycle.
3. There is no significant difference in mean attitude scores between male and female students taught stoichiometry using the problem-solving approach.
4. There is no significant interaction effect between teaching methods and gender on students' attitudes toward stoichiometry in chemistry.

Theoretical Framework

This study is grounded in the theory of constructivism, introduced by Bruner in 1961. Constructivism is a learning theory that highlights the active involvement of learners in building their own understanding and knowledge of the world. It views learning as a complex process where individuals actively engage with new information, connect it with prior knowledge and experiences, and construct new understandings. The theory suggests that learning is not merely the transfer of knowledge from teacher to student but a process of internal sense-making and creating meaning. According to constructivism, knowledge is not something passively received; rather, it is actively constructed by learners based on their experiences and interactions with the environment. Constructivist learning underscores the role of social interaction and collaboration in the learning process. The socio-cultural perspective on constructivism emphasizes that learning is both an individual and social process that occurs through interaction with others. These interactions provide learners with opportunities to share perspectives, co-construct meaning, and negotiate understanding, enabling them to connect what they learn to real-world contexts. This helps students see the relevance of their learning and apply their knowledge meaningfully.

In terms of instructional practices, constructivism promotes learner-centered approaches that encourage active participation and inquiry. Teachers act as facilitators, guiding students as they explore, question, and build knowledge. These methods may include hands-on activities, group discussions, problem-solving tasks, and the use of technology to support discovery and investigation. Constructivism challenges traditional, teacher-centered approaches by advocating for active, collaborative, and student-centered learning experiences. It emphasizes the importance of prior knowledge, social interactions, and real-world applications in the learning process, encouraging learners to take ownership of their education. This approach helps students develop critical thinking, problem-solving abilities, and lifelong learning skills. The constructivist theory serves as a solid foundation for the 7E learning instructional strategy, which emphasizes students actively constructing their understanding of concepts. The 7E model promotes learning through experiences, interactions, hands-on activities, and reflective processes, aligning closely with the principles of constructivism.

Research Methodology

This study adopted a pretest-posttest, quasi-experimental design with a control group. The design involved two instructional approaches—problem-solving and the 7E learning cycle—as independent variables, while gender (male and female) was included as a moderator variable. The dependent variable was students' attitudes toward stoichiometry in chemistry. The quasi-experimental design was chosen due to the inability to randomly assign participants to experimental groups. Intact classes were used to avoid disrupting the schools' normal activities. Quasi-experimental designs are practical alternatives to pure experimental designs when randomization is not feasible (Ajaja, 2013). The study's population comprised 19,874 senior secondary school chemistry students from 187 public secondary schools in the Delta Central Senatorial District. The target population included SSII chemistry students in public secondary schools in the district. A sample of 218 SSII chemistry students was drawn from four mixed public secondary schools in the area.

The instrument used for data collection was the **Stoichiometry Attitude Scale (SAS)**, a 25-item questionnaire developed by the researcher to measure students' attitudes toward learning chemistry. The responses were framed using a four-point Likert scale: Strongly Agree (SA = 4), Agree (A = 3), Disagree (D = 2), and Strongly Disagree (SD = 1). Students were required to indicate their level of agreement with each item by selecting one option. The face validity of the instrument was established by three experts: an experienced chemistry teacher, a science education specialist, and a measurement and evaluation expert from Delta State University, Abraka. The reliability of the SAS was tested using Cronbach's Alpha, a suitable method for evaluating the reliability of Likert-scale instruments. To determine the reliability index, the instrument was administered to 20 chemistry students from a school in Warri North Local Government Area, outside the study area. The responses were analyzed using Cronbach's Alpha in the Statistical Package for Social Sciences (SPSS), resulting in a reliability index of 0.75. To analyze the data, research questions were addressed using mean and standard deviation, while hypotheses were tested using t-tests, Analysis of Variance (ANOVA), and Analysis of Covariance (ANCOVA) at a 0.05 level of significance.

Results

Research Question 1

What is the difference in the mean attitude scores among students taught biology using the 7E learning cycle, problem-solving strategy, and lecture method?

Table 1: Descriptive Statistics for Posttest Mean Attitude Scores and Standard Deviations

Method	N	Posttest Mean	Standard Deviation
7E Learning Cycle	92	71.15	10.56
Problem Solving	53	75.00	10.66
Lecture Method	73	77.90	9.39

Table 1 illustrates the posttest mean attitude scores of students taught biology using the three methods. Students taught using the 7E learning cycle had a mean score of 71.15 with a standard deviation of 10.56, while those taught using the problem-solving strategy had a mean score of 75.00 and a standard deviation of 10.66. Students taught through the lecture method achieved a higher mean score of 77.90 with a standard deviation of 9.39. These results indicate a noticeable difference in the mean scores among the three instructional methods, with the lecture method leading, followed by problem-solving, and the 7E group scoring the lowest.

Hypothesis 1

There is no significant difference among the mean attitude scores of students taught biology using the 7E learning cycle, problem-solving strategy, and lecture method.

Table 2: ANOVA Statistics Comparing Pretest Mean Attitude Scores

Source	Sum of Squares	DF	Mean Square	F	Sig (2-tail)
Between Groups	556.34	2	278.17	1.97	0.141
Within Groups	30,300.75	215	146.93		
Total	30,856.09	217			

As shown in Table 2, there was no significant difference in the pretest mean attitude scores among the groups since the p-value (0.141) is greater than the 0.05 significance level. Thus, the ANOVA test was deemed appropriate for testing the hypothesis, with the results presented in Table 3.

Table 3: ANOVA Results Comparing Posttest Mean Attitude Scores

Source	Sum of Squares	DF	Mean Square	F	Sig (2-tail)
Between Groups	1,885.31	2	942.65	9.043	0.000
Within Groups	22,412.20	215	104.24		
Total	24,297.50	217			

Table 3 indicates that the observed difference in posttest scores was significant, as the calculated p-value (0.000) is less than 0.05. To determine the specific differences between the groups, a Scheffe post hoc analysis was conducted.

Table 4: Scheffe Test Results for Pairwise Comparisons

Method (i)	Method (j)	Mean Difference	Std. Error	Sig. (p-value)	95% Confidence Interval
7E Learning Cycle	Problem Solving	-3.35	1.76	0.094	-8.19 to 0.49
	Lecture Method	-6.75	1.60	0.000	-10.70 to -2.81

Problem Solving	7E Learning Cycle	3.35	1.76	0.094	-0.49 to 8.19
	Lecture Method	-2.90	1.84	0.291	-7.45 to 1.64
Lecture Method	7E Learning Cycle	6.75	1.60	0.000	2.81 to 10.70
	Problem Solving	2.90	1.84	0.291	-1.64 to 7.45

The Scheffe test results in Table 4 show that there was no significant difference between the 7E learning cycle and the problem-solving strategy ($p = 0.094$). A significant difference was found between the 7E learning cycle and the lecture method ($p = 0.000$). No significant difference was observed between problem-solving and the 7E group ($p = 0.094$). A significant difference existed between the problem-solving strategy and the lecture method ($p = 0.029$). Overall, the lecture method demonstrated a significantly higher mean attitude score compared to the 7E learning cycle and the problem-solving strategy. Therefore, the null hypothesis (H_{01}) is rejected, indicating that there is a significant difference among the mean attitude scores of students taught using the three instructional strategies, favoring the lecture method.

Research Question 2

What is the difference in the mean attitude scores of male and female students taught biology using the 7E learning cycle?

Table 5: Descriptive Statistics for Mean Attitude Scores of Male and Female Students Taught Biology Using the 7E Learning Cycle

Sex	N	Mean	Mean Difference	Standard Deviation
Male	41	69.97	2.12	8.14
Female	51	72.09		12.16

Table 5 presents the mean attitude scores of male and female students taught biology using the 7E learning cycle. Male students had a mean score of 69.97 with a standard deviation of 8.14, while female students scored higher with a mean of 72.09 and a standard deviation of 12.16. The mean difference between male and female students was 2.12, favoring the females.

Hypothesis 2

There is no significant difference in the mean attitude scores of male and female students taught biology using the 7E learning cycle.

Table 6: Independent Sample t-Test for Male and Female Students Taught Biology Using the 7E Learning Cycle

Sex	N	Mean	Standard Deviation	df	t	Sig (2-tail)
Male	41	69.98	8.15	90	-0.957	0.341
Female	51	72.10	12.16			

Table 6 shows that the calculated p-value of 0.341 is greater than 0.05, indicating no significant difference in the mean attitude scores of male and female students taught biology using the 7E learning cycle. Consequently, the null hypothesis is not rejected.

Research Question 3

What is the difference in the mean attitude scores of male and female students taught biology using the problem-solving strategy?

Table 7: Descriptive Statistics for Mean Attitude Scores of Male and Female Students Taught Biology Using Problem-Solving Strategy

Sex	N	Mean	Mean Difference	Standard Deviation
Male	26	72.15	5.58	9.01
Female	27	77.74		11.56

Table 7 highlights the mean attitude scores of male and female students taught biology using the problem-solving strategy. Male students had a mean score of 72.15 with a standard deviation of 9.01, while female students scored higher, with a mean of 77.74 and a standard deviation of 11.56. The mean difference between male and female students was 5.58, favoring the females.

Hypothesis 3

There is no significant difference in the mean attitude scores of male and female students taught biology using the problem-solving strategy.

Table 8: Independent Sample t-Test for Male and Female Students Taught Biology Using Problem-Solving Strategy

Sex	N	Mean	Standard Deviation	df	t	Sig (2-tail)
Male	26	72.15	9.01	51	1.959	0.056
Female	27	77.74	11.56			

Table 8 indicates that the calculated p-value of 0.056 is greater than 0.05, showing no significant difference between the mean attitude scores of male and female students taught biology using the problem-solving strategy. Thus, the null hypothesis is not rejected.

Research Question 4:

What is the interaction effect of teaching methods (7E, problem-solving, and lecture) and sex on students' attitudes towards biology?

Table 9: Descriptive Statistics for the Interaction Effect of Teaching Method and Sex on Students' Attitudes

Method	Sex	N	Mean	Mean Difference	Standard Deviation
7E	Male	41	69.97	-2.12	8.14
	Female	51	72.09		12.16
Problem Solving	Male	26	72.15	5.58	9.01
	Female	27	77.74		11.56

Lecture	Male	36	76.36	3.04	9.78
	Female	37	79.40		8.84

Table 9 shows the mean scores for male and female students across different teaching methods. The mean interaction score for males and females using the 7E learning cycle is 69.97 and 72.09, respectively, with a mean difference of -2.12 favoring females. Similarly, for the problem-solving strategy, male and female mean scores are 72.15 and 77.74, respectively, with a mean difference of 5.58 in favor of females. For the lecture method, males scored 76.36, while females scored 79.40, yielding a mean difference of 3.04 in favor of females.

Hypothesis 4

There is no significant interaction effect between teaching methods and sex on students' attitudes towards biology.

Table 10: ANCOVA Results for the Interaction Effect of Teaching Methods and Sex on Students' Attitudes

Source	Type III Sum of Squares	df	Mean Square	F	Sig (p-value)
Corrected Model	4,314.635	6	719.106	7.593	0.000
Intercept	71,812.189	1	71,812.189	758.258	0.000
Pre-Attitude Score	1,744.410	1	1,744.410	18.419	0.000
Groups	1,449.766	2	724.883	7.654	0.001
Sex	783.782	1	783.782	8.276	0.004
Group * Sex	120.014	2	60.007	0.634	0.532
Error	19,982.870	211	94.706		

Table 10 indicates that the interaction effect between teaching methods and sex on students' attitudes is not significant, as the calculated p-value (0.532) is greater than 0.05. Therefore, the null hypothesis is not rejected. This result suggests no significant interaction effect between teaching methods and sex on students' attitudes towards biology.

Discussion

The study revealed a significant difference in the mean attitude scores of students taught stoichiometry using the 7E learning cycle, problem-solving strategy, and the lecture method. This variation in attitude scores can be attributed to the different academic activities students engaged in during the instruction. The post-test analysis indicated that students taught using the lecture method and problem-solving strategy achieved higher mean attitude scores compared to those taught with the 7E learning cycle. This aligns with findings by Akparobore et al. (2024), which suggest that the 7E instructional strategy, through personalized learning and active engagement, fosters deeper conceptual understanding, potentially improving students' attitudes toward stoichiometry in chemistry. However, the lower attitude scores of students exposed to the 7E method may stem from their unfamiliarity with this innovative approach, as they are accustomed to traditional lecture-based methods commonly used in Nigerian secondary schools. The higher attitude scores of students taught through the lecture method compared to problem-solving strategies may also reflect the long-standing prevalence of lectures as the dominant teaching method, leading to a positive predisposition among students toward this approach.

Additionally, the study found no significant difference in the mean attitude scores between male and female students taught stoichiometry in chemistry using the 7E learning cycle, problem-solving strategy, or the lecture method. This outcome could be attributed to the equal participation of both genders in the teaching and learning activities, enabling all students to engage directly with the instructional procedures. This finding aligns with Gok and Silary (2010), who investigated the impact of problem-solving strategies on students' achievement, attitude, and motivation. According to Akparobore et al. (2024), the student-centered nature of the 7E instructional strategy addresses the diverse learning needs and preferences of all students, contributing to comparable attitude scores between male and female participants. However, this finding contrasts with Smith and Johnson (2020), who reported significant gender-based differences in academic performance. The results are consistent with a study conducted by Achugbu and Anulika (2020) on the impact of problem-solving strategies on secondary school students' chemistry achievement, which also found no significant gender-based differences in achievement tests.

Finally, the study revealed no significant interaction effect between teaching methods and gender on students' attitudes toward chemistry. This suggests that the teaching method did not interact with gender to influence students' attitudes toward stoichiometry. Instead, students' attitudes were primarily shaped by their predisposition toward the instructional strategies. This finding is in agreement with research by Ajaja and Eravwoke (2012), who examined the effects of learning cycles on biology and chemistry students' achievement and found no significant interaction between method and gender. Similarly, Akunya (2022) investigated the effects of Polya's problem-solving strategy on students' academic achievement and retention in economics, reporting no significant interaction effect between gender and teaching method. Shaheen and Kayani (2017) also observed similar results in their study on improving students' attitudes toward biology as a subject, further supporting the findings of this study.

Conclusion

The findings of this study suggest that the 7E learning cycle and problem-solving strategies are effective methods for teaching chemistry, particularly stoichiometry. These findings align with the principles of constructivist theory, which highlights the importance of student-centered learning for enhanced educational outcomes. Furthermore, it was concluded that the 7E instructional strategy is not influenced by gender, making it an inclusive approach for teaching.

Recommendations

1. Chemistry teachers should be encouraged to utilize the 7E instructional strategy, especially when teaching stoichiometry concepts in senior secondary schools.

2. Schools should ensure the employment of well-trained and qualified teachers for chemistry instruction and provide adequate facilities and resources to enhance the teaching and learning process.

3. Seminars and workshops should be organized for chemistry teachers to train them on the effective implementation of the 7E instructional strategy in teaching chemistry.

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